Final Report

Integrated Energy and Power Master Plan (IEPMP) 2023

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Acronym	Definition
ADB	Asian Development Bank
AFVs	Alternative Fuel Vehicles
AGC	Automatic Generation Control
AID2020	Automobile Industry Development Policy 2020
APSCL	Ashuganj Power Station Company Ltd.
ASEAN	Association of South East Asian Nations
ATS	Advanced Technology Scenario
BAPEX	Bangladesh Petroleum Exploration and Production Company Limited
BAU	Business as Usual
BBS	Bangladesh Bureau of Statistics
Bcm	Billion cubic meters
Bcf	Billion cubic feet
BCMCL	Barapukuria Coal Mine Company Limited
BD	Barrels per Day
BDP 2100	Bangladesh Delta Plan 2100
BEEER	Building Energy Efficiency & Environment Rating
BERC	Bangladesh Energy Regulatory Commission
BGDCL	Bakhrabad Gas Distribution Company Ltd
BNBC	Bangladesh National Building Code
BPC	Bangladesh Petroleum Corporation
BPDB	Bangladesh Power Development Board
BREB	Bangladesh Rural Electrification Board
BRT	Bus Rapid Transportation
Btu	British thermal unit
CAF	Central Asian Flyway
CAPEX	Capital Expenditure
CCGT	Combined Cycle Gas Turbine
CCS	Carbon Capture and Storage (Sequestration)
CCUS	Carbon Capture, Utilization and Storage
CFL	Compact Fluorescent Lamp
CHP	Combined Heat and Power
CIF	Cost, Insurance and Freight
CNG	Compressed Natural Gas

COP	Conference of Parties
CP	Contract Price (of Saudi Arabian LPG)
CPGCBL	Coal Power Generation Company Bangladesh Limited
CSR	Corporate Social Responsibility
CT	Carbon Tax
DAS	Distribution Automation System
DCI	Decarbonization Index (CO_2/TPES)
DCPL	Dhaka Chittagong Pipeline
DES	District Energy System
DES	Delivered ex-ship
DESCO	Dhaka Electric Supply Company Limited
DFI	Development Finance Institution
DMINB	Dhaka Mahanagar Imarat Nirman Bidhimala
DMS	Distribution Management System
DPDC	Dhaka Power Distribution Company Limited
EAAF	East Asian-Australasian Flyway
ECA	Environmental Conservation Act
ECA	Ecologically Critical Areas
ECAs	Export Credit Agencies
EDMC	Energy Data and Modelling Center, IEEJ
EE&C, EEC	Energy Efficiency and Conservation
EECMP	Energy Efficiency and Conservation Master Plan
EEI	Energy Efficiency Index (TPES/GDP)
EES&L	Energy Efficiency Standards and Labelling
EEV	Energy Efficient Vehicle
EHS, SHE	Environment, Health and Safety; Safety, Health and Environment
EIA	Environment Impact Assessment
EMP	Environment Management Plan
EMRD	Energy and Mineral Resources Division
EMS	Energy Management System
ERL	Eastern Refinery Limited
ESCO	Energy Service Company
SG	Environmental, Social and Governance
ESMP	Environmental and Social Management Plan
ETS	Emission Trade Scheme
EV	Electric Vehicle

FEED	Front End Engineering and Design
FERC	Federal Energy Regulatory Commission
FGMO	Free Governor Mode of Operation
FID	Final Investment Decision
FIT	Feed in Tariff
FLNG	Floating LNG
FREL	Forest Reference Emission Level
F/S	Feasibility Study
FSRU	Floating Storage and Regasification Unit
FSU	Floating Storage Unit
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GHP	Gas Heat Pump
GIIP	Gas Initially In-Place
GIS	Geographic Information System
GSMP 2017	The Gas Sector Master Plan Bangladesh 2017
GT	Gas Turbine
GTCC	Gas Turbine Combined Cycle
GTL	Gas to Liquids
HCU	Hydrocarbon Unit
HDTs	Heavy Duty Trucks
HDV	Heavy Duty Vehicle
HGA	Host Government Agreement
HSD	High Speed Diesel
HTGR	High Temperature Gas-cooled Reactor
IBFPL	India Bangladesh Friendship Pipeline
IBRD	International Bank for Reconstruction and Development
ICE	Internal Combustion Engine
IDA	International Development Association
IDCOL	Infrastructure Development Company Limited
IEA	International Energy Agency
IEEJ	The Institute of Energy Economics, Japan
IEEUV	Imported Energy Efficient Used Vehicle
IEPMP	Integrated Energy and Power Master Plan
IFC	International Finance Corporation
IHS CERA	IHS Cambridge Energy Research Associates, Inc.

IMF	International Monetary Fund
IMO	International Maritime Organization
INDCs	Intended Nationally Determined Contributions
IOC	International Major Oil Company
IPCC	Intergovernmental Panel on Climate Change
IPP	Independent Power Producer
IRR	Internal Rate of Return
ISO	International Organization for Standardization
IT	Information Technology
ITS	Intelligent Transportation System
JCC	Japan Crude Cocktail (Average custom clearance price of crude oil)
JGTDSL	Jalalabad Gas Transmission and Distribution System Ltd
JICA	Japan International Cooperation Agency
JKM	Japan/Korea Marker (of LNG price)
JLC	Japan LNG Cocktail (Average custom clearance price of LNG)
JOCL	Jamuna Oil Company Limited
KGDCL	Karnaphuli Gas Distribution Company Ltd
kgoe	Kilogram Oil Equivalent
LBM	Liquefied Bio Methane
LCOE	Levelized Cost of Electricity
L-CNG	LNG-based Compressed Natural Gas (Service Station)
LDC	Least Developed Country
LEED	Leadership in Energy and Environment Design
LGV	Light Goods Vehicle
LNG	Liquefied Natural Gas
LOLE	Loss-of-Load Expectation
LPG	Liquefied Petroleum Gas
LPV	Light Passenger Vehicle
LWR	Light-Water (nuclear) Reactor
MCPP	Mujib Climate Prosperity Plan (MCPP-M: MCPP Maximized)
MDMC	Multi Divided and Multi Connected
METI	Ministry of Economy, Trade and Industry, Japan
MM	Million
MMBtu	Million BTU
MMcfd	Million cubic feet per day
MN	Methane Number

MOEF	Ministry of Environment, Forest and Climate Change
MPEMR	Ministry of Power, Energy and Mineral Resources
MPL	Meghna Petroleum Limited
MRT	Mass Rapid Transit
Mt	Million tons
$MtCO_2e$	Million tons of CO_2 Equivalent
MTG	Methanol to Gasoline
Mtoe	Million tons oil equivalent
MTPA	Million Tons Per Annum
MW	Mega Watts
MWh	Mega Watt hours
NACOM	Nature Conservation Management
NBP	National Balancing Point (of UK)
NBR	National Board of Revenue
NC	National Communication
NDC	Nationally Determined Contributions
NEP	National Environment Policy
NESCO	Northern Electricity Supply Company Limited
NLDC	National Load Dispatch Center
NG	Natural Gas
NGV	Natural Gas Vehicle
NOx	Nitrogen Oxides
NPV	Net Present Value
NWPGCL	North-West Power Generation Company Ltd.
NZS	Net-zero Scenario
O&M	Operation and Maintenance
OECD	Organisation for Economic Cooperation and Development
OPEC	Organization of the Petroleum Exporting Countries
OPEX	Operating Expenditure
PD	Power Division
PGCB	Power Grid Company of Bangladesh
PGCL	Pashchimanchal Gas Company Ltd
PHD	Propane Dehydrogenation
PLDV	Passenger Light Duty Vehicle
PM	Particulate Matter
PNG	Piped Natural Gas, Pipeline Natural Gas

POCL	Padma Oil Company Limited
PP2041	Perspective Plan (of Bangladesh 2021 -) 2041
PS	Performance Standards
PSC	Product Sharing Contract
PSMP	Power System Master Plan
PV	Photovoltaics
R&D	Research and Development
RE	Renewable Scenario (RE10:10% Renewable Scenario)
REB	Rural Electrification Board
REF	Reference Scenario
RERED-II	Rural Electrification and Renewable Energy Development II (World Bank)
RES	Renewable Energy Sources
RLNG	Regasified LNG
RPCL	Rural Power Company Limited
RPGCL	Rupantarita Prakritik Gas Company Limited
RPS	Renewable Portfolio Standard
S&L	Standards and Labelling
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
SCADA	Supervisory Control and Data Acquisition
SCFD, scfd	Standard Cubic Feet per Day
SDGs	Sustainable Development Goals
SEA	Strategic Environment Assessment
SEO	Strategic Environmental Objectives
SESMP	Strategic Environmental and Social Management Plan
SEZ	Special Economic Zone
SGCL	Sundarban Gas Company Ltd
SGFL	Sylhet Gas Fields Limited
SID	Statistics and Informatics Division
SMDS	Shell Middle Distillate Synthesis
SMR	Single Mixed Refrigerant
SMR	Small Modular Reactor
SOx	Sulphur Oxides
SPA	Sale and Purchase Agreement
SPM	Single Point Mooring
SREDA	Sustainable and Renewable Energy Development Authority

SS	Service Station
Tcf	Trillion cubic Feet
TGTDCL	Titas Gas Transmission and Distribution Company Ltd
toe	Ton(s) Oil Equivalent
TPES	Total primary energy supply
TRBS	Trucks and Buses
UNECE	UN Economic Commission for Europe
UNFCCC	United Nations Framework Convention on Climate Change
UNPRI	United Nations Principles for Responsible Investment
USC	Ultra-Supercritical pressure thermal power plant
USGBC	U.S. Green Building Council
VP	Virtual Pipeline
VRE	Variable Renewable Energy
WMA	Wildlife Management Area
WTI	West Texas Intermediate
WZPDCL	West Zone Power Distribution Company Limited
3Es plus S	Energy Security, Economic Efficiency, Environment and Safety
8FYP	8th Five Year Plan July 2020 – June 2025

Executive Summary

1. Background and Purpose of Study

The People's Republic of Bangladesh (hereinafter referred to as "Bangladesh") is pushing forward its economic growth aggressively under the Vision 2041 aiming to achieve a high-income country status by its 70th anniversary of independence. Bangladesh seeks to expand its economy by more than fivefold from now, and thus energy demand will inevitably increase. With rising global concerns on climate change, Bangladesh declared at the 2021 COP26 held in Glasgow, U.K. that the country will strive for achieving an up to 40% clean energy use in its power generation mix[1]. Thus, this Master Plan aims to create a low-carbon economy with secure and affordable energy supply.

Considering the recent movements as above, Bangladesh wanted to review the existing long-term energy plans such as 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), and consolidate them into a comprehensive national plan setting out a tangible and practicable development roadmap. To this end, Bangladesh requested Japan for necessary support in formulation of the *Integrated Energy and Power Master Plan (IEPMP)* with a view to setting out middle/long term energy policies to establish a low carbon/decarbonized society. The Ministry of Power, Energy and Mineral Resources (MPEMR) of the Government of Bangladesh and the Japan International Cooperation Agency (JICA) discussed the above request and signed the Record of Discussion on 14 March 2021.

In accordance with the above agreement, this draft IEPMP has been developed. It aims to establish a clean and efficient energy supply/demand system as the platform for sustainable development of Bangladesh. It aims to develop a long-term energy plan up to 2050 with a concept of “S plus 3E” representing Safety, Energy Security, Economic Efficiency, and Environment as the central pillars, each element of which denoting the following:

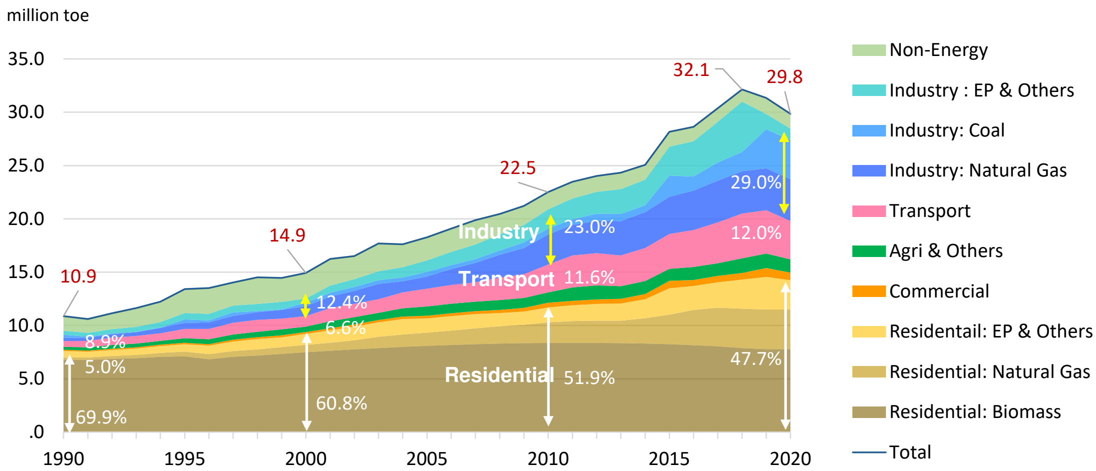
1） Safety: energy must be supplied safely and stably;
2） Energy Security: maximize the use of indigenous energies and prepare energy import infrastructure;
3） Economic Efficiency: provide modern/convenient energies at minimum/affordable cost;
4） Environment: secure sound environmental conditions and lower the GHG emissions to a lowest possible level.

[1] https://unfccc.int/sites/default/files/resource/BANGLADESH_cop26cmp16cma3_HLS_EN.pdf

2. Status and Issues of Energy Sector

2.1 Energy Demand

In Bangladesh, per capita total primary energy supply in 2020-21 was 331kg in oil equivalent, which was below one-fifth of the world average (1,801kgoe in 2020)[2]. In the energy consumption, traditional firewood and natural gas combined, mostly produced indigenously, account for more than 50%, followed by electricity and petroleum products as motor fuel. Electricity consumption stayed at 560kWh/year in 2020-21 or 17.4% of the world average at 3,212kWh in 2020[3]; it will expand vigorously as the key driver to push the economic development while improving the people's quality of life.



Source：IEA World Energy Balances 2022

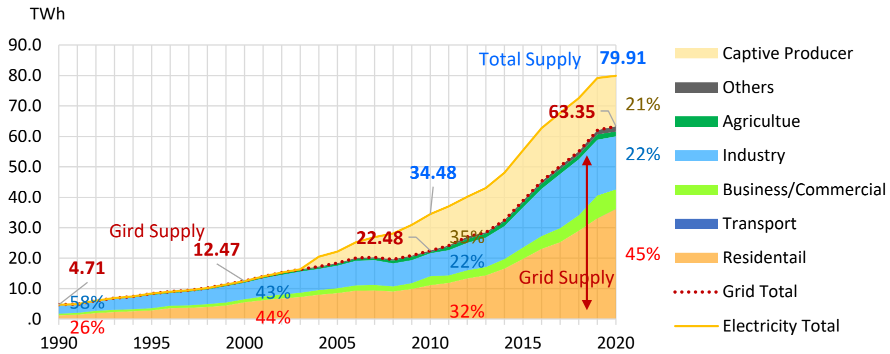
Figure S.2-1 Energy Consumption by Sector

The residential sector is the largest energy consumer in Bangladesh though its share is gradually decreasing. It consumed 48% of the total energy in 2020, of which 55% was primary biomass (mainly firewood) while consumptions of natural gas (26%) and electricity (19%) are increasing. Since city gas supply for the residential and commercial sectors is regulated by the government policy, domestic fuel demand replacing firewood is causing a rapid increase of LPG import. It is necessary to ensure a sound balance of city gas, LPG and electricity to accommodate modernization of energy in these sectors, in line with overall development plans of metropolitan areas. The second largest sector is the industry sector at 29%; it mainly consumes natural gas (45%) and coal (42%) while electricity consumption (12%) is increasing. The transport sector energy consumption is relatively small in Bangladesh reflecting low penetration of private cars, but, judging from precedents at other countries, a robust increase may occur in the coming decades. This Master Plan aims to introduce Electrical Vehicles (EVs) proactively targeting the share of

[2] 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. Ditto for the per capita electricity consumption.

[3] Electricity generation for Bangladesh, while electricity consumption for the world average.

EVs in the vehicle stock in 2050 to be 40% for Passenger Light Duty Vehicles (PLDVs) and 10% for trucks and buses. Nevertheless, oil consumption will keep increasing reflecting high demand for mobility. In the agricultural sector, a certain amount of diesel is used by pumps for the irrigation system.



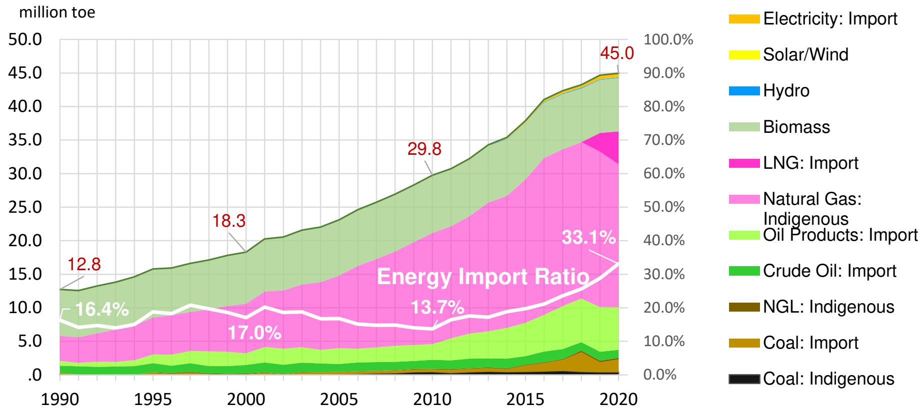
Source: IEA World Energy Balances 2022

Figure S.2-2 Electricity Consumption in Bangladesh

In 2020, electricity comprised 23% of the energy consumption. Of the foregoing, 45% was used in the residential sector while 43% was used in the industry sector as on-gird and captive power generation 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 will come back on to the previous trend and will expand considerably.

2.2 Energy Supply

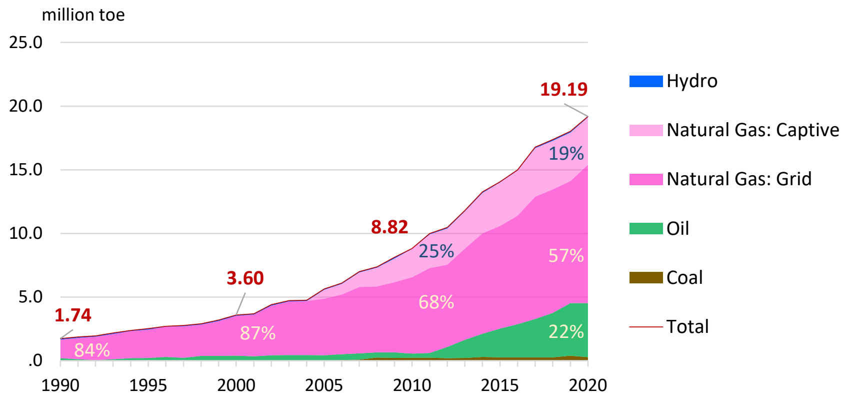
Energy utilization in Bangladesh have historically depended on a system developed with indigenous energies; conventional biomass and natural gas combined exceeded three-fourth of the total energy supply. A small amount of petroleum products as motor fuel and coal for industry use was imported but the import ratio remained below 20%. However, signs of peaking in natural gas production have created a concern on stable supply of energy and power, leading to import of LNG and coal since 2018. The import energy ratio jumped to 33.1% in 2020. On the other hand, while construction of fundamental energy infrastructure is essential to support economic development and better quality of life, it is also an important issue for the government to implement efficient and lower-carbon use of energy in coping with the global warming issues.



Source: IEA World Energy Balances 2022

Figure S.2-3 Primary Energy Supply in Bangladesh

Presently most of the power generation is driven by natural gas; it amounted to 75% of the entire power supply including the grid and captive generations combined. Some dual fuel power plants are run by oil as and when required. Small scale generators are run in rural areas with diesel oil, while coal fired power generation started in 2006 at a mine mouth plant and at Payra on imported coal in 2020. Hydro remains in a limited amount as the country is geologically located in the estuary of big rivers.



Source: IEA World Energy Balances 2022

Figure S.2-4 Power Sources in Bangladesh by Energy Input

3. Energy Demand Outlook

3.1 Methodologies and Assumptions

An econometric model is developed for projection of energy demand outlook. Energy demand functions are estimated by sector applying regression analysis in relation to GDP, energy prices and other relevant factors based on the historical data; the IEA statistics is mainly used on energy. Subsequently , energy demand is estimated by applying the demand functions and external assumptions/projections for future GDP, energy price scenarios, and other factors. In this process, assumptions on economic growth typically represented by GDP growth rate, population growth, energy price scenario and evolution of technology progress have substantial impacts on the projection. Assumptions are developed, at the outbreak of the COVID-19 pandemic, as follows.

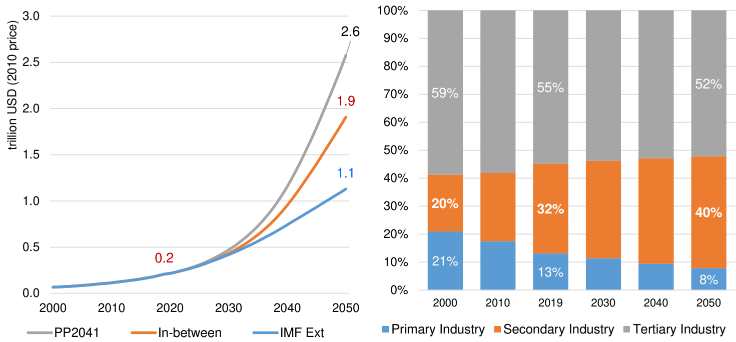
1) GDP Assumptions

Three cases are examined for the GDP projection, which are;

a. PP2041 Case; based on the projections of the Perspective Plan 2041, which seeks for an optimistic economic growth to achieve a high-income country status by 2041 accelerating development.

b. IMF Extension Case; based on the projections of the IMF World Economic Outlook, which envisages a relatively moderate growth.

c. In-between Case: a projection in-between the above two cases, which may represent a view to achieve a steady development.



	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 Composition GDP Growth Rate

Figure S.3-1 Scenarios on GDP Growth

This Master Plan adopts the PP2041 GDP case, the basis for the present national development plan, as the main scenario and an exercise case is run on the In-Between GDP case.

2) Population Growth

Projection by Perspective Plan 2041 is adopted basically, which envisages that the population of Bangladesh will grow from 168 million in 2020 to 191 million in 2030, 210 million in 2041 and 214 million in 2050 at a rate of 0.9% per annum on average but decelerating gradually.

3) Energy Prices

Price scenarios are assumed by the IEPMP Study Team based on the IEA World Energy Outlook 2021. They are set forth differently on three technology evolution scenarios as explained in Section 3.2. In the Advanced Technology Scenario (ATS), the central scenario adopted in this

Master Plan, international oil price is projected to rise from 2020 to 2030 backed by the sustained demand recovery from COVID-19. While the international natural gas price rose in 2021, the ATS assumes that the market will calm down toward 2050 since developed countries will reduce fossil fuel consumption and their natural gas demands will decline in the long run. The international hydrogen and ammonia prices are estimated by the Study Team assuming a declining trend over time.

Table S.3-1 Assumption on Future Energy Prices

Real Term (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 Term

	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: IEPMP Study Team in reference to IEA World Energy Outlook 2021

3.2 Scenario Setting on Technical Progress

On evolution of energy related technologies and policies that will guide the direction and indicate the goal to be pursued in this Master Plan, three scenarios are considered as below:

- Reference Scenario (REF): a so-called business as usual case where energy consumption will follow the past trends. Technology development and improvement in quality of life will progress likewise as observed in the past.
- Advanced Technology Scenario (ATS): on top of the REF, utmost efforts will be made to keep energy-based emissions of GHGs as low as possible, while assuring adequate and stable supply, introducing energy conservation measures and adopting cleaner energy options that are affordable and practicable.
- Net-zero Scenario (NZS): Under the NZS, Bangladesh is assumed to achieve net-zero emissions of energy-based GHGs by 2050 by applying every available option and, if insufficient, by regulating energy consumption.
  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.

These scenarios are compared as shown in Table S.3-2.

Table S.3-2 Scenario Setting for Energy Demand Forecast

	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.

Note: For the purpose of calculation, NZS (Net Zero Scenario) 2050 is developed arbitrarily. Hence, Bangladesh is planning to adopt NZS (Net Zero Scenario) by 2070.

1) Technology Setting

Starting from the Reference Scenario, significant technology progress is assumed for ATS and NZS, main items of which are as summarized in Tables S.3-3 and S.3-4. These projections are made not on the review on individual technologies but on an overall review of studies and analyses available at present. For example, gross energy conservation is thought to have improved at around 2% per annum in the past, according to various studies; this is incorporated in the energy demand functions for REF. In view of this, an additional 50% (annual +1% = 2% x 50%) improvement is assumed for ATS and a 100% for NZS.

Table S.3-3 Technology Setting (Demand side)

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

Plausibility of these assumptions and scenarios must be discussed and reviewed periodically. Technologies may develop faster or slower than are presently projected. Even innovative technologies and institutions beyond the present horizon may emerge in the future, while some of ongoing attempts would not fully materialize. We should keep our eyes on their development.

Table S.3-4 Technology Setting (Supply side)

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*), 50% hydrogen co-firing will start around 2040 (2045*). 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

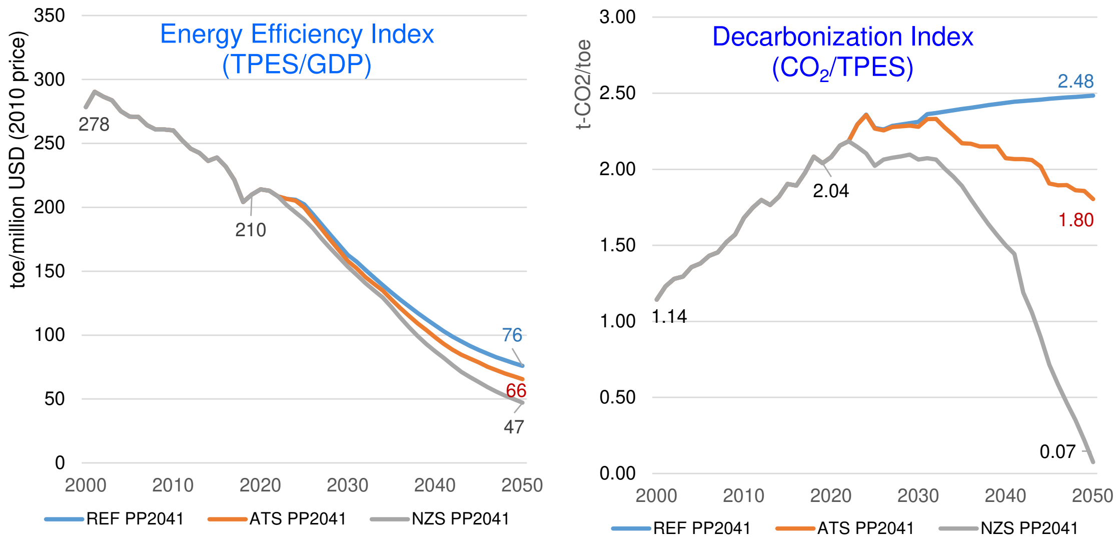
2) Comparison of Three Scenarios

Preliminary evaluation was made on the three scenarios in terms of their appropriateness and practicability applying two indices, namely, energy efficiency index and decarbonization index, where;

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. Applying the PP2041 GDP case, it falls 64% between 2019 and 2050 in REF (at 3.2% annual decline), 69% in ATS (3.7%), and 78% in NZS (4.7%). As a reference, India's EEI decreased by 2.4% annually between 2010 and 2019, and China's EEI by 3.5% annually between 1996 and 2019 after achieving the US$1,300 (in 2010 price) of real GDP per capita, respectively, which is close to the present situation in Bangladesh. The estimated EEI improvement in ATS is almost the same with China's experience, and in NZS it is considerably greater than the above.

Energy-related CO_2 emissions will be the largest in REF, followed by ATS and NZS. It will grow significantly in REF to 401 million tons-CO_2 in 2050, which is about a half of Japan's emissions in 2019. In ATS, it will grow moderately to 266 million tons-CO_2, almost two thirds of that in REF. The emissions of NZS PP2041 are, by definition, almost zero in 2050.



Source: IEPMP Study Team

Figure S.3-2 Comparison of Three Scenarios on Technology Development

Decarbonization Index (DCI: CO_2/TPES) follows very different paths in the three scenarios. It will continue to grow in REF, while it will gradually decline in ATS. In NZS, applying a backcasting approach, it needs to drop sharply to achieve net zero in 2050. It is apparently difficult without placing an extreme stress on the economy.

It is not an easy task to reduce carbon emissions in the process of economic development. In Asia, no country, including Thailand, Indonesia, China, India, and Vietnam, has succeeded in reducing DCI on average in the industrialization period after achieving US$1,300 (2010 price) of real GDP per capita. It is really a challenging task to reduce DCI in the industrialization stage, save for the NZS scenario with substantial difficulties.

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

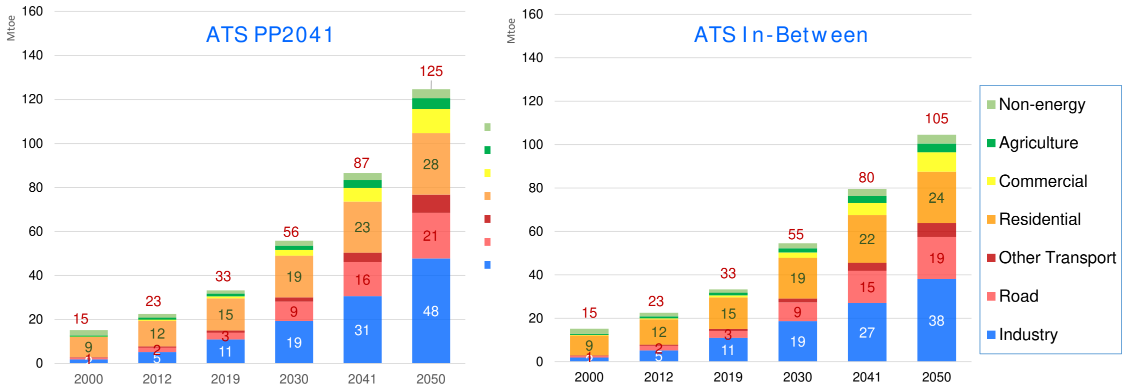
The Bangladesh government prefers the ATS In-Between case to be chosen as the basis for the Power Development Plan (PDP).

3.3 Energy Demand Outlook

In keeping with high economic growth, final energy consumption of Bangladesh will expand 3.75-fold between 2019 and 2050 for ATS scenario with the PP2041 GDP assumption at an average annual growth rate of 4.4%, while it will expand 3.14-fold at annual 3.8% with In-between GDP assumptions.

- Industry sector: to lead the country's economic growth, energy consumption will rapidly increase even after introducing significant energy efficiency and conservation measures.
- Transport sector: fuel consumption will grow fast to reflect increasing demand for mobility.

- Residential sector: 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 by substantial efficiency improvement.
- Commercial sector: energy consumption will grow fast to support modernization of life and society, but the overall amount will remain relatively small.
- Agricultural sector: continues to consume certain amount of energy for irrigation and agricultural machines.
- Non-energy sector: energy consumption will expand mainly as feedstock for fertilizer and petrochemical industries. Sectoral trends are analyzed as below.

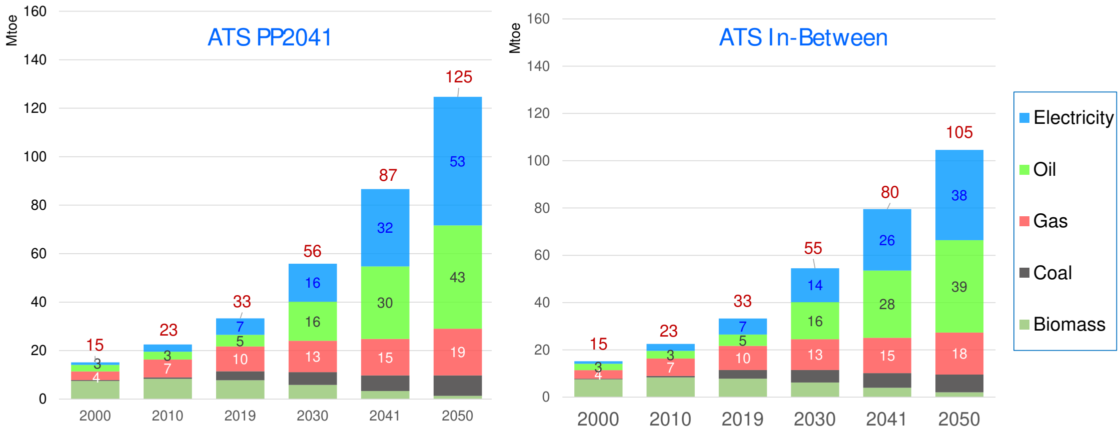


Source: IEPMP Study Team

Figure S.3-3 Final Energy Consumption by Sector

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. This is partly because household sector is assumed to use LPG, classified as oil, instead of city gas. Cooking fuel selection must be reassessed to find an appropriate solution. 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.

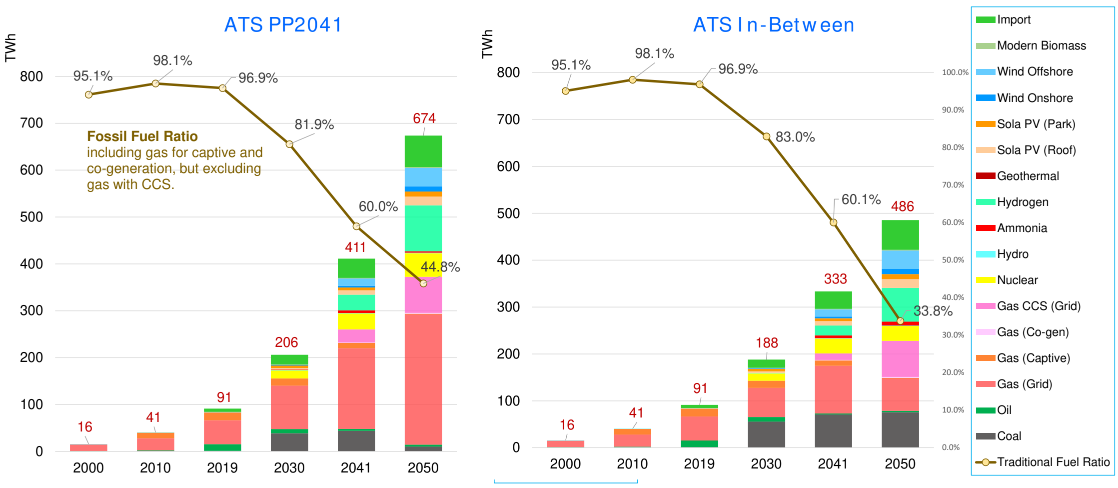
The magnitude and structure of the electricity demand are most important in simultaneous achievement of high economic growth and carbon neutrality. The national power demand will expand 7.82-fold in the PP2041 case between 2019 and 2050, and 5.63-fold in the In-Between case as shown in Figure S.3-4.



Source: IEPMP Study Team

Figure S.3-4 Final Energy Consumption by Source

In order to construct a low-carbon economy, every clean energy such as nuclear, hydro, solar PV, wind, CCS[4], ammonia, hydrogen, etc. must be introduced extensively. In contrast, the conventional fossil fuel ratio including natural gas used at captive and co-generation users needs to be decreased from 91% in 2019 to below 60% in 2041 and about 40% in 2050.



Source: IEPMP Study Team

Figure S.3-5 Outlook of Electricity Supply Mix (TWh)

4. Energy Supply

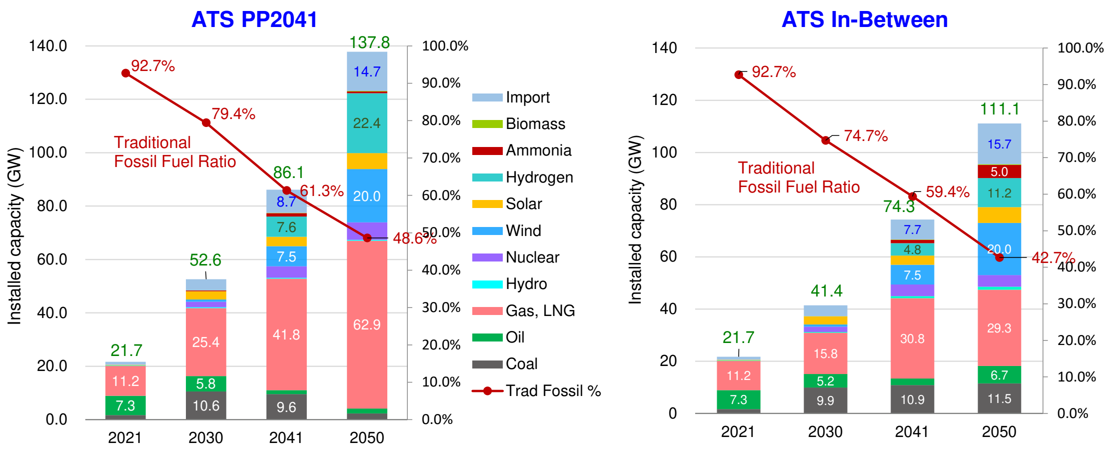
4.1 Power Supply

To accommodate the increasing demand, power generation capacity will be expanded 6.4-fold for the ATS PP2041 case and 5.2-fold for the ATS In-Between case between 2021 and 2050. The

[4] Carbon Capture and Storage/Sequestration (CCS) is not an energy but a technology. However, as it offsets carbon emissions, CCS is treated as if a sort of clean energy in this report.

existing power plants will gradually retire to 6.7 GW in 2041 and almost nil by 2050. New power plants must be constructed in a grand scale. In the course of the power development, a significant amount of clean generation will be introduced to ensure the country's commitment to create a low carbon economy.

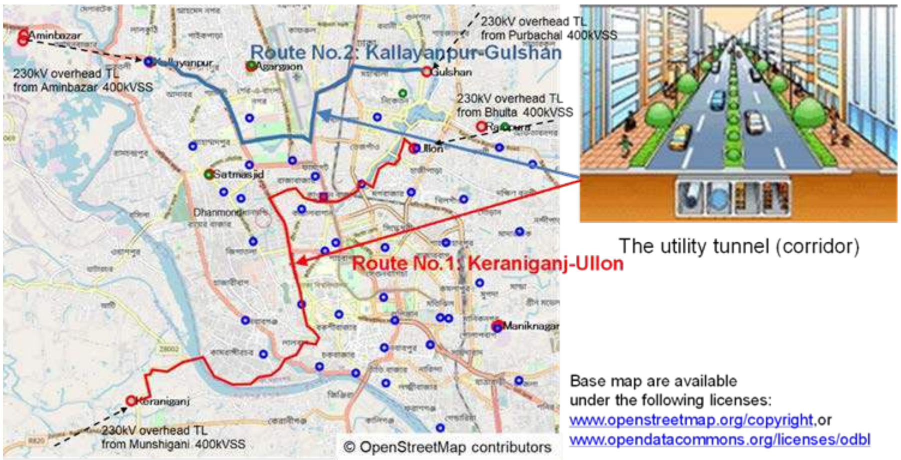
Fossil fuel thermal power generation (including those with CCS) accounts for the majority of the power source during the projection period, but its share declines significantly from the present 93% to around 60% in 2041 and further downward in the following years. Natural gas will be dominant among fossil fuels as it is cleaner than others. Oil-fired thermal power, which currently accounts for 34% of the total, will gradually decline due to retirement. Coal-fired thermal power currently accounts for 8%, and will increase to 20% in 2030, but will drop to 2% in 2050 with gradual retirement for the PP2041 case. Longer plant life is considered for these coal power plants in the In-Between case. Then, increase in natural gas plant will be controlled and clean power generation will be introduced proactively. Towards 2050, the ratio of wind power and hydrogen-fired thermal power will increase, and the composition ratio in 2050 will be 15% and 16% for the PP2041 case and 18% and 10%, respectively. Since growth of the electricity demand and hence carbon emissions is slower for the In-Between case, introduction of the expensive hydrogen fuel is slower compared with the PP2041 case.



Source: IEPMP Study Team

Figure S.4-1 Power Generation Mix (Installed Capacity): PP2041

In addition to the substantial construction of the power generation system, transmission and distribution systems must be developed in alignment with other social sectors. In particular, the modern metropolitan power system should be designed in line with city development plans. In these efforts, modern innovative technologies with digitization must be introduced to create a smart electricity system, which is particularly important to efficiently utilize variable renewables such as solar and wind as well as to cope with changes in daily load curve pattern.

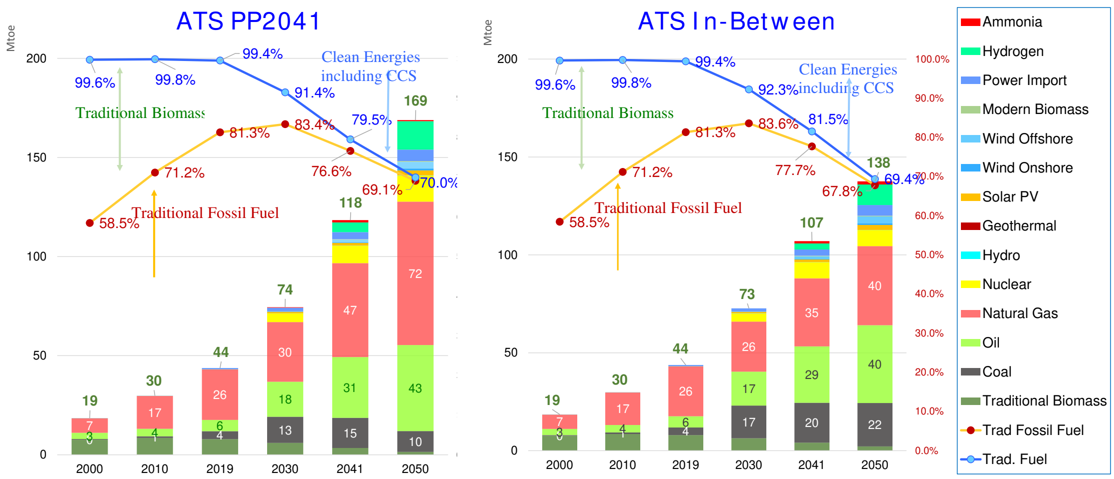


Source: IEPMP Study Team

Figure S.4-2 Example of 230kV underground cable routes

4.2 Primary Energy Supply

Total primary energy supply (TPES) is a sum of the final energy consumption excluding electricity, a secondary energy, and the fuel input in power sector. In the 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. In the ATS In-between, TPES will expand by about three-fold to 138 Mtoe in 2050, which is close to that of Thailand in 2019.



Source: IEPMP Study Team

Figure S.4-3 Primary Energy Supply

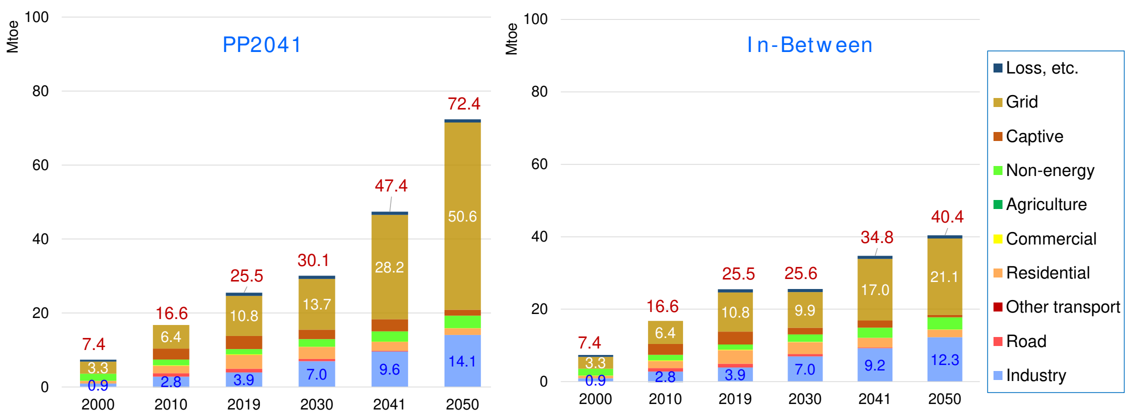
Traditional biomass consumption, mainly firewood, is being replaced with modern fossil fuels such as coal, oil or natural gas. This trend continues and traditional biomass consumption will almost disappear by 2050. On the other hand, clean energies such as solar PV, wind, CCS, nuclear, ammonia and hydrogen will be introduced. These clean energies will exceed 20% of the TPES by

2041 and reach almost 30% in 2050.

Gas will remain as the largest energy source. It is relatively low carbon footprint and the existence of domestic supply infrastructure will keep gas as the most preferred energy. Clean energies will increase the share, but the present primary energy supply mix will be kept by and large while traditional fossil fuels still play certain roles.

1) Natural Gas

Natural gas consumption will expand 2.8-fold between 2019 and 2050 for the PP2041 GDP case and 1.7-fold for the In-Between case. The main driver is the power sector. Because of its lower carbon footprint among fossil fuels, natural gas consumption by power sector will expand 3.6-fold in the PP2041 and 1.6-fold in the In-Between during the same period. As illustrated in the figure below, natural gas demand will be greatly affected by the electricity demand and selection of fuel to aim at low carbon society. The industry sector gas consumption will grow steadily but in relatively small quantity. The residential sector natural gas consumption is projected to reduce in view of the present national policy. But this may need a review as discussed below.

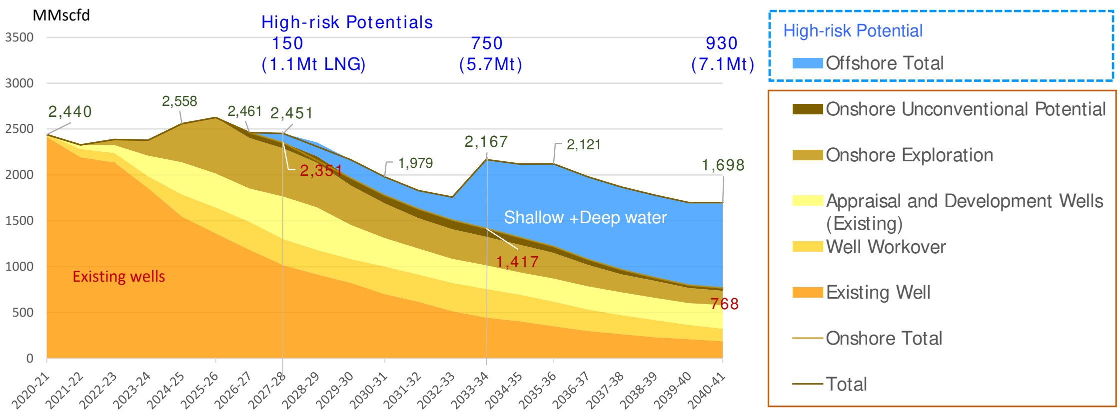


Source: IEPMP Study Team

Figure S.4-4 Natural Gas Demand Outlook

Historically natural gas has supported energy supply in Bangladesh. Gas resources are depleting and various countermeasures are proposed such as to reactivate existing onshore fields and to explore offshore blocks. However, production is forecast to decline even if high-risk potentials such as offshore potentials are developed.

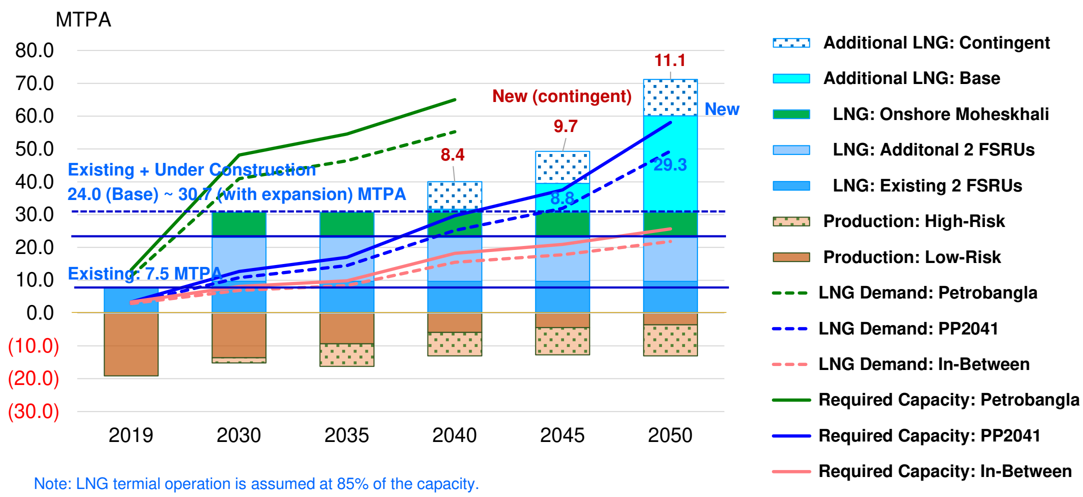
The supply gap against the increasing demand will be filled with LNG import. In addition to the presently operating two FSRUs (Floating Storage and Regasification Unit), plans are ongoing to install additional two FSRUs and one onshore LNG terminal. These will suffice the requirement of the LNG import capacity until the mid-2040s. However, unless the abovementioned high-risk potentials are materialized, additional plans must be considered to start by as early as 2040.



Source: Petrobangla

Figure S.4-5 Natural Production Outlook

It should be noted that, in the central scenario of this Master Plan, natural gas use as city gas is projected to decrease in the long run. This policy reflects the declining trend of gas resources as well as the obsolete city gas infrastructure and old-fashioned market structure. Biomass notably firewood is widely used in Bangladesh and still amounts to two-thirds of the home cooking fuel. This is being replaced by LPG quite rapidly. If this policy continues, a huge number of LPG cylinders must be distributed by trucks. This will significantly impact the already congested traffics in the metropolitan areas. It is necessary to reconsider the policy on appropriate distribution of cooking fuel among city gas, LPG and, to a lesser extent, electricity.



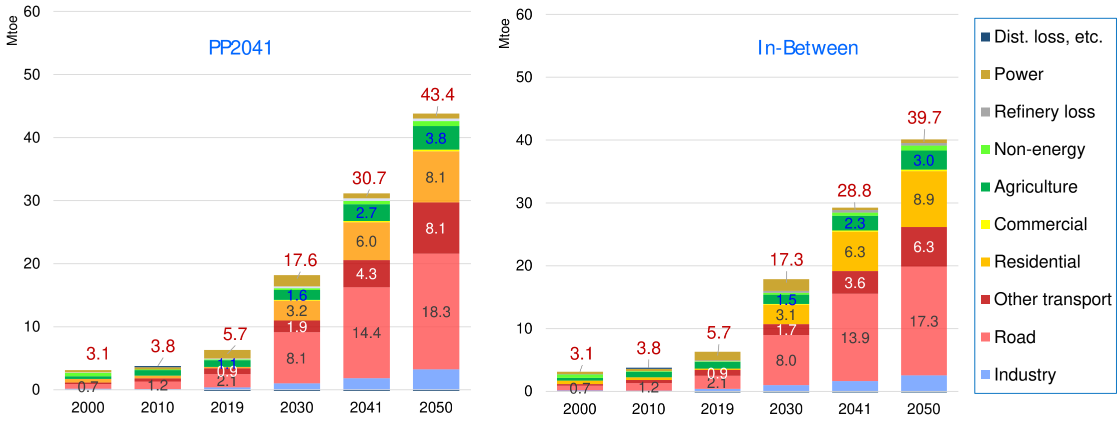
Source: IEPMP Study Team

Figure S.4-6 Requirement for LNG Import Terminals

Bangladesh is not endowed with good deepwater points for ocean class port. LNG import plans are not free from this issue. In addition, as natural gas will dominate as the main energy source over time with its relatively low carbon footprint among fossil fuels, its transmission and distribution system must be further developed. For its stable and efficient operation, it is particularly important to construct pipeline loops in the central area covering Dhaka and western part of the country with multiple input points. Needless to say, gas system should be upgraded to eliminate leakages and to be ready for introduction of smart systems for efficient management of the overall system.

2) Oil

Consumption of petroleum products is forecast to expand 7.6-fold between 2019 and 2050 for the PP2041 GDP case and 7.0-fold for the In-Between case. 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.



Source: IEPMP Study Team

Figure S.4-7 Outlook of Oil Demand

To accommodate the increasing demand, expansion of the national refining capacity is projected. This plan aims to maintain certain independence on product supply, but the assumed capacity expansion is relatively small compared with the recent world trends in distillation unit capacity ranging 100-200 kbd. An in-depth review is necessary to look into the balance between the domestic refinery and product import for reliable petroleum supply, including their preferable site locations.

In this plan, after construction of the Moheskhali LPG import terminal with its 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. It is necessary to consider the appropriate distribution of cooking fuel among city gas, LPG and electricity.

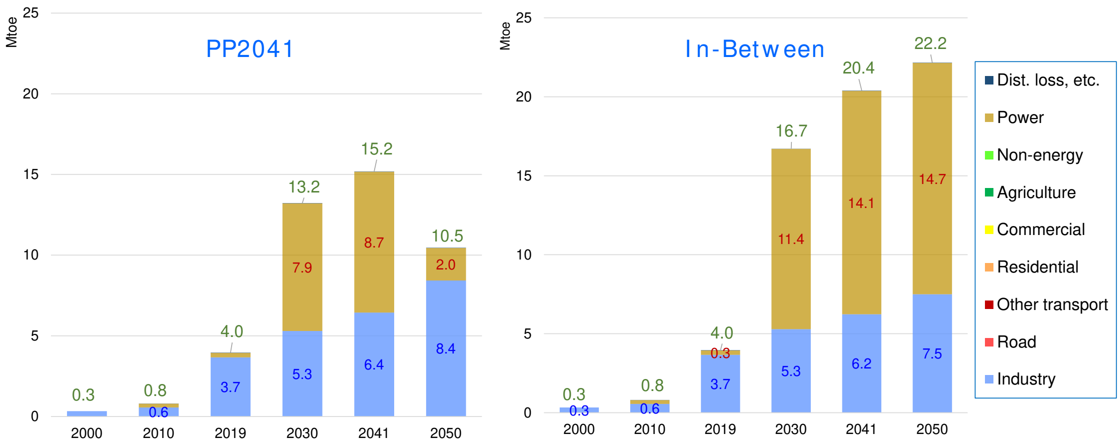
Table S.4-1 Petroleum Supply Plan

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**	**5.0**	**8.5**
ERL-1	1.5	1.5	1.5	
ERL-2		3.0	3.0	3.0
ERL-3 (replace ERL-1)				5.0
Other small refineries	0.5	0.5	0.5	0.5
Product import (excl LPG)	**8.9**	**10.0**	**20.4**	**24.6**
BPC@Chittagong	4.5	5.0	5.0	5.0
IBFPL		1.0	1.3	1.3
SPM-1@Chittagong		3.0	9.0	9.0
New SPM@TBD (excl crude oil)			5.1	9.3
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	0.1	0.2
New LPG Terminals@TBD		0.9	2.9	7.8

Source: IEPMP Study Team

3) Coal

In Bangladesh, coal is mainly used in the industry and power sectors. Industry coal consumption is not so large in comparison with other countries, since typical coal consuming industries such as cement and large-scale blast furnace steel production do not exist in Bangladesh.

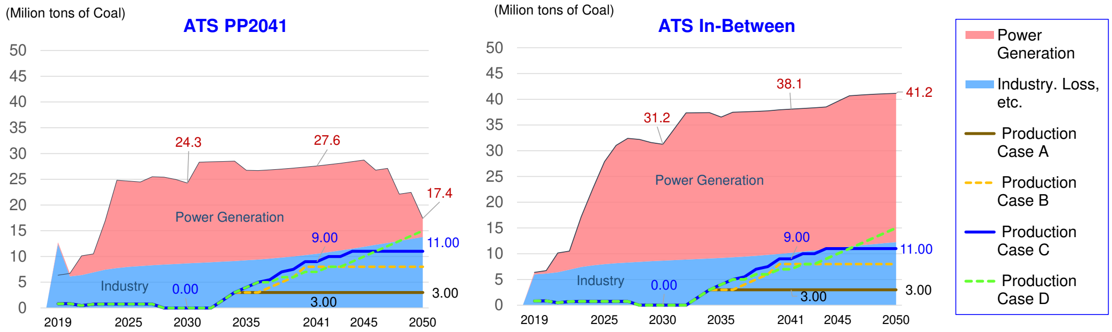


Source: IEPMP Study Team

Figure S.4-8 Coal Demand outlook

Power supply with imported coal started at the Payra power station in 2020. Coal consumption for power will continue to increase during the 2030s, but will gradually move to ammonia-cofiring to curtail GHG emissions. Eventually, coal consumption for power will peak and then decrease during the 2040s. Ammonia co-firing and CCS, both technologies for reducing GHG emissions, are still in their infancy; adoption of them must be investigated carefully. An appropriate guideline for use of coal as one of the primary energies must be laid out in view of economics, energy security and environmental considerations.

Utilization of domestic coal has some role for establishment of reliable energy platform. Figure S.4-9 shows the outlook of demand/supply balance of coal. Although the gap with import is still large at present, imported coal can be reduced at an early stage of the projection by shortening the preparation period for development of new coal mines. If this will be the case, it is also necessary to identify the appropriate system to effectively transport the indigenous coal.

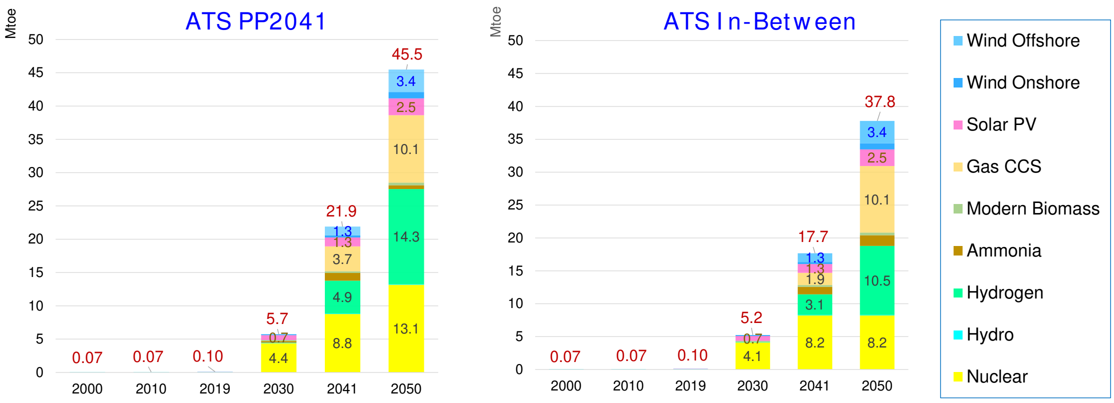


Source: IEPMP Study Team

Figure S.4-9 Demand/Supply Balance of Coal

4) Other Energy sources

To build a low carbon economy, clean energy supply 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 37.8 million toe for the In-Between case. The share of clean energy will increase from almost nil in 2019 to 27% in 2050 for the PP2041 case.



Source: IEPMP Study Team

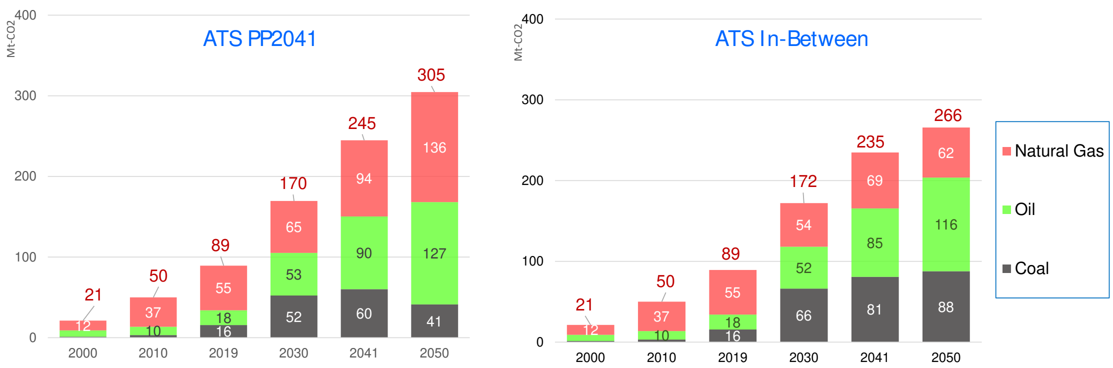
Figure S.4-10 Outlook of Clean Energy Supply

Among the energy sources, nuclear, hydro and CCS will play important roles. In Bangladesh, geothermal resources are non-existent, and variable renewable energies notably solar and wind are relatively limited as land available for these is limited due to high population density. Their introduction is scheduled at a maximum level reasonably possible, but the share of these variable new energies will still remain below 20% even in 2050.

On the way to become a clean energy economy as above, it is important to develop an action plan on how to take in these fast-developing technologies, not only in the areas of production and import but also of transportation, storage, and utilization of them, while making timely investment decisions. To start with, Bangladesh should join the related global endeavors and tackle the R&D activities on these technologies. It may start with study and investigation and may develop into pilot projects and eventually to commercial applications. Such activities will also bring up experts on these new technologies who are essential to make the country ready for a clean energy economy. To enable this, Clean Energy Roadmap should be prepared, though many concepts and technologies are still vague and uncertain at present, to identify the pathway and steps toward a low-carbon economy.

4.3 CO_2 Emissions

CO□ emissions from energy use reflect the amount of fossil fuels in TPES. The emissions of ATS PP2041 will be relatively moderate at 305 million tons-CO_2 in 2050. That of ATS In-between will be even slower at 266 million tons-CO_2 in 2050.



Source: IEPMP Study Team

Figure S.4-11 Energy-Related CO_2 Emissions by Source

Energy-related CO2 emissions will increase from 57 MtCO2e in 2012 to 170 MtCO2e in 2030 in the ATS PP2041 case. For methane, only natural gas leakage is considered, which would occur along the supply chain, especially in the distribution system. It is assumed that 0.1% of the natural gas sales volume leaks out from the system as per the default IPCC value. Then, methane emissions will slightly increase from 0.5 MtCO2e in 2012 to 0.7 MtCO2e in 2030 in the ATS PP2041 case. The total GHG emissions in 2030 will be 299 MtCO2e as estimated in Table S.4-2.

Table S.4-2 GHG emissions by sector/gas ($MtCO_2e$)

		2012	2030			Remarks
			NDC conditional	ATS PP2041	ATS In-between	
Energy		93.09	226.56	205.59	207.89	The figures in 2012 and NDC conditional are from Updated NDC.
	Energy-related CO_2	57.4		169.7	172.1	IEPMP study.
	Methane from the gas distribution	0.5		0.7	0.6	IEPMP study.
	Other	35.19		35.19	35.19	The figure in 2012 is calculated as: (Energy) - (Energy-related CO_2) - (Methane from the gas distribution). The figures in ATS PP2041 and ATS In-between are assumed the same as that in 2012.
GHGs other than energy		75.96	93.38	93.38	93.38	The figures in 2012 and NDC conditional are from Updated NDC, and those in ATS PP2041 and ATS In-between are assumed as the same as that in NDC conditional.
Total		169.05	319.94	298.97	301.27	

Source: Nationally determined contribution and the IEPMP Study.

5. Other Important Investigations

1) Strategic Environmental Assessment is conducted on the above plan. The outcome is summarized in Chapter 8 Environment and Social Considerations.

2) A detailed investigation on the energy data management system is conducted as reliable and quick data compilation is essential for business operations and policy making. Analysis and recommendations are summarized in Section 9.3 Energy Data management system.

3) An in-depth review on the legal framework of LNG import is conducted with a view to strengthening the legal system as well as negotiation skills related to LNG purchase in the international market. Analysis and recommendations are summarized in Section 9.4.

6. Way Forward

In the voyage to materialize the Vision 2041 whereby Bangladesh will achieve a high-income country status by 2041, energy will play an important role to drive the development. For the ATS PP2041 case, energy demand will expand 3.75-fold from now to 2050, while electricity demand 7.82-fold showing that electricity will be the main energy to drive the economic growth. At the same time, along the global movements on climate change, Bangladesh has determined to aim at building a low carbon society. For a country going to take-off toward modernization, simultaneous pursuit of these objectives will be a great challenge. In consideration of the current status of the nation and the pathway to its goal, it should be noted that particular attention be given to the following points in implementing this Master Plan:

1) Re-confirm the clean energy target as of 2041

2） Reinvent energy efficiency and conservation actions
3） Maximize the benefits of indigenous conventional and renewable resources
4） Strengthen the energy organizations including human resources
5） Prepare market design and policy supports for clean energy development
6） Ensure safe and reliable nuclear power generation
7） Adopt novel and innovative energy technologies
8） Formulate a Clean Energy Roadmap to promote introduction of low-carbon technologies

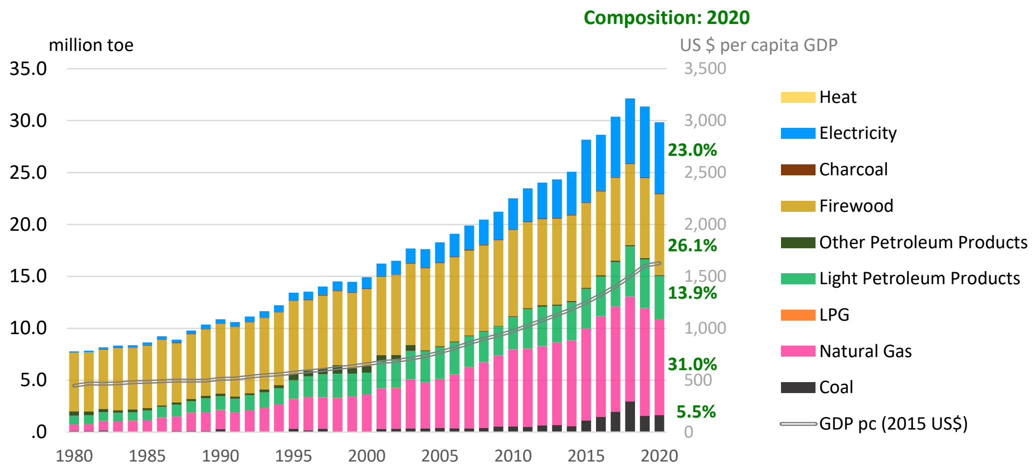
Part 1 Energy in Bangladesh: Present Status and Trends

Chapter 1 Development Goal and Energy Master Plan

1.1 Background and Purpose of Study

In the People's Republic of Bangladesh (hereinafter referred to as "Bangladesh"), per capita total primary energy supply in 2020-21 was 331kg in oil equivalent, which was below one-fifth of the world average (1,801kgoe in 2020)[5]. In the 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 proactively under the Vision 2041 aiming to achieve a high-income country status by the 70th anniversary of its independence. Bangladesh seeks to expand its economy by more than fivefold from now, entailing the inevitable and rapid growth in energy demand. Among others, electricity consumption per capita, which stayed at 560kWh/year in 2020-21 or 17.4% of the world average of 3,212kWh in 2020[6], will expand greatly as the key driver to push the economic development while improving the people's quality of life.

In order to accommodate the increasing demand with affordable energy supply, various challenges must be overcome in relation to constraints on the indigenous energy resources, country's energy security, climate change issues, and so on. To this end, Bangladesh has developed major long-term energy plans such as 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 consolidate them into a comprehensive national plan setting out a tangible and practicable development roadmap. Thus, the

[5] 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.

[6] Electricity generation for Bangladesh, while electricity consumption for the world average.

Bangladesh government requested Japan to support formulation of the Integrated Energy and Power Master Plan (IEPMP) with a view to setting out middle/long term energy policies to establish a low carbon/decarbonized society. The Ministry of Power, Energy and Mineral Resources (MPEMR) and the Japan International Cooperation Agency (JICA) discussed the above request and signed the Record of Discussion on 14 March 2021.

In accordance with the above agreement, the draft IEPMP, as appended herewith, has been developed with a view to establishing a clean and efficient energy supply/demand system as the platform for sustainable development of Bangladesh. It develops a long-term energy plan up to 2050 with a concept of “S plus 3E” representing Safety, Energy Security, Economic Efficiency and Environment as the central pillars, each element of which denoting the following:

1) Safety: energy must be supplied safely and stably;
2) Energy Security: maximize the use of indigenous energies and prepare energy import infrastructure;
3) Economic Efficiency: provide modern/convenient energies at minimum/affordable cost;
4) Environment: secure sound environmental conditions and lower the GHG emissions to a lowest possible level.

1.2 Study Framework

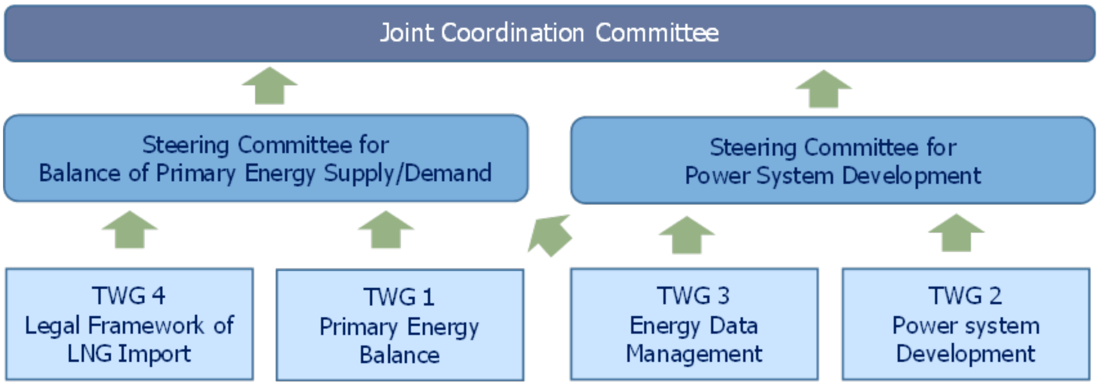
The study for drafting the IEPMP was conducted by the joint team of experts from Bangladesh and Japan. Under the Joint Coordination Committee (JCC), two steering committees (SCs) were nominated for Balance of Primary Energy Supply/Demand and Power System Development. Under the SCs, four technical working groups were nominated to look into specific areas as assigned below:

TWG1: Study on energy demand forecast and demand/supply balance

TWG2: Development of power system including all of generation, transmission and distribution

TWG3: Construction of energy data management system

TWG4: Study on legal framework for LNG import



Source: IEPMP Study Team

Figure 1.2-1 Organization for Study

Local consultants were also engaged for effective conduct of research on energy consumption, information gathering on electricity system planning and strategic environmental impacts. For collection of detail and accurate information on energy in Bangladesh, their activities and analysis were highly helpful.

Figure 1.2-1 shows the study flow. At first, following data collection, scenarios on the long-term energy demand outlook were developed by July 2022. Through feedback from and intensive discussions with the MPEMR and a wide range of stakeholders, the main scenario was set out. It was followed by analysis on the power mix and the primary energy supply mix with environmental and social considerations. Based on these analyses, the first draft of this Master Plan Report was prepared. The draft was reviewed and discussed closely at two Retreat meetings held in October and November, and was revised and updated accordingly. In the course of the study, particular issues on energy management were also looked into, i.e., energy data management system and legal framework on LNG import.

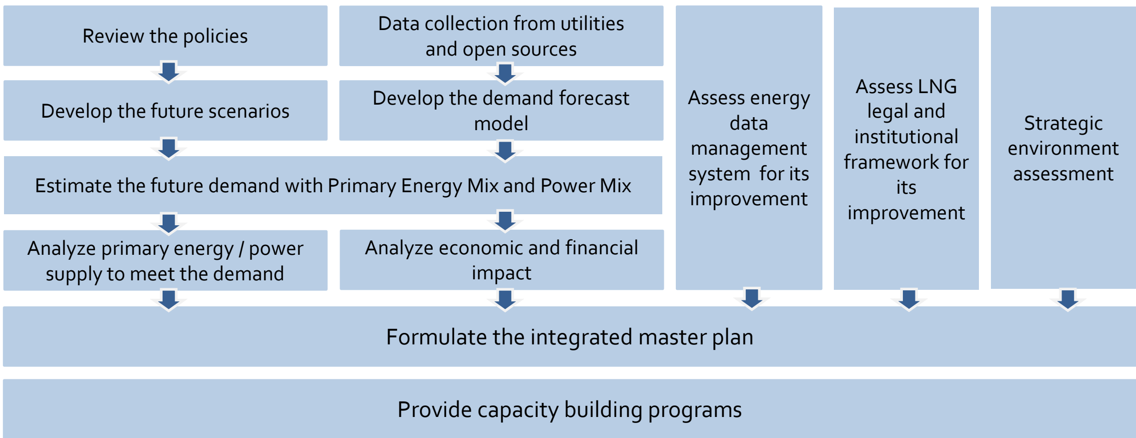


Figure 1.2-2 Flow of the Study

The Study team also worked closely with other ongoing projects as below being implemented by JICA to enhance understanding of related issues, eliminate duplication of work and share useful information among each other.

- Financing Project for Energy Conservation (Yen loans)
- Preparatory Research on Phase 2 of Matarbari Ultra Super Critical Coal-Fired Power Plant

(Research)

- Project for Digitization of Gas Network System and Improving Management Efficiency in Gas Sector (Technical Assistance)
- Research on Information Gathering and Confirmation on Strengthening Power Grid Connection in BBIN Countries in the South Asia Region (Research)
- Research on Information Gathering and Confirmation on Long-Term Low Emissions Strategy based on the Paris Agreement (Research)
- Research on Basic Information Gathering and Confirmation (Research)
- Capacity Building: Delta Plan 2100 (Country-by-Country Training)

In the course of the study, the Study Team has implemented frequent and extensive exchanges with stakeholders through individual interviews and open discussions. Main stakeholders' meetings were held three times inviting more than 100 participants as follows:

1st stakeholders meeting: 23 November 2021 at Sheraton Hotel. The inception meeting to present and discuss the study plan and contents.

2nd stakeholders meeting: 3 July 2022 at Intercontinental Hotel. The interim meeting to present and discuss the interim outcome of the study.

3rd stakeholders meeting: 13 December 2022 at Intercontinental Hotel. The final meeting to present and discuss the Draft Final Report of the study.

In addition, supplemental meetings were held from time to time with various focused groups to obtain information and comments. The Study Team would like to extend its great appreciation to all these groups for their valuable information and comments.

1.3 Composition of Report

This report is structured as follows:

Part 1 Energy in Bangladesh: Present Status and Trends

1) Development goal and Energy Master Plan (Chapter 1)
2) Present status and trends of energy and environment in Bangladesh and the world. (Chapter 2 &3)

Part 2 Draft Integrated Energy and Power Master Plan

1) Long-term energy demand outlook (Chapter 4)
2) Energy supply: power supply and primary energy supply (Chapter 5 ~ 7)
3) Environmental and social considerations (Chapter 8)]

Part 3 Building Prosperous Affluent Society

1) Specific analysis on energy management: energy data management and legal framework on LNG import (Chapter 9)
2) Conclusion and recommendation (Chapter 10)

This report is edited with a view to showing the comprehensive flow of the overall analysis. Therefore, it is significantly simplified and only the gist of analysis is presented. For detailed background data, analyses and discussions, please refer to Appendixes.

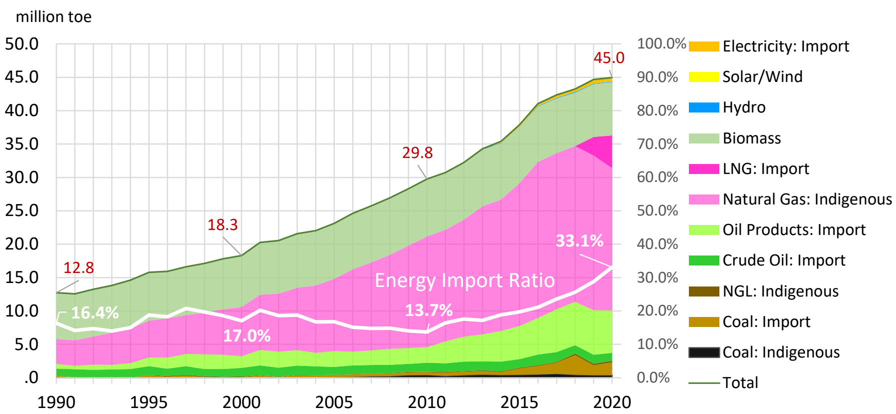
Chapter 2 Present Energy Status and Energy Policies

In the history of Bangladesh, conventional biomass and natural gas have been the main sources of energy, while per capita energy consumption remained below one fifth of the world average as mentioned in Chapter 1. However, reflecting the economic growth in recent years, this picture is changing with increasing energy consumption in power generation and industries. In the process of high economic growth led by the government, consumption of energy and power will be further accelerated. This chapter analyzes present status and issues of the primary energy supply, electricity demand/supply, energy utilization/efficiency and energy legislation in this country.

2.1 Primary Energy Supply

2.1.1 Overview of Energy supply

Until recent years, energy utilization in Bangladesh has depended on a small system developed with indigenous energies; conventional biomass (mainly firewood) and natural gas combined comprised more than 3/4 of the total energy supply[7]. A small amount of petroleum products as motor fuel and coal were imported but the energy import ratio remained below 20%. However, signs of peaking in natural gas production have created serious concerns on stable supply of energy and power, leading to expanding import of LNG and coal since 2018. The import energy ratio jumped to 33.1% in 2020. Since increase in indigenous energy production is not expected in the near future, energy import may increase rapidly. On the other hand, while construction of fundamental energy infrastructure is essential to support economic development and 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

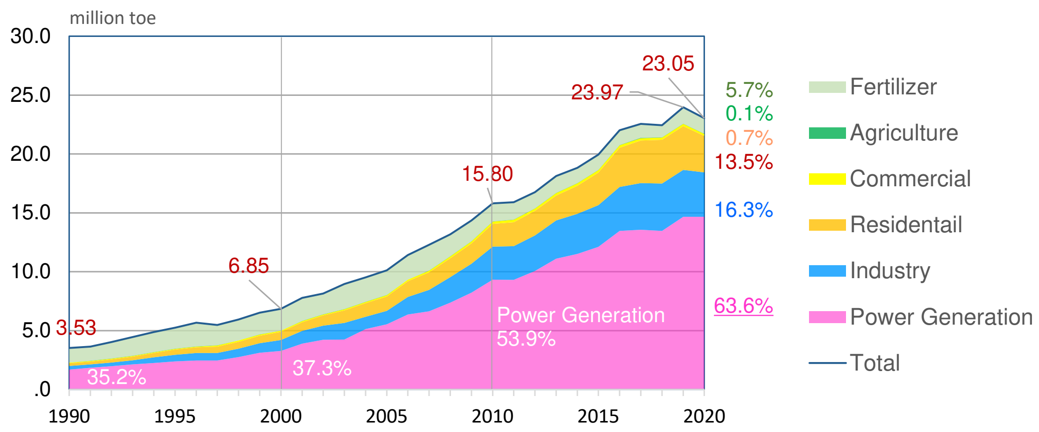
Figure 2.1-1 Primary Energy Supply in Bangladesh

As status and issues on each energy segment are analyzed in depth in Appendix A, they may be summarized as follows:

[7] IEA World Energy Balances 2022, which is referred to as IEA statistics in this report.

(1) Natural Gas

In the history of Bangladesh, indigenous natural gas has been the base energy source and natural gas pipeline network is developed nationwide. More than 60% of natural gas is used for power generation, followed by industry, residential use, fertilizer production, commercial use and irrigation for agriculture. On the other hand, exploration activities in recent years are not so successful and the 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.

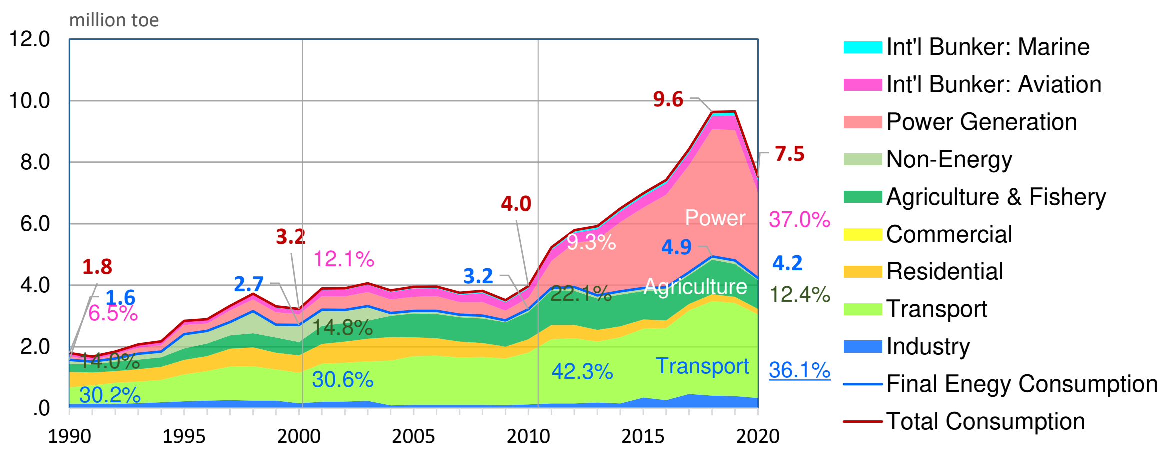


Source: IEA World Energy Balances 2022

Figure 2.1-2 Natural Gas Consumption in Bangladesh

(2) Oil

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



Source: IEA World Energy Balances 2022

Figure 2.1-3 Consumption of Petroleum Products in Bangladesh

There is a refinery in Chittagong with a refining capacity of 30,000BD, and very small condensate fractionators around natural gas fields, while 90% of petroleum products are imported. To cope with future demand increase, expansion of the Chittagong refinery is planned with a total capacity of 100,000BD. It is an important issue for the country's energy policy how to ensure expanding supply of petroleum products against fast increasing demand.

(3) Coal

Coal is one of the core energy sources for developing industry and power generation in Bangladesh. Despite the fact that the first and only coal mine in the country, Barapukuria, started production in 2005, the country's coal supply mostly depends on import (82.3% in 2020: Figure 2.1-1). A substantial amount of coal resources is identified in Bangladesh. However, due to high population density and anticipated impacts on agriculture, the primary economic sector of the country, it is necessary to solve a lot of difficult problems before developing these resources. Environment friendly advanced technology must be adopted for developing indigenous coal resource along with import.

(4) Conventional Biomass

According to the IEA statistics, the entire amount of biomass consumption is attributed to the residential sector. Almost all of it comprises primary solid biomass (firewood and animal wastes) while charcoal is less than 1%. Use of cleaner cooking fuel is an urgent issue for improving people's quality of life, and thus promotion of gaseous fuel (city gas and LPG) and switching to electricity should be listed among important policy objectives.

(5) Renewable Energy

The amount of renewable energies introduced at the end of 2021 was 777MW, of which 543MW was solar PV and 230MW hydro, while wind power and biomass generation remained at a very limited level. In the course of future promotion, solar PV and wind are deemed to play the core role in view of the resource potential. However, with dense population, procurement of necessary land is an issue. It is also necessary to achieve a manageable balance with the stability of the grid when introducing variable renewable energies such as solar and wind.

2.1.2 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 the Energy and Mineral Resources Division (EMRD). PD is responsible for electricity, while EMRD is responsible for oil, natural gas and mineral resources.

Petrobangla is one of the state-owned corporations under the EMRD and has jurisdiction over mineral resources including natural gas, LNG and coal. Another public institution is the Bangladesh Petroleum Corporation (BPC), which supply petroleum products in 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 described below:

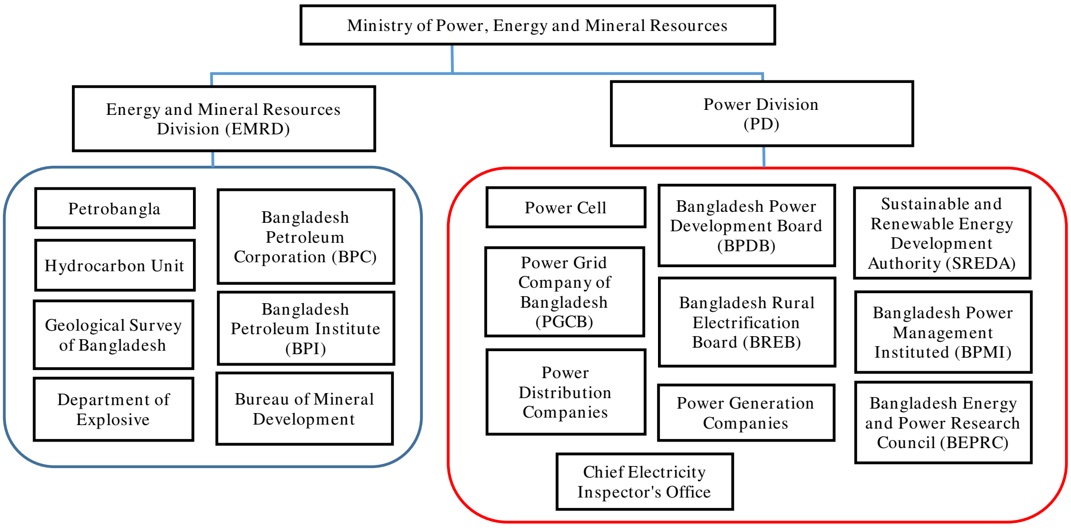
a. Petrobangla:

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, it will be another important issue how to consider introduction of private sectors into these operations in the course of developing the energy infrastructure for the country.



Source: Ministry of Power, Energy and Mineral Resources

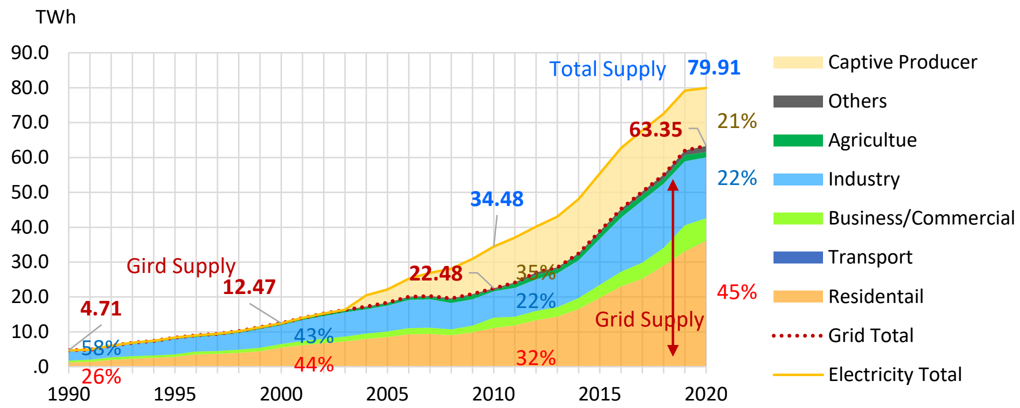
Figure 2.1-4 Ministry of Power, Energy and Mineral Resources Organization Chart

2.2 Electricity Supply

2.2.1 Electricity Demand

In Bangladesh, substantial efforts were made to develop electricity supply system after the turn of the century. Electricity supply jumped 6.4-fold between 2000 and 2020. A 100% electrification was achieved in 2021. Nevertheless, electricity consumption per capita was 560kWh in 2020-21, merely a 17.4% of the world average (3,212kWh in 2020)[8], comprising 23% of the country's energy consumption (as per Figure 1.1-1). More than 40% of electricity is used by the residential sector while more than 40% is also used by the industry on grid and captive power generation at industries combined.

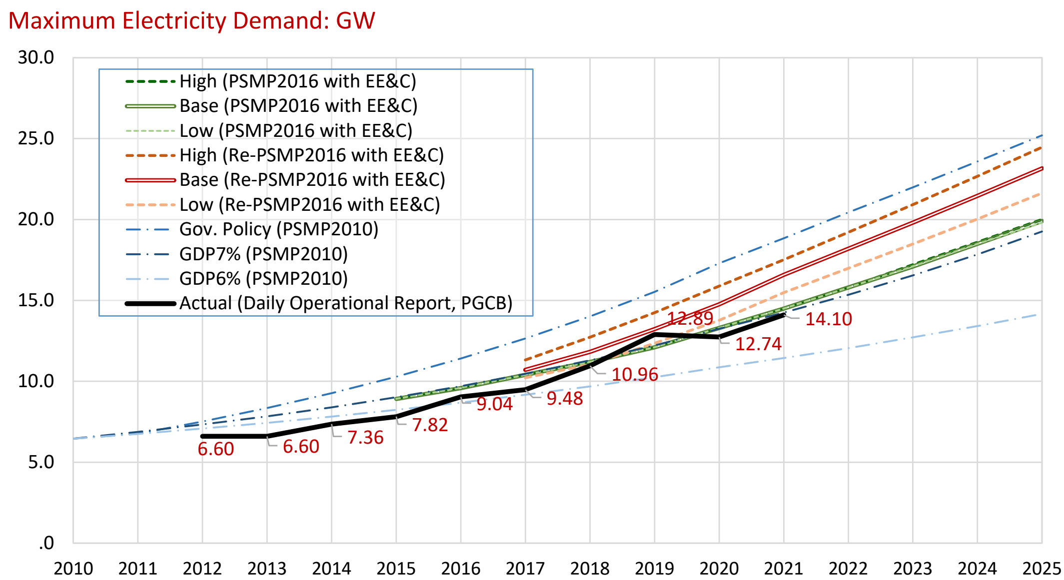
[8] Electricity generation for Bangladesh, while electricity consumption for the world average.



Source: IEA World Energy Balances 2022

Figure 2.2-1 Electricity Consumption in Bangladesh

Electricity demand recorded a transitory jump in 2019, but remained dull 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. Therefore, it is essential to develop power generation sources, efficient operation of them, and transmission and distribution networks under an appropriate planning.



Source: PSMP 2016 and Power Division

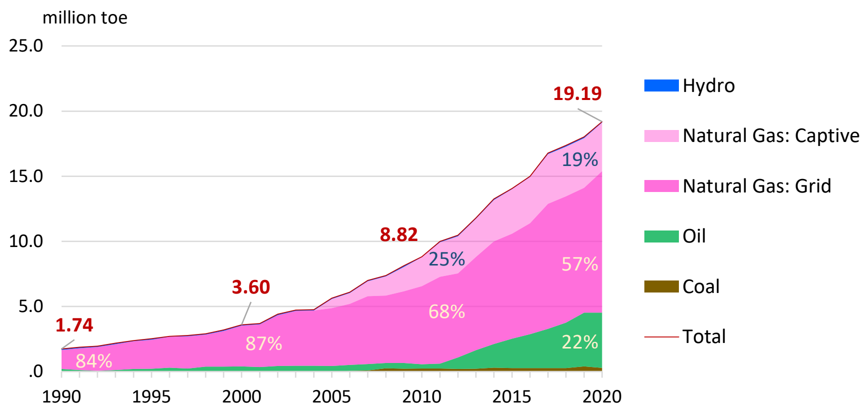
Figure 2.2-2 Maximum Electricity Demand: Recent Years vs. Past Master Plan

As shown in Figure 2.2-2, 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 ceased, it will return to the long-term growing trend. Since the electricity demand is expected to grow rapidly but encountering various impacts of uncertain factors, it is necessary to review it periodically and fine tune the development plans for power generation sources as well as transmission and distribution systems.

2.2.2 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% of the whole power supply including the grid and captive 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 geographically situated in the estuary of big rivers.

Indigenous natural gas supply has been stagnant in recent years and adversely affecting operation of the gas-fired power stations. Thus, LNG import started in 2018. Since there are also difficulties in developing indigenous coal mines the Payra coal-fired power plant was built to run on 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 at a site 140km west of Dhaka.



Source: IEA World Energy Balances 2022

Figure 2.2-3 Power Sources in Bangladesh by Energy Input

In the process of developing the power supply system to cope with the expected demand growth, major issues are anticipated as described below:

(1) Development of Power Sources to Secure Supply

a. Conventional Thermal Plants

Bangladesh has traditionally used natural gas as the base fuel for power generation. However, as the gas resources were anticipated to peak, construction of coal thermal plants to use imported coal were proposed. Among the plants, the Payra plant was completed and started operation; No.1 plant in May and No.2 plant in December 2020. However, the Government of Bangladesh announced in June 2021 a moratorium on 10 coal-thermal plant plans in consideration of the intensifying global movements towards low-carbon, net-zero emissions society. Coal thermal plants are, together with gas-fired power plants, among the most promising options for Bangladesh which needs to construct a fundamental power generation system. It should be carefully considered how to treat the plans for introducing coal-fired plants in the process of power development with due consideration on the global warming issue.

b. Nuclear Power Generation

In Bangladesh, the Rooppur nuclear power plant (1,200MWx2) is under construction 140km west of

Dhaka. This plant is constructed under the support of Russia. Since nuclear power plants are in general designed with large capacities in the range of 1,000 MW or greater for economies of scale, it is also necessary to consider the impact on the yet small power system in the event of a nuclear plant shutdown.

c. Renewable Energy Generation

Potential renewable energy sources in Bangladesh are as follows:

- Hydro: since most part of the land is located in the estuary of large rivers and low-lying swamps and situated at 5m or less above sea level, the potential for hydro power is limited.
- Wind: suitable sites for wind power are unevenly distributed along the coast and introduction of large-scale onshore wind power is limited. Offshore wind power has certain potential while it is necessary to develop a transmission network serving Dhaka and other high demand areas.
- Solar: though being deemed most promising, suitable sites are unevenly distributed and concentrated in the south-eastern coastal areas. Development of the transmission network is a challenge likewise wind power.

In a large-scale introduction of variable renewable energies, it is generally anticipated to encounter challenges such as steepening of demand change (called "duck-curve phenomena"), low inertia due to increased number of power sources connected via inverters, and a decline in synchronization power (out-of-step of synchronous generators). In addition, a number of local issues may arise in the distribution system, such as complexity of power flows, overloads, voltage deviations and others.

d. Thermal Power to Burn Ammonia and Hydrogen

These technologies are yet in the development and demonstration stage worldwide. Bangladesh in short of financial and technical base may be in the position to wait and see how these would be developed as affordable technology to become realistic options for the country.

(2) Power Plant O&M and Supply-Demand Balancing Operations

Around 2013 through 2015, load shedding was frequently used to maintain supply-demand balance when high demand arises. This was caused by decreases in generator output and thermal efficiency and equipment failures due to lack of regular maintenance as well as lack of the authority of NLDC to comprehensively manage and coordinate the generator operations.

There has been a significant improvement in maintaining the supply-demand balance in recent years, and that there is rather an excess of supply capacity over electricity demand. Nevertheless, more than 2,000 MW of generators were shut down or operating below capacity due to insufficient gas supply on the day of operation, unplanned maintenance, etc.

(3) Reserves for Frequency Regulation

At the time of formulating the PSMP 2016, the generators in Bangladesh did not have sufficient automatic supply and demand adjustment functions resulting in frequency fluctuations of 50 Hz ± 1.0 Hz or more. Presently generators implementing governor-free operation (primary reserves) are secured to some extent leading to improvements in frequency fluctuation to about 50Hz±0.5Hz. The reserve for primary frequency control needs to improve to narrow down the frequency fluctuation range. However, governor-free operation alone does not have sufficient ability to maintain the frequency. Therefore, when there are large deviations, the gap not returning to normal must be adjusted by other means. The EMS of NLDC and the generators are still not linked online but rather coordinated through telephone instructions. With the present system, the country may face technical difficulties in the future with increases in variable renewable energy (VRE) such as solar and wind power.

(4) Development and Operation of Transmission Network

To cope with increasing electricity demand, large scale power plants will be developed along the southern coastline to utilize imported coal and LNG. In line with this, a 400 kV transmission line is presently under construction connecting to Dhaka, the demand center, and an additional plan to construct a 765kV line is being developed. For developing the transmission network, it is necessary to consider distribution of regional demands to formulate an appropriate plan. It is also important to install a measure to maintain the system in case any single power source drops out.

It is also necessary to establish a framework that relevant organizations shall understand specific points peculiar to important demand-intensive areas such as Dhaka and fully coordinate as one-team to implement the plan.

In Bangladesh, import of electricity from Nepal and Bhutan is planned. Since large-scale import-fuel based power plants are considered on the southern coast, import of electricity is expected to ease the bias in transmitting large amounts of power from the south to the north. However, when the the above plan is fully implemented, there will be 12 connection points with neighboring countries, and their combined capacity will exceed 10 GW accounting for 14% to 20% of the total demand of between 50 and 70 GW projected for 2041. Detailed techno economic analysis considering system security shall be required for selection of the optimal interconnection points with neighboring countries.

2.3 National Policies on Energy and Environment

2.3.1 Social and Economic Policy

The social and economic policies presently effective in Bangladesh are as follows:

a. Very long term "Bangladesh Delta Plan 2100" (October 2018),
b. Long term "Perspective Plan of Bangladesh 2021-2041" (March 2020),
c. Short- to-medium term "8th Five Year Plan July 2020-June 2025 (May 2020).

1) Bangladesh Delta Plan 2100

Bangladesh Delta Plan 2100[9] (hereinafter referred to as BDP2100) was developed by the Planning Commission in October 2018.

Bangladesh, geographically featured as a delta region, is known as one of the most densely populated

[9] Planning Commission, access on March 2022, http://www.plancomm.gov.bd/site/files/fd6c54f6-dfab-4c71-b44a-e983ffd2bdee/-

countries in the world. It needs to maintain limited arable land through proper management of the water environment and thereby to secure land for its industries. With this background, BDP2100 aims at making the delta region as 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 an 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 touches upon energy and indicates a policy of promoting development of renewable energy from the standpoint of preserving the water environment, sustainable development, and mitigating the effects of climate change. In particular, it targets for at least 30% energy production from renewable sources by 2041 in the context of being a prosperous country.

2) Perspective Plan of Bangladesh 2021-2041

The Perspective Plan of Bangladesh 2021-2041[10] (hereinafter referred to as PP2041) 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 2.3-1 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

Source: Planning Commission, Bangladesh Delta Plan 2100

Among 11 sectoral strategies for achieving the socio-economic goals, energy and environment are discussed intensely. Among others, it emphasizes (1) balanced development of power generation, transmission and distribution, (2) enhanced private involvement, (3) broadening of electricity imports from all three neighboring countries, and (4) development of renewable energy.

3) 8th Five Year Plan July 2020-June 2025

The 8th Five Year Plan July 2020-June 2025[11] (hereinafter referred to as 8FYP) was developed by 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. The 8FYP is

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

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

the first of these and will cover the five-year period beginning July 2020. The plan defines six core themes, taking into account the impact of the 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 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[12].

Among others, the 8FYP aims at economic recovery slowed by COVID-19 focusing on labor-intensive and export-oriented manufacturing industry.

Table 2.3-2 GDP Growth Projections: 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

2.3.2 Energy Policy

1) Energy Mix

Bangladesh Delta Plan 2100 (BDP2100), Perspective Plan 2021-2041 (PP2041), and 8th Five Year Plan July 2020-June 2025 (8FYP) commonly refer to expansion of renewable energy, though the degree of actual recommendations varies.

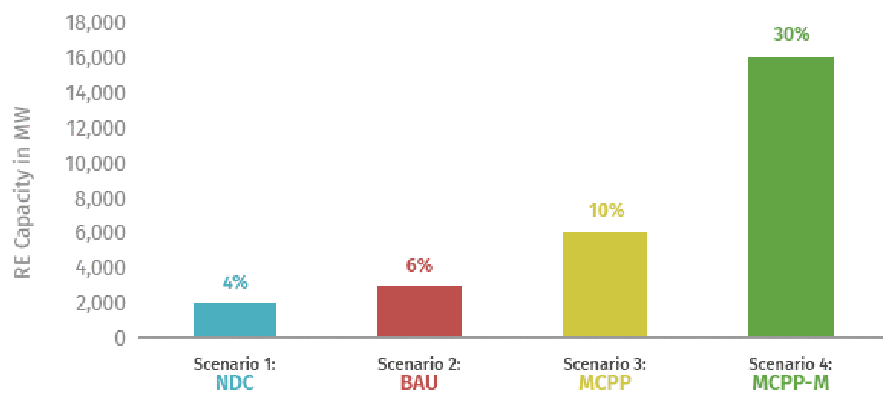
[12] This refers to reducing supports from the international society, increasing responsibility toward the international society, limit of international competitive edge derived from low-cost labor, etc.

Table 2.3-3 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	Gas/LNG	57.4%	45%	29%	35%
	Coal	2.8%	27%	30%	35%
	Liquid Fuel	32.4%	17%	9%	1%
Note: Power generation by renewable energy is not listed in the generation mix in this table, being classified as power purchase.	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

The energy mix aimed at in these policy texts is becoming 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". As a result, the increase in coal-fired power generation projected in PSMP 2016 cannot be materialized, while the policy ambition indicates an increase of renewable energy far beyond the present plans.



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 2.3-1 RE share in 2030 energy mix

It is also indicated[13] that "we should consider not only renewable energy but also various clean energy options such as nuclear power, hydrogen, and CCS[14]." 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,

[13] Interview to the official of the government of Bangladesh

[14] Carbon Capture and Storage/Sequestration (CCS) is not an energy but a technology. However, as it offsets carbon emissions, CCS is treated as if a sort of clean energy in this report.

which has a low geographic density of energy production, cannot supply sufficient amount of energy. Given these circumstances, it is reasonable to consider options such as nuclear power, hydrogen, and CCS, that are clean energies with high energy density.

2) Energy Efficiency

The Energy Efficiency and Conservation Master Plan 2016 (EECMP 2016) sets out energy efficiency policies with a view to reducing the energy intensity (primary energy per GDP) by 15% by 2021 and 20% by 2030 compared to 2013. Energy efficiency is a very important virtual energy source, and will be discussed in Chapter 3.

3) Electricity

Following the achievements by the Perspective Plan of Bangladesh 2010-2021 (April 2012), the Perspective Plan of Bangladesh 2021-41 (PP2041) was set out in March 2020. The PP2041 provides the main pillars of the electricity policy. It envisages that, with an 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, in order to cope with concerns on environment and climate change, it is necessary to reduce fossil fuel consumption and increase introduction of clean technologies and renewable energies. Main objectives of PP2041 are as follows:

a. Strategy of electricity and energy:

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

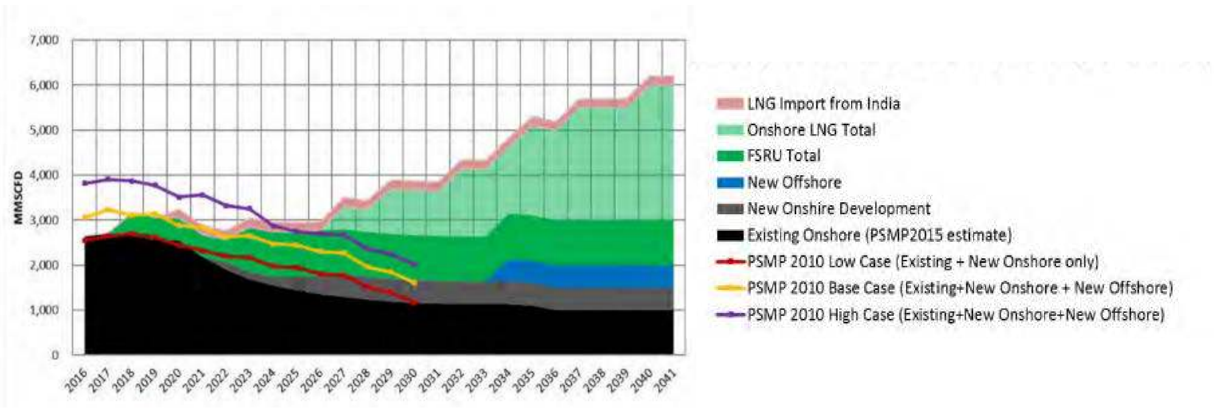
- Reducing capital investment costs
- Phasing out high-cost liquid fuel-based power stations and moving to lower-cost fuels
- Moving away from over-reliance on fossil fuels:
- A balanced mix of low-cost fuel-based power generation and renewable energy.
- Use of imported hydropower and solar power from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

4) Natural Gas

The PSMP2016 covers requirement for natural gas, oil, coal and other primary energies comprehensively. It forecasts natural gas production up to 2041; domestic production that peaked in 2017 will keep declining and LNG import will be used to make up the natural gas supply shortfall. LNG terminals will be constructed onshore as well as offshore with FSRUs (floating storage and regasification unit), and regasified LNG will be supplied. Import of RLNG (regasified LNG) via pipeline is also considered as good seaport is scarce in the western part of the country.



Source: PSMP2016

Figure 2.3-2 Natural Gas Supply Scenario: PP2041

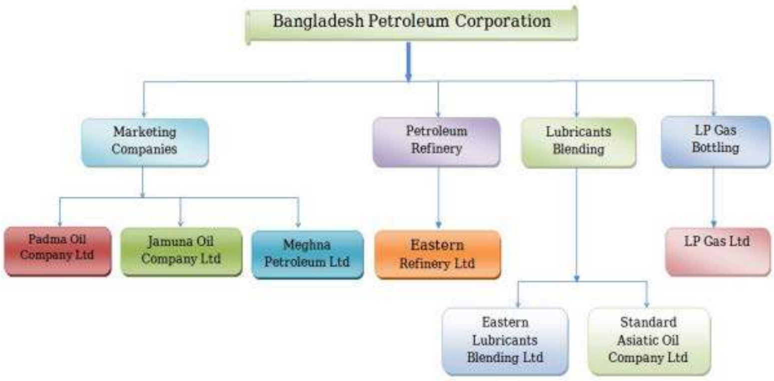
The Gas Sector Master Plan Bangladesh 2017 (GSMP2017) was developed in February 2018, funded by the World Bank RERED-II[15]. The report covers gas demand forecast, least cost supply study, infrastructure planning for gas transportation, study of domestic gas network, LNG import planning, and gas supply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

In order to promote domestic natural gas exploration, multi-client survey is going on. Bangladesh offshore Model Production Sharing Contract (PSC) has been finalized. Preparation of bidding document and data packages ae in progress for declaration of bidding round.

5) Oil

Bangladesh Petroleum Corporation (BPC) was established under the MPEMR in accordance with the Bangladesh Petroleum Corporation Ordinance and started its activities on January 1, 1977 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." BPC delegates its function to the subsidiaries on petroleum product sales, petroleum refining, lubricating oil blending, and LPG bottling.

[15] Ministry of Power, Energy and Mineral Resources, 「GAS SECTOR MASTER PLAN BANGLADESH 2017」



Source: BPC

Figure 2.3-3 Diagram of BPC's Subsidiaries

As shown in Table 2.3-3, PP2041 envisages substantial expansion of the domestic refining capacity and installing petroleum pipeline throughout the country to ensure quick and easy supply of oil to the demand point along with adequate safety measures to protect the environment.

6) Coal

The PP2041 aims at the share of coal in the power generation mix to be 30% in 2031 and 35% in 2041 in order to adopt a least-cost power generation approach. To this end, PSMP2041 highlights the need of extracting more domestic coal for long term energy security as well as substantial investment in coal import infrastructure such as ports and transportation measures.

The Coal Policy was drafted in 2007, but the final report has not been completed. Currently, consumers are free to determine the import source, import price, and so on for imported coal at their own discretion. At present, the government is facing problems on relocation of residents, environmental issues, and investment in development, resulting in suspension of the draft Coal Policy. In view of the rising concern on the climate change as well as energy security, the Coal Policy needs to be established firmly to show the policy on domestic coal development and import infrastructure building.

Table 2.3-4 Cost of Electricity Generation by Fuel

Fuel Type	Unit Cost
	Tk./kWh
Furnace Oil (Heavy Fuel Oil)	17
HSD (Diesel Gas Oil)	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

7) Renewable Energy

Since 2008, many plans and guidelines have been formulated in Bangladesh on promotion of renewable energy as shown below:

Table 2.3-5 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
	Eighth Five Year Plan July 2020-June 2025
2021	NDC
2022	[Draft] Renewable Energy Policy, 2022

Source: Compiled by IEPMP Study Team from various sources of information

Among others, 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 the 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, the targets for installation of the renewable power generation (cumulative) were revised to 2.47GW by 2021 and 3.864GW by 2041.

Table 2.3-6 Renewable Energy Targets in 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: PSMP 2016

Following this, in the Bangladesh Delta Plan 2100, the renewable energy target was revised to 30% in the total electric power generation by 2041. In addition, PP2041 further pushed up the target that 35% of the total energy mix is to be supplied by domestic renewable energy together with cross-border energy import (assuming hydro power generation in neighboring counties) in 2041.

In 2021, NDC (Nationally Determined Contributions) was submitted to UNFCCC as an update of INDC submitted in 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. The 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. 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 2.3-7 Possible Mitigation Actions in NDC (Renewables)

Category	Unconditional	Conditional
Grid-connected Solar	581 MW	2,227 MW
Wind	149 MW	597 MW
Biomass	20 MW	50 MW
Biogass	5 MW	5 MW
New Hydro	100 MW	1,000 MW
Solar Mini-grid	56.8 MW	56.8 MW
Waste-to-Electricity	N.A.	128.5 MW
Total	911.8 MW	4114.3 MW

Source: Mitigation Action, NDCs 2021 Bangladesh

2.3.3 Climate Policy

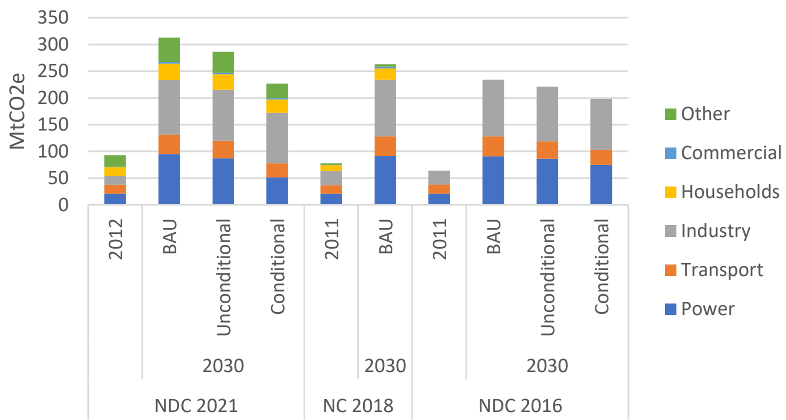
In response to rising concern on climate change, Bangladesh submitted an updated Nationally Determined Contribution (NDC) to the UNFCCC Secretariat on 26 August 2021, and the preliminary report of the Mujib Climate Prosperity Plan was released in September 2021. Outline of the foregoing is summarized as follows:

1) Updated NDC (Nationally Determined Contribution)

Bangladesh's NDC presently states:

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.

The above targets are updated from reduction levels 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 (Figure 2.3-4).



Source: NDC2021, NC2018, NDC2016

Figure 2.3-4 Evolution of Energy-related Emissions in NDCs

A set of potential mitigation actions for the unconditional and conditional contribution scenarios are summarized in Table 2.3-8, where 'other' represents brick kilns sector separated from the industrial energy consumption.

Table 2.3-8 Possible Mitigation Actions: NDCs 2021

	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 meters	● Implementation of renewable energy projects of 4,114.3 MW ● Coal power plant with Ultra super critical technology-12,147 MW ● Installation of new Combined Cycle Gas based power plant (5,613 MW) ● Efficiency improvement of Existing Gas Turbine power plant (570 MW) ● Installation of prepaid meters ● 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

2) Mujib Climate Prosperity Plan

The overview of the Mujib Climate Prosperity Plan is shown in Table 2.3-9.

Table 2.3-9 Overview of 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="5"></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 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 as described below, in which shares of renewable energy is assumed as shown in Table 2.3-10.

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 updated continuously along with future 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).

Table 2.3-10 Renewable Energy in Energy Mix and Loweing Energy Intensity

	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%	

Source: Mujib Climate Prosperity Plan, 2021

3) National Adaptation Plan

The National Adaptation Plan (NAP) was approved by the Bangladesh government and published on 2 November 2022. The NAP encompasses eight distinct sectors: 1) water resources; 2) disaster, social safety and security; 3) agriculture; 4) fisheries, aquaculture and livestock; 5) urban areas; 6) ecosystems, wetlands and biodiversity; 7) policies and institutions; and 8) capacity development, research and innovation. The NAP devised 113 interventions, including 90 high-priority and 23 moderate-priority ones. An appraisal of the cost of the 113 interventions defined a total investment of BDT 20,037 billion (equivalent to US $230 billion) over 27 years (2023-2050).

2.3.4 Environmental Policies

The first environmental law in Bangladesh, 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 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. It 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 Bangladesh Environmental Protection Act and Environmental Court Act.
b. Ensure proper observance of all relevant laws and create wide public awareness in this regard.

NEP2018 also lays down institutional set-up that NEC shall be chaired by the Head of the Government as well as comprehensive guidance on implementation of the policy. The updated environmental policy under NEP2018 includes 24 sectors; for details of them please refer to Appendix A.

[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.

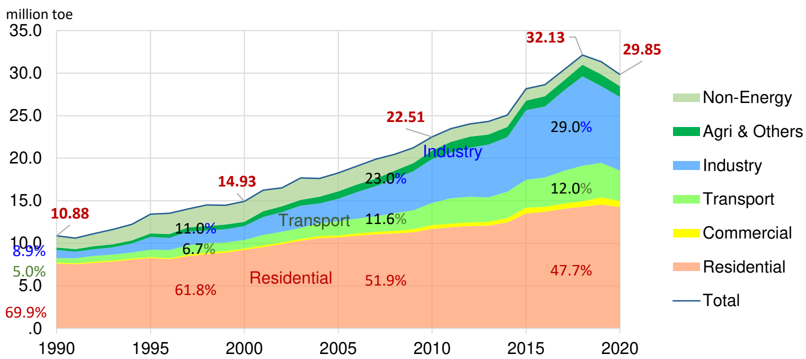
Chapter 3 Energy Efficiency and Conservation

Improving energy efficiency and conservation (to be abbreviated from time to time in this Report as "EEC" or "EE&C") enables socio-economic development with less energy consumption and GHG emissions. It resembles a discovery of hidden energy sources that will accompany no CO_2 emissions. Since its progress depends heavily on social determination, political guidance and development of innovative technologies, its future trend is generally defined by normative analysis and political goals. In this context, energy efficiency and conservation are discussed in this chapter to set out its basic trend as the preconditions on energy demand forecast to be developed in Chapter 4.

3.1 Overview of EECMP 2016

3.1.1 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, 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 according to IEA data[18]. About a half of the energy is consumed by the residential sector, while the industrial use is increasing rapidly.



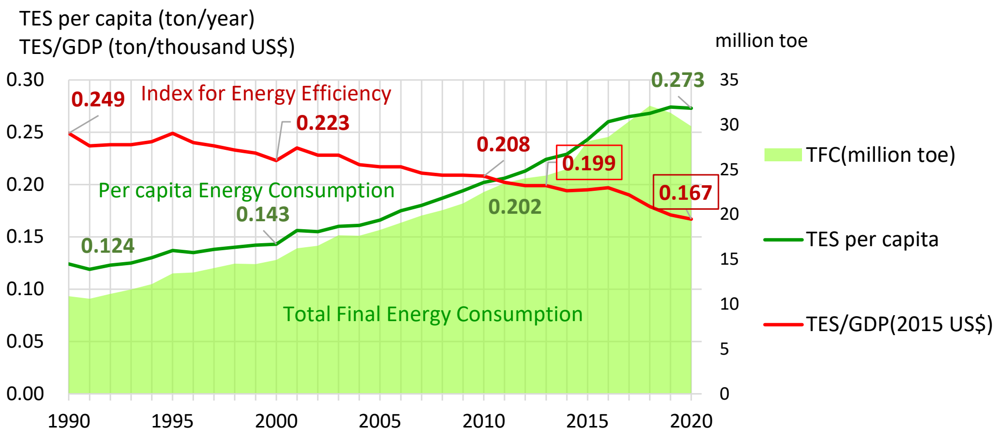
Sources：IEA World Energy Balances 2022

Figure 3.1-1 Final Energy Consumption by Sector

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

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. It is observed that energy intensity for 2013 was 0.199 of that of 2013 and 0.167 (16.1%%) in 2020.

[18] Sector-specific national data's availability is slightly low especially for understanding 30 years tendency. Some part of SREDA National Energy Balance Report and its figures are referred in Chapter 9 and Appendix. This Section deals with topic for EECMP 2016 using IEA data as alternatively. This principle is also addressed in other Chapters.



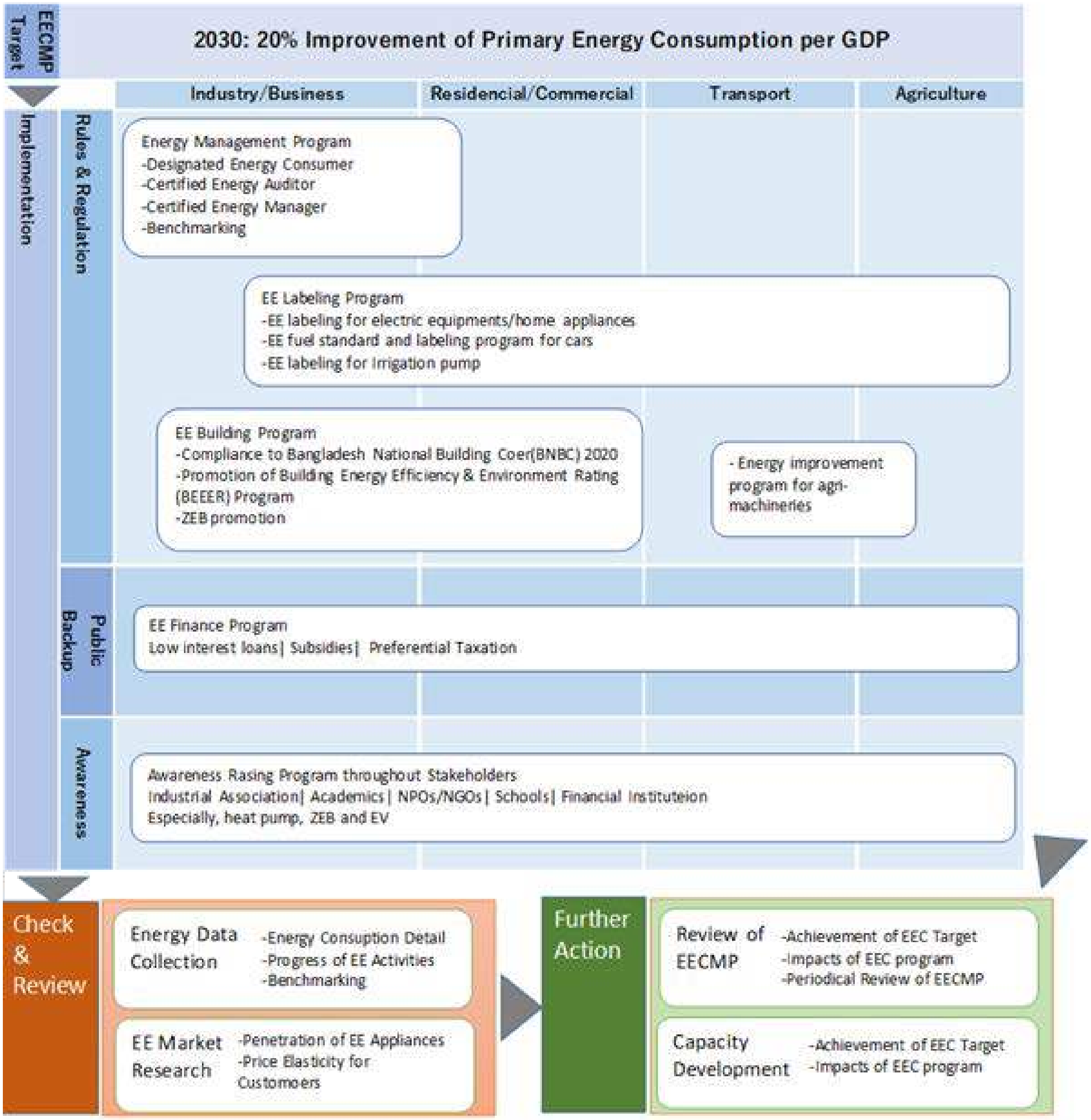
Source：IEA World Energy Balances 2022

Figure 3.1-2 Primary Energy Consumption per GDP: Bangladesh

3.1.2 Updated EECMP 2016

As the top policy on energy efficiency and conservation, the Energy Efficiency and Conservation Master Plan 2016 up to 2030 (EECMP2016) was announced by the Sustainable and Renewable Energy Development Authority (SREDA), Power Division, of the Ministry of Power, Energy and Mineral Resources, in May 2016.

The action plan based on EECMP2016 is updated as shown in Fig 3.1-3 and in progress.



Source: SREDA

Figure 3.1-3 Updated EE&C Action plan

The updated tentative EEC action plan covers not only Industry sector and Residential / Commercial sector but also Transportation sector as well as Agriculture sector. The effective programs that are being implemented for each sector include the Energy Management Program, EE Labeling Program, EE Building Program, Energy improvement program, EE Finance Program and Awareness Raising Program. While in progress, each program will be checked and reviewed through Energy Data Collection and EE Market Research programs for further actions.

1) Industry Sector

Programs for this sector mainly aim for reduction in electricity intensity comprising extension of the coverage of the Designated Large Energy Consumers (DCs) program and improvements on the Certified Energy Auditors program ruled under the Energy Management System, as elaborated below:

- Expanding of Designated Large Energy Consumers (DCs) program including enhancement on capacity development program
- Expansion of Certified Energy Auditors program including those of SREDA members
- Technical survey for Certified Energy Auditors program in order to collect supplementary information on the steel sector (the on-going plan on ”Benchmarking Program”)
- Mobilization of public finance to promote dissemination of energy efficient equipment

2) Residential and commercial sector

Programs are considered on energy efficiency standards for equipment such as home appliances and energy efficiency labeling (S&L) including an energy rating program on buildings. For introduction of S&L program, common rules and technical issues on home appliances (LEDs, air conditioners, fans, refrigerators) are formulated and program operation is being improved. The Bangladesh EES&L policy is featured with introduction of voluntary actions at the beginning, to be converted to a mandatory system later on. The Bangladesh National Building Code 2020 also sets out standards on energy efficiency. It is planned to gradually reduce the applicable areas covered by this code. The Building Energy Efficiency & Environmental Rating program (BEEER) and net Zero Energy Building (ZEB) are the main tools for energy saving in commercial buildings, and their integration into one scheme needs to be considered toward 2030.

3) Transportation

With the rapid economic growth of Bangladesh in the coming decades, transportation sector's energy consumption is expected to increase vastly. In light of this situation, the Updated Energy Conservation Master Plan tries to accommodate transport sector energy efficiency measures, especially for road transport.

4) Agriculture

As agriculture accounts for a large share of the value added in Bangladesh’s economy, it is essential to consider energy consumption for irrigation. The Updated Energy Conservation Master Plan, therefore, includes energy conservation measures for irrigation.

5) Others

In addition to annual collection of energy data on oil, gas, coal and electricity (renewable), indicators that express EE&C programs implementation and achievement will be put together. Tracking of the progress is still facing difficulties. Except for the Energy Balance report, challenges of data shortage need to be addressed. The building up of the monitoring system and tracking its progress on each program are potential seeds for further progress. Some part of general or sector-specific programs should be implemented with a prioritized manner to make the success story of data collection and/or monitoring system as flagship initiatives.

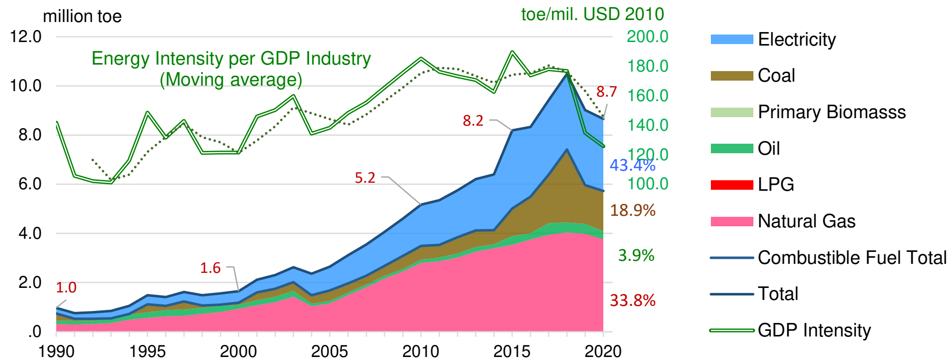
3.2 Industry Sector

3.2.1 Energy Consumption Trend

Industrial energy consumption expanded 5.3-fold between 2000 and 2020 according to IEA as shown in Figure 3.2-1. Fuel consumption expanded 4.8-fold while electricity 6.3-fold. While natural gas is the largest single energy source comprising 43.4% of the total, coal consumption is increasing whereas consumption of petroleum products remains minimal. Energy intensity (energy consumption per industrial sector GDP) has kept an upward trend until 2010 and then leveling 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.

Comparing Bangladesh's energy intensity (industrial energy consumption per total GDP) in 2020 with Southeast Asian countries, Bangladesh had a good record. According to IEA statistics, energy intensity of Bangladesh (0.032 toe/ $1,000) was well below Malaysia (0.053), Indonesia (0.054), and Thailand (0.072).

According to the IEA data, electricity's share was 43% in 2020. Figure 3.2.-1 shows trends toward electrification and slowdown on gasification since late 2000s. Therefore, energy-saving measures for electricity are considered important.



Source: IEA World Energy Balances 2022

Figure 3.2-1 Industry Sector Final Energy Consumption

3.2.2 Main Policies and Programs in EECMP

Under the EECMP 2016, programs for the industry sector launched an improved system of energy management and adoption of equipment with improved energy efficiency as described below:

1) Energy Management System (EMS)
   - Designation of large energy consumers (DC: Designated Large Energy Consumer), the number of which was expanded from 113 to 150.
   - Nomination of energy manager and energy auditor: 18 Certified Energy Auditors (including SREDA members) are nominated.

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

3) Designation of large energy consuming entities

Large energy consuming entities (are designated by the government as DC: Designated Consumers. This program sets forth energy consumption criteria for each target sub-industry to nominate DCs among industry energy users. The DCs must establish relevant Energy Management System (EMS).

The initial energy consumption criteria by sub-industry are shown in Table 3.2-1. Once the program turns out to be a success, the criteria for DCs will be expanded and amended.

Table 3.2-1 Criteria for 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.

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.

3.2.3 Overview of Current status of EEC

1) Expansion of Designated Energy Consumers

While 113 DCs were initially listed in EECMP2016, SREDA has now increased the number to 150 candidates. In addition, DCs themselves are learning the importance of EEC through SREDA's educational programs. This effort will widen the coverage of energy users recognizing importance of EEC and create a firm platform to promote it.

2) Energy Audit

In 2018, MoEFCC submitted Third National Communication to UNFCCC, which is a reporting system under UNFCCC, addressing climate change issues as shown in Table 3.2-2.[19] It assumes the level of energy efficiency improvement and coverage ratio by sector targeting to be achieved by 2030.

Table 3.2-2 Assumption of future Coverage Ratio of Energy Management in submitted UNFCCC report: 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 benchmarking program is a system that sets target values for the large energy consuming sub-sectors using specific processes, such as steel-making, cement manufacturing, paper & pulp, soda chemical, etc., based on a specific energy consumption as described in kgoe or toe of unit production (t), or floor area (m^2) for commercial sectors. Periodical energy consumption and production data must be reported to SREDA through an annual energy report[20].

Currently, experts visiting programs are planned to be conducted. The above-mentioned benchmark and relevant technical information will be used as a reference in the "Sector Based Guidance for implementation of energy audit by Certified Energy Audit".

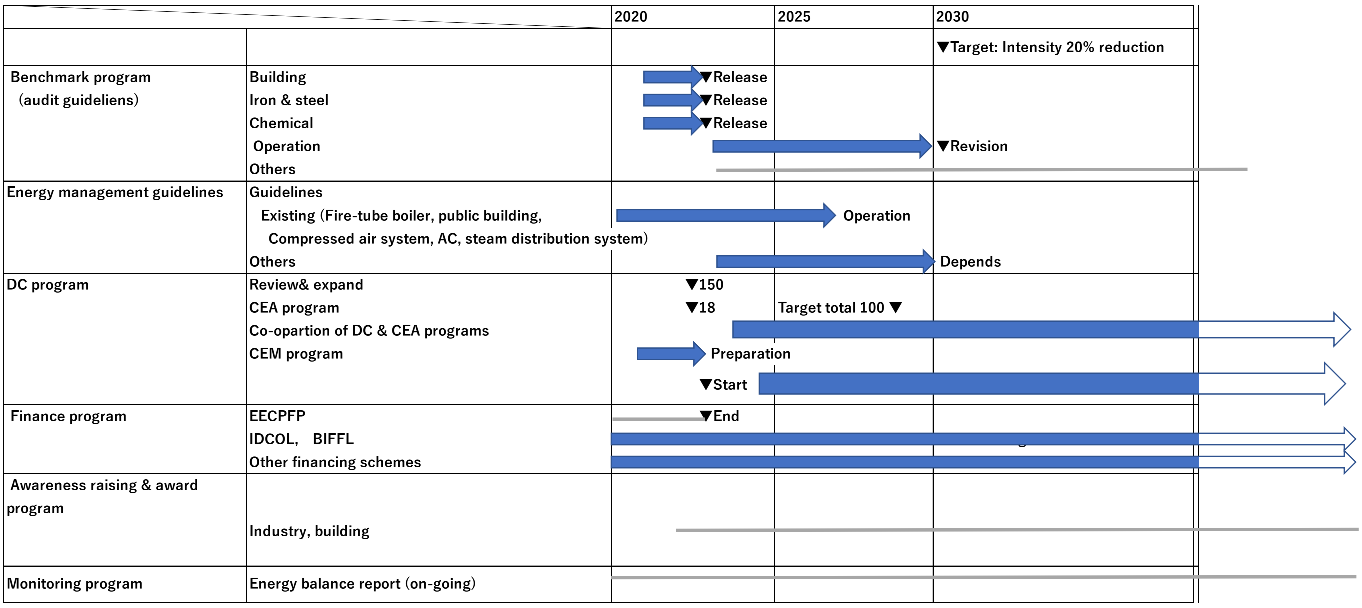
4) Other energy saving actions and role of finance

The textile industry of Bangladesh has developed its export competitiveness among the world market, and hence has accomplished a level of advanced international standards including practices of EEC, which serves as a good role model from private sector industries. In addition, utility and chemical companies sub-sectors possessing large EEC potential are required to participate in the EEC programs.

The catalyst and leverage functions of public financing are working effectively. Public and

19 MEFCC"Third National Communication of Bangladesh to the UNFCCC" https://unfccc.int/sites/default/files/resource/TNC%20Report%20%28Low%20Resolation%29%2003_01_2019.pdf
20 Factories with significant improvements in energy efficiency should receive awards from SREDA.

private financial institutions are making use of the energy conservation technology list. As of December 2022, 43 companies were awarded the loan, amounting to BDT 21 billion. There are wide varieties in borrowers including textile, cement, glass, electronics, and other sectors which contribute to the EEC activities. In the SREDA website several success stories are cited as show cases[21].



Source: SREDA

Figure 3.2-2 Target Realization Rate by Program

3.2.4 Next step

1) Energy Management System has started successfully, which need to be monitored continuously through the energy management systems instituted at respective DCs.

At present, 18 personnel including SREDA members hold the title of Certified Energy Auditor. It is observed that seeds for improving energy efficiency are certainly growing, especially among experts. The National Energy Balance Reporting provides information on economy wide progress on EECMP. These kinds of data collecting activity will also contribute to monitor and track the progress, which improves future EECMP activities.

2) Human Resources

It is important, in addition to Certified Energy Auditors, to encourage activities of excellent staff through experts' registration system. An "award system" designed for excellent staff by sector would honor and encourage more effective EE activities; it can also be used as a knowledge sharing platform. Furthermore, it is important to implement diagnosis projects by Certified Energy Auditors and excellent staff (including foreign engineers) to (1) build up a showcase database and (2) accumulate technical know-how.

21 SREDA, https://eecpfp.sreda.gov.bd/

3) Awareness improvement and Stakeholder Involvement using BAT list, catalyst role of finance

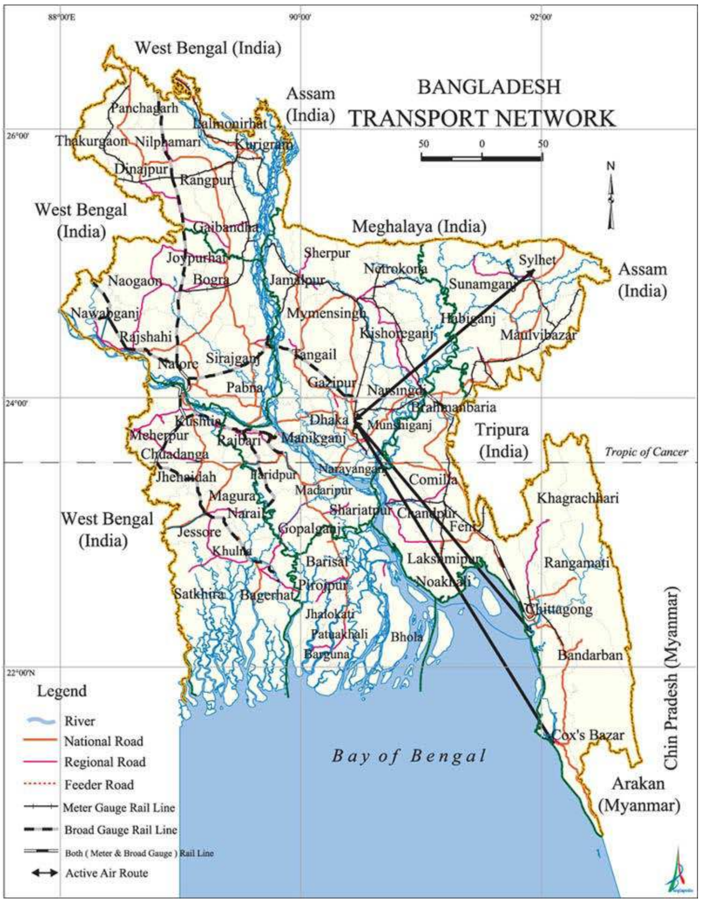
For wider awareness and promotion of EE activities, it will be helpful to continuously update the existing "Best Available Technologies (BAT) list" used in finance sector. The list is a kind of compilation of the EEC success stories achieved in Bangladesh. The continuous updating of BAT[22] list and disseminating of technologies, such as cogeneration, energy efficient boilers, generators, furnaces, will contribute to enhancing industrial energy management system in the future.

SREDA may disseminate updated BAT information to other relevant ministries, energy experts and manufacturers of energy intensive sectors and other stakeholders with financial institutions. Based on these efforts, suppose the introduction of BAT technology be successfully implemented, energy efficiency will be improved significantly in the future.

3.3 Transportation Sector

3.3.1 Overview of Energy Consumption

Owning to its flat topography and abundant rivers, Bangladesh historically has developed with water transport as the primary mode of transportation, with the total distance of water transport of 13,000 km (700 rivers). Along with construction of bridges and roads, it shifted to land transport since the 1990s. In terms of railroads, the total track length was expanded to 2,892 km, and the number of stations reached 517 by 1985. Since the 1990s, road construction has been actively carried out, expanding road transport services greatly. The total road length was 375,353km in 2020 and the number of registered vehicles 4.3 million units in 2019.



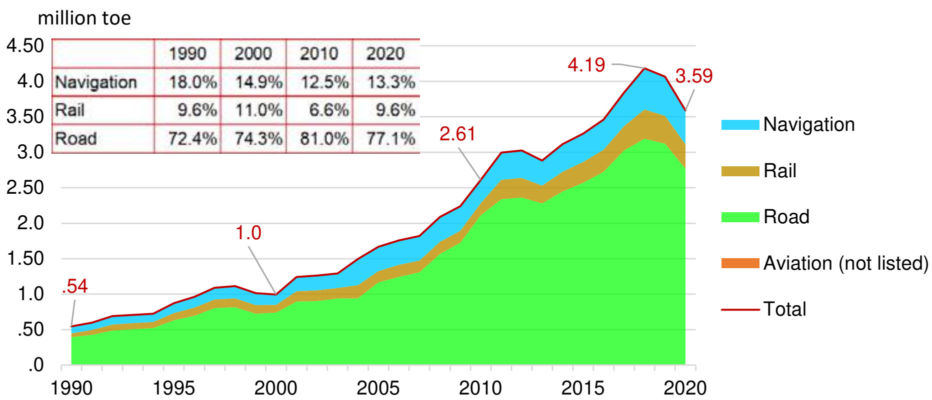
Source: National Encyclopedia of Bangladesh

Figure 3.3-1 Bangladesh Transport Network

[22] Japanese Business Alliance for Smart Energy Worldwide published "Smart Energy Products & Technologies 2023"
https://www.jase-w.eccj.or.jp/technologies/index.html
The Japan Iron and Steel Federation published "Technologies Customized List for India and ASEAN"
https://www.jisf.or.jp/en/activity/climate/Technologies/index.html

As shown in Figure 1.1-1 (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 it is lower than the share of the industry sector that increased from 8.9% to 29.0% in the same period.

Figure 3.3.2 shows the energy consumption by energy sector. Road transportation dominates among sectors at 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 addition, it should be noted that energy efficiency in other sectors will be mostly fixed at the time of constructing infrastructure such as railways and port facilities. On the other hand, 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.



Source: IEA, World Energy Balances 2022

Figure 3.3-2 Transportation Sector Energy Consumption

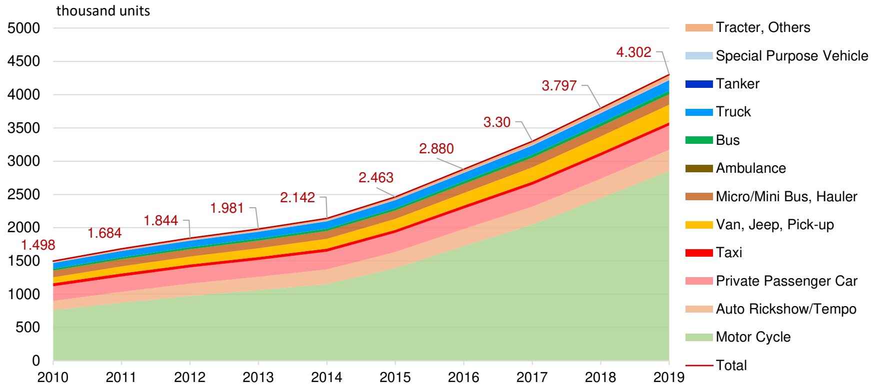
3.3.2 Road vehicles and energy consumption

The number of road vehicles increased 2.9-fold from 1.5 million units in 2010 to 4.3 million in 2019 at an average annual rate of 12.4%. As an easy mobility, motorcycle has increased 3.8-fold in the same period. Together with rickshaws, the share of small vehicles exceeds 70%. By contrast, the number of light duty vehicles such as passenger cars, taxis and vans is still low. 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 3.3-1 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%

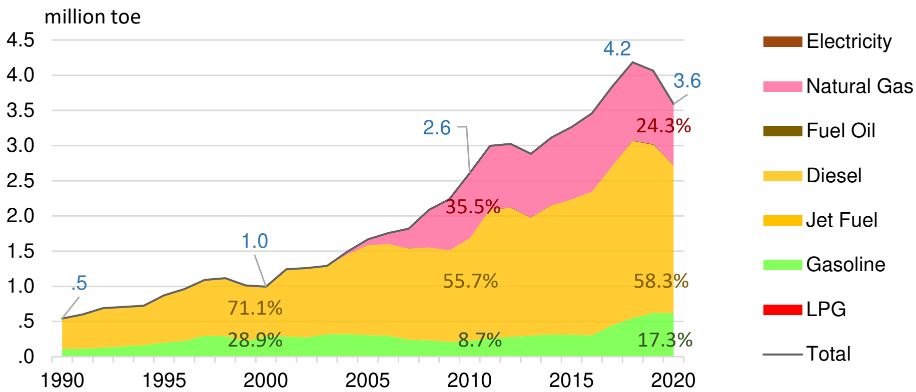
Source: Bangladesh Bureau of Statistics (BBS), "Statistical Yearbook Bangladesh 2020", May 2021



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

Figure 3.3-3 Number of Registered Motor Vehicles

Figure3.3-4 shows the energy sources of road transportation. CNG was introduced around 2005 to cope with severe air pollution, especially in Dhaka, and its use has rapidly spread among passenger cars, taxis and auto rickshaws. Thus, the growth in gasoline demand was kept minimal, but turned to increase around 2017 due to shortage in natural gas supply. At present, consumption of diesel for buses and trucks dominates in the road sector.



Source: IEA, World Energy Balances 2022

Figure 3.3-4 Energy Consumption in the Road Transport by Fuel Type

3.3.3 Direction of EEC policies

(1) Policy Overview

In the transportation sector, energy efficiency improvement has two aspects, i.e. improvements in transportation infrastructure and vehicle efficiency.

In the PP2021 formulated in 2010 emphasized multimodal transportation, developing national roads, improving inter-city and inter-regional connections, and improving maintenance of the transportation network. Since then, transportation infrastructure including roads and bridges has been improved substantially. Major cities are now connected by air as well. Bangladesh's first elevated railroad, MRT Line 6, started operation in December 2022 with three more MRT lines in plan (Line-1, Line-5 North, and Line-5 South). The PP2041 has also moved ahead on introduction of CNG to cope with air pollution.

Subsequently, PP2041 formulated in 2018 prioritized development of roads to accelerate economic growth. In 8th Five-Year Plan (2020-2025), construction of two-lane rural roads totaling 16,000 km was planned. The urban transport development strategy was set out to improve convenience, safety, and economic efficiency with synergistic effect on energy efficiency. It specifically includes programs on:

a. Mass Rapid Transit (MRT/Metro Rail) initially in Dhaka, and expanded to peripheral areas and eventually to all principal cities.
b. Bus Rapid Transport (BRT) with dedicated lanes.
c. Intelligent Transportation Systems (ITS) including traffic management, electronic road pricing, integrated ticketing system, traveler information system, etc.
d. Linkage of cities and towns around metropolitan areas by MRT and BRT.
e. Upgrading of roads and provision of pedestrian sidewalks
f. Promotion of high efficiency and alternative fuel vehicles.

On the vehicle fuel efficiency, Bangladesh is looking to proactive introduction of energy efficient vehicles (EEVs). These are; fuel-efficient internal combustion engine (ICE) vehicles, hybrid vehicles (HV), electric vehicles, and alternative fuel vehicles (CNG, LPG, biodiesel, ethanol, hydrogen, fuel cells, etc.) that qualify certain criteria on carbon emissions and fuel consumption. Bangladesh aims to become a regional market hub for EEVs through strategic investments. The Automotive Industry Development Plan 2020[23] aims at introduction of high-performance vehicles and advanced technologies to the domestic market by 2030. To this end, proactive policies are considered such as attractive taxation and tax break for EEV assemblers. Incentive system is also considered in launching Technology Acquisition Fund to support investment in R&D and acquisition of technologies such as batteries, charging stations, and electric vehicle development.

In coming decades, motor vehicles will increase rapidly along with economic development together with shifting from two-wheeled motorcycles to four-wheeled vehicles. These will push up fuel demand significantly. In this regard, preparation of efficient infrastructure and efficient vehicles is essential. Facing decline in domestic natural gas production, CNG as motor fuel will no longer be recommended.

[23] 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

Electric Vehicles (EVs) will be prioritized including construction of recharging station networks.

As an immediate target, shifting from low- to high-efficiency vehicles should be enhanced by adopting financial incentives such as subsidies and preferential vehicle registration taxes, setting regulations on fuel efficiency standards and making them visible to consumers through a labeling program. These efforts will keep increases in motor fuel demand as reasonably low as possible.

(2) Priority Areas

As discussed in the above, existing policies and strategies such as PP2041 and AID2020, will dramatically improve transportation energy efficiency. The energy efficiency master plan, therefore, should focus on the areas that have not been addressed by these policies, one of which is controlling energy efficiency level of imported used vehicles.

Regarding the imported used vehicles, they accounted for 80% of Bangladesh's vehicle ownership in 2021 and a certain number of them will remain in the market until 2030. Furthermore, considering the lifetime of vehicles, imported used vehicles are expected to account for more than 70% of the stock in 2030. For this reason, policies that promote fuel-efficient used vehicles will be beneficial even after 2030, when Bangladeshi-made high-efficiency vehicles are expected to become widely available. In particular, it will be essential to consider energy efficiency management measures for imported used vehicles as discussed below:

1. Regulations and standards

Currently, imported used vehicles are restricted to those with less than 5 years of age. Along with this regulation, the following fuel efficiency standards should be introduced to further promote energy-efficient vehicles.

- Establishment of fuel efficiency standards and emission regulations for each type of imported energy efficient used vehicle (IEEUV)
- Fuel efficiency standards consistent with international discussions such as WP.29 (UNECE World Forum for Harmonization of Vehicle Regulations)

2. Labeling System

The labeling system provides a clear indication of the fuel efficiency level of each vehicle. This allows consumers to easily compare vehicle specifications. It can also increase consumers' awareness of and willingness to purchase IEEUVs. Since the standards and labeling systems are already in place in the residential and commercial sectors, it is desired to make good use of the operating rules, knowledge and procedures learned from these existing systems.

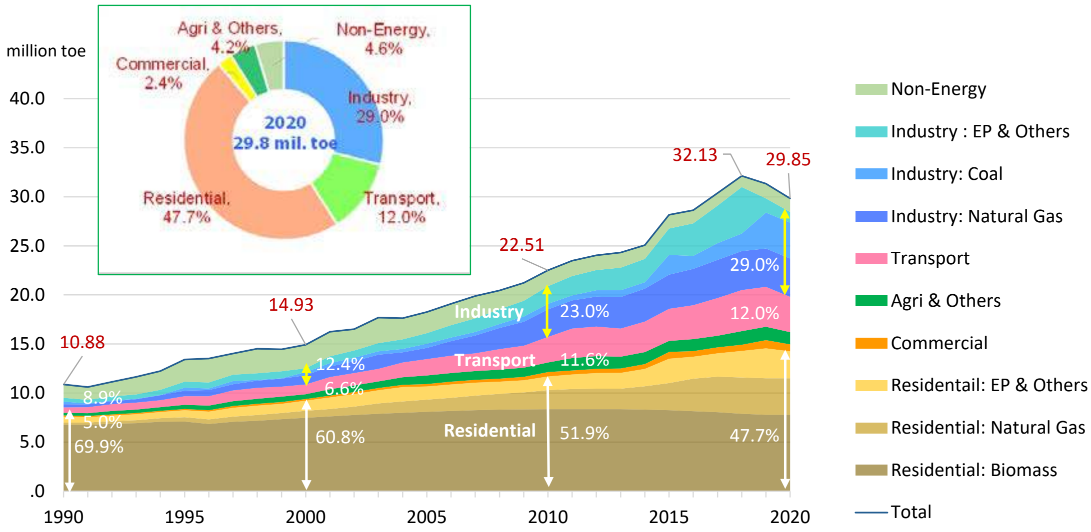
3. Tax Incentives and Subsidies

Fiscal measures such as tariff reductions, tax incentives, and subsidies will enable IEEUVs to compete in the market. Good synergies can be expected by establishing financial incentives in harmony with the existing AID and PP Vision 2041.

3.4 Residential and Commercial Sector

3.4.1 Energy Consumption Trends

According to the IEA statistics, residential sector energy consumption dominates in Bangladesh, though its share declined to below 50% in 2020. Meanwhile, the share of commercial sector energy consumption was reported to be only 2.4% in 2020. Biomass consumption mainly comprising firewood is listed only for the residential sector. Its share in the total demand declined from 50.2% in 2000 to 26.1% in 2020 with penetration of natural gas for cooking and electricity for lighting and other appliances.

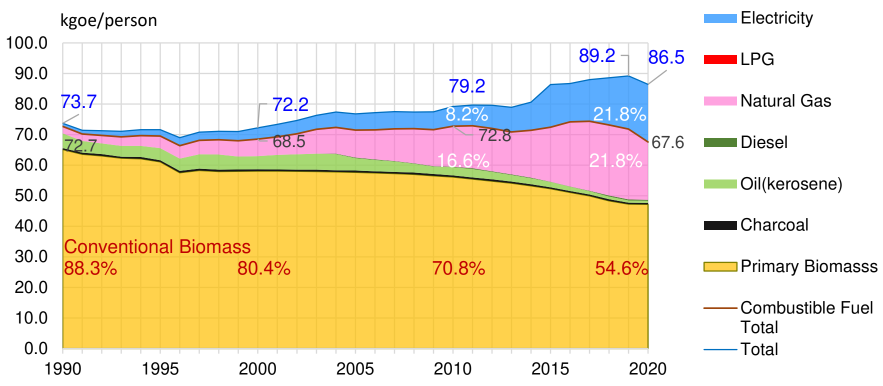


Source: IEA World Energy Balances 2022

Figure 3.4-1 Trends of Final Energy Consumption by Sector

1) Residential Sector

In the residential sector, biomass consumption in 2020 comprised 54.6% of the total energy consumption and 69.8% of the fuel consumption. There is still a big room to be replaced with modern fuels. Charcoal consumption, which generally increases in the urbanization process of developing countries, is very limited as 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 with the global average, but is expected to grow rapidly accelerated by introduction of electric appliances.



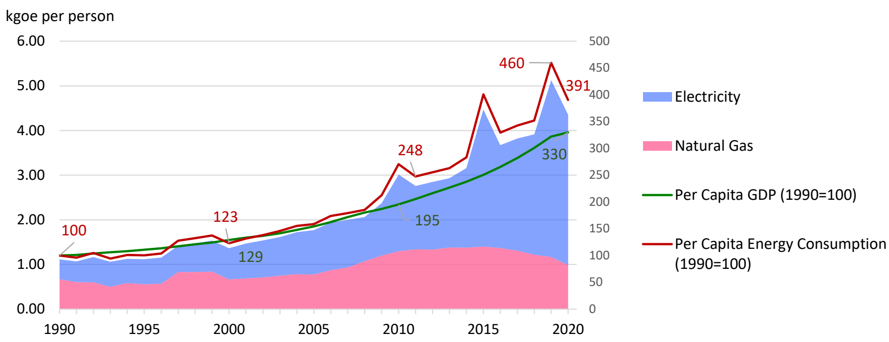
Source：IEA World Energy Balances 2022

Figure 3.4-2 Residential Sector Energy Consumption per Capita

When firewood for cooking and hot water supply is switched to modern energies such as gas and electricity, energy efficiency will be substantially improved. This will keep growth of the overall energy consumption relatively low.

2) Commercial Sector

The IEA statistics says that the commercial sector energy consumption is merely 2.4% of the total final consumption. It lists only natural gas and electricity ignoring charcoal, LPG and diesel. Collection of more precise information is necessary to discuss EEC of this sector. Along with economic development, electricity consumption grows steadily as observed in the emerging economies.



Source：IEA World Energy Balances 2022

Figure 3.4-3 Commercial Sector Energy Consumption Per Capita

3.4.2 Overview of EEC policies

The EEC programs for the residential and commercial sectors under EECMP2016 mainly comprise adoption of high efficiency appliances and buildings as summarized in Table 3.4-1. It is planned that the residential sector will be introduced with high efficiency appliances by 2020 and the highest efficiency ones by 2030, while buildings are expected to achieve the world's 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 for the residential sector and 10% for buildings. The latter is estimated relatively low as it is not easy for existing buildings to introduce EEC measures with new equipment. To achieve these targets, EECMP2016 sets out EE Labeling Program for the residential sector and EE Building Program for buildings.

Table 3.4-1 EE&C Programs for residential and commercial sector: 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

3.4.3 EEC Policies and Future Directions for Residential Sector

For the residential sector, Energy Efficiency Standards and Labelling (EES&L) program is the most promising policy for promoting sale of high efficiency products. Current status of the EES&L program is prepared by SREDA as summarized in Table 3.4-2. The Bangladesh EES&L policy is featured with introduction of voluntary actions at the beginning, and a shift to a mandatory system at a later stage.

It is necessary to accelerate the introduction of EES&L programs and/or the shift to mandatory scheme at an earliest possible stage, focusing on appliances with large power consumption such as lighting, refrigerators, TVs, and air conditioners. As free CFL distribution programs were conducted to date, consumers are now encouraged to use more energy efficient LED lighting.

The global demand for air conditioners in 2020 is estimated to be 107.45 million units. The largest market is China at 42.14 million units followed by other Asia at 16.20 million units. Air conditioner demand in Bangladesh was 1.84 million units in 2020[24]. Although the market in Bangladesh is still small, its demand is growing steadily. Penetration of inverter type (variable speed) air conditioners, that are 15-30% more energy efficient than non-inverter types (fixed speed), remains at 42% in the Asian market.

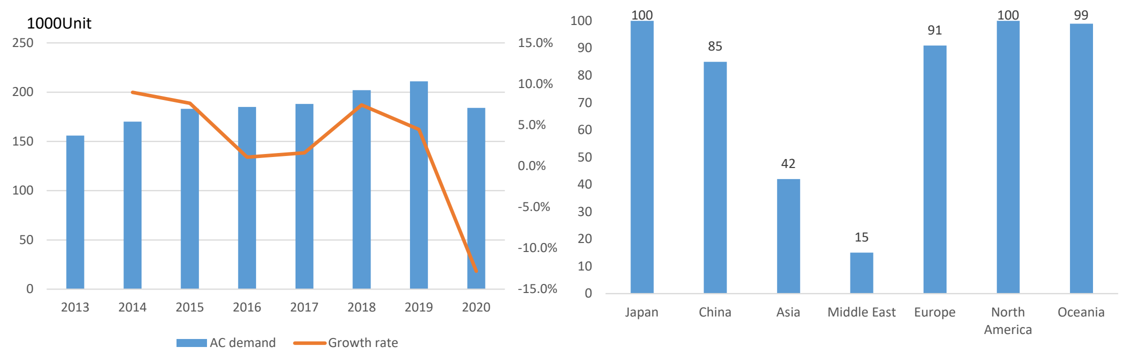
Besides of air conditioners, efficient machinery usage is suggested in heat generation and consumption as clean cooking and hot water usage will become more common in a country. It includes prepaid gas meter, auto ignition burner and auto temp controlled oven.

[24] JRAIA (The Japan Refrigeration and Air Conditioning Industry Association) data

Table 3.4-2 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



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

Figure 3.4-4 Air Conditioner Penetration in Bangladesh and World

Table 3.4-3 summarizes the actions required under the EES&L implementation procedures. To ensure reliability of EES&L program, it is necessary to establish the followings:

a. Testing laboratories that can accurately test the energy-saving performance of equipment. In the early stage of the program, international third-party testing laboratories may be adopted.

b. Database of energy efficiency information on equipment with engagement of manufacturers/importers. Data can be collected efficiently, for example, by providing a website for program participants to register themselves.
c. 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 3.4-3 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

3.4.4 EEC Policies and Future Directions for Commercial Sector

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

1) The Dhaka Mahanagar Imarat Nirman Bidhimala (DMINB 2008)

DMINB-2008 mainly refers to building set back, floor area ratio, maximum ground coverage, and mandatory open space. It stipulates passive approaches to reduce energy use in buildings. Buildings are not regulated or inspected for any active energy or water saving measures.

2) Bangladesh National Building Code (BNBC)

BNBC was enforced in 1993 as a mandatory legal document for building construction. It was amended in 2017 (1) for 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. The updated version of BNBC was proposed in 2020 with an addition of energy efficiency requirements on buildings. Its proper enforcement and compliance check of the code is a key to successful implementation.

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

The USGBC LEED is a widely accepted rating system and is popular in Bangladesh. 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 the LEED certified factories.

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

Presently there is no green building rating system in Bangladesh. In line with EECMP2016, SREDA has developed Building Energy Efficiency & Environmental Rating program (BEEER), the first draft of which was published in November 2017. The rating system is designed as a holistic approach to green buildings taking account of the entire environmental footprint of buildings (e.g., water, wastes, resources). SREDA is preparing for its implementation by conducting evaluations of ten selected buildings and plans to begin implementation in 2023.

With the aim of achieving a net-zero annual primary energy consumption in non-residential buildings, net Zero Energy Building (ZEB) initiatives are being developed, using a combination of energy efficiency and renewable energy. BEEER and ZEB are the main tools for energy saving in commercial buildings, and their integration into one scheme needs to be considered toward 2030.

To further promote above energy saving efforts, a multifaceted approach will enable the users to enjoy the benefit of EEC. Various collaborative actions need to be reflected into the future regulations, including those for awareness raising on pay-back periods of EEC-related investment, nurturing of technical expertise, and relaxation of access to affordable finance. Many initiatives have been proposed by policymakers and financial organizations, but little progress has been made so far.

3.5 Agricultural Sector

According to SREDA, agricultural energy consumption was 1,103 ktoe in FY 2019-2020[25], 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 the irrigation season.

Table 3.5-1 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
Commercial	176	72	0	707	955
Residentail	3,506	1,090	0	3,107	7,703
Transport	954	3,360	0	0	4,314
Industry	5,556	400	3,900	3,208	13,064
Total	10,222	5,863	3,900	7,154	27,139
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: Excluding biofuels and waste

Source: SREDA

25 SREDA National Energy Balance 2019-20

In FY 2018-19, there were 1.58 million irrigation pumps; 79% of them were driven by diesel and the rest electricity. To reduce diesel consumption, Bangladesh is promoting the use of solar PV driven pumps. As a short-term measure to promote energy conservation, introduction of EES&L will be beneficial. SREDA plans a labeling program on pumps to start as a voluntary system in 2023 and to be made a compulsory regulation from 2025. It expects replacement of old pumps with high efficiency ones. Switching from diesel to electricity is also important. It will also be effective to introduce independent PV systems 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 in collaboration with relevant ministries that will consider 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 utilizing low-carbon clean energy.

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

Part 2 Draft Integrated Energy and Power Master Plan

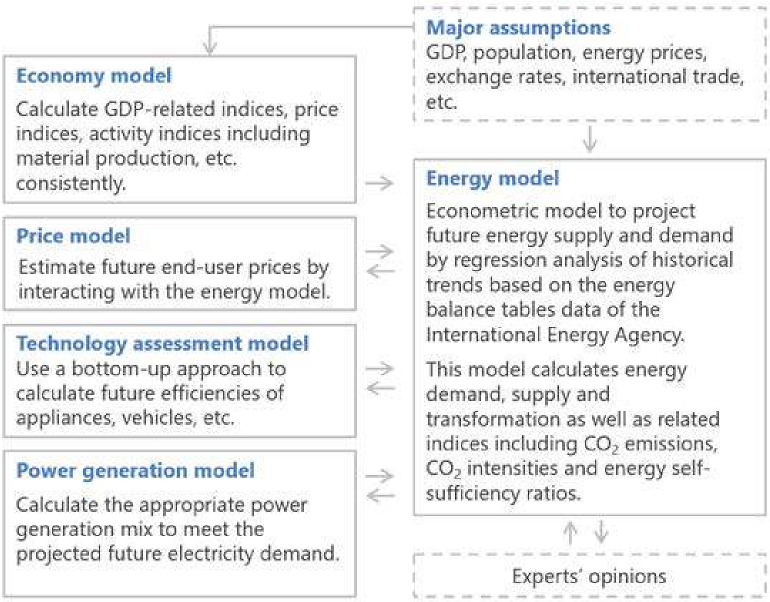
In Part 2, the mainstream of the Draft Integrated Energy and Power Master Plan (IEPMP) is discussed starting from energy demand projection and followed by power supply development plan, primary energy supply plan, estimation of required investment for energy infrastructure, and environmental and social considerations on the plan. Subsequently, policies and institutions are discussed for implementation of the plan in Part 3.

Chapter 4 Long-term Energy Demand Outlook

4.1 Methodology and Development Scenario

4.1.1 Model Structure and Design

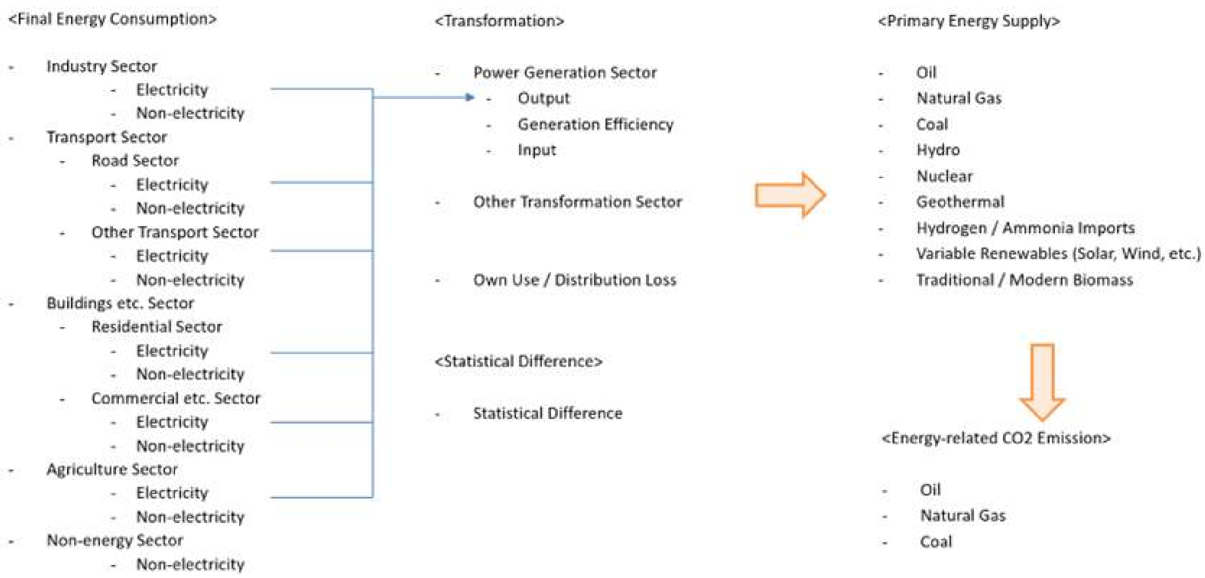
An econometric model is developed by the IEPMP Study Team to forecast long-term energy demand. It is a tool to forecast economic activities with a conception that the past action pattern and trend will be in principle maintained in the future. It is composed of multiple behavior equations to explain the relationship between energy demand and explanatory variables, sub-equations to consider the relationship between explanatory variables and relevant influential factors, and definition equations; these equations are aggregated into an integrated system as shown in Figure 4.1-1. Main equations are obtained by regression analysis on the historical data, and some are defined by analysis on the existing but incomplete data, information by hearing, literature, and/or normative analyses. At the same time, important preconditions are given as assumptions to run the model such as economic growth rate, technology development, and environmental and social constraints as socio-economic development goals.



Source: IEPMP Study Team

Figure 4.1-1 Structure of Energy Demand Model

The energy demand model is structured as shown in Figure 4.1-2. It estimates the final energy demand by sector. Then, energy consumption for generation and transmission/distribution of electricity, refining and other purposes are calculated by specific models as the transformation sector energy demand. These are aggregated into the primary energy supply requirement.



Source: IEPMP Study Team

Figure 4.1-2 Energy Model System

As always, historical data are inconsisitent and history deviates from the past model and forecast. The future is uncertain and unpredictable, and it would not be just a copy of the past as regression equations can propose. Socio-economic climate may change, and hence national development target. In this regard, the model and its outcome should be reviewed and updated periodically.[26]

4.1.2 GDP Assumptions

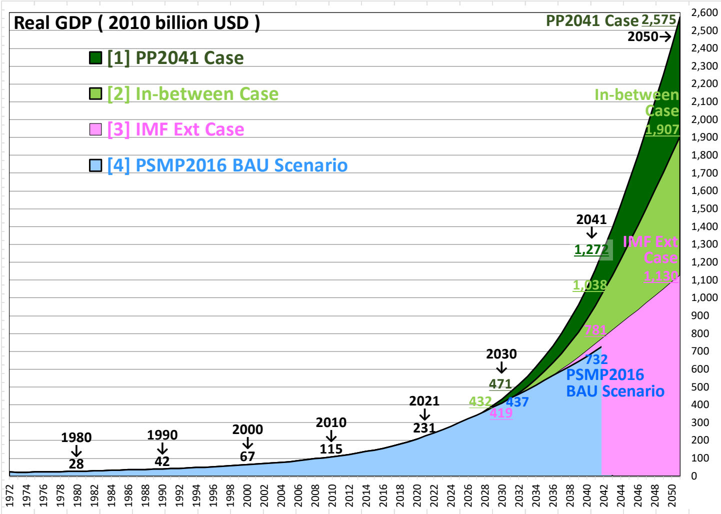
GDP largely represents the economic activity level of a country and is the most important factor in the forecast of energy demand. GDP is usually discussed outside of the energy demand model and given to the model as an external assumption, because discussion on the economic outlook is complicated and it is not practical to incorporate it in the energy demand model.

The present main economic development scenario for Bangladesh is the one developed for the PP2041 as shown in Figure 4.1-3. It aims to achieve US$2.6 trillion in 2010 US dollars of real GDP in 2050. In comparison with this, another case was considered extending the mid-term economic outlook developed by IMF, or IMF Ext Case; GDP will be US$1.1 trillion in 2050. Since the difference of these projections is very large in the long-run, an In-between Case is considered as a projection in between these two projections, where GDP 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 PSMP2016 as the BAU case.

After discussions with stakeholders including the Planning Commission, Finance Division and other

[26] For details of the energy demand model and its application, please refer to Appendix C.

ministries, this Master Plan adopts the PP2041 Case, the present official development scenario, as the main case and the In-between Case as an exercise case.

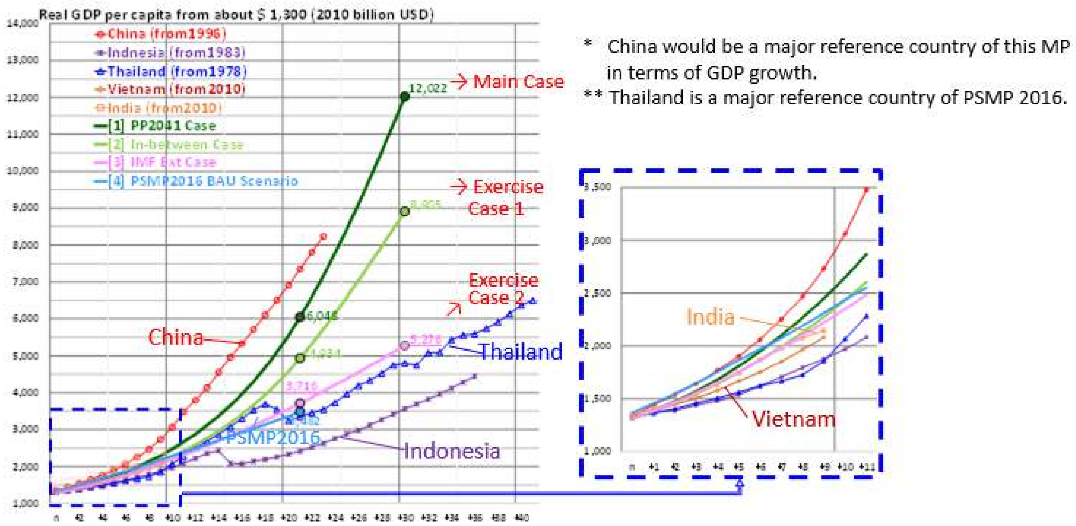


Case	from 2021			
	to 2041	Annual Average GR	to 2050	Annual Average GR
	Times	%	Times	%
[1] PP2041	5.5	+8.9%	11.2	+8.7%
[2] In-between	4.5	+7.8%	8.3	+7.6%
[3] IMF Ext	3.4	+6.3%	4.9	+5.6%
[4] PSMP2016	3.2	+5.7%		

Source: IEPMP Study Team

Figure 4.1-3 GDP Growth Scenarios

In Figure 4.1-4, these projections are compared with the records of economic growth in other Asian countries after achieving per capita GDP of US$1,300 in 2010 US Dollars. The GDP projection for PP2041 is ambitious compared with them except for China as shown in Figure 4.1-4. PP2041 sets the target to achieve per capita GDP of US$16,000 in nominal term and become a high-income country in 2041. The projection made in this case achieves the target and will come closer to US$17,000 in 2041.



Source: IEPMP Study Team/ World Development Indicators

Figure 4.1-4 Growth of per capita GDP after surpassing US$1,300

As for the concerns on the effects of COVID-19 pandemic and geopolitical tensions, it is considered in this analysis that these events are fugitive and will have limited effects on the long-term economic development trends or target, while the global concerns on the climate change and cleaner world will dominate eventually. Nevertheless, to examine the case of slower economic growth, In-between Case is run as an exercise case to consider the gloomy situation of the world economy today.

4.1.3 International Energy Price Assumptions

Price scenarios on the international oil, coal and natural gas prices in real term are assumed based on the IEA World Energy Outlook 2021 as shown in Table 4.1-1. International ammonia price is estimated by the IEPMP Study Team. These prices are projected differently for three scenarios as discussed in 4.1.4. Since early 2022, world energy prices have been fluctuating significantly reflecting geopolitical tensions and reduced supply of oil and gas from Russia. In the long run, however, it is assumed that energy prices will come back onto the traditional track as previously projected.

Table 4.1-1 International Energy Price Outlook

Real price (US$ 2020)

	Oil (US$/bbl)			Coal (US$/tonne)			Natural Gas (US$/MBtu)			Hydrogen (US$/Nm3)	Ammonia (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 (US$/bbl)			Coal (US$/tonne)			Natural Gas (US$/MBtu)			Hydrogen (US$/Nm3)	Ammonia (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: IEPMP Study Team

4.1.4 Scenario Approach on Technology Development

To examine direction of the energy policy mainly in view of technology development and measures to cope with global climate change, three energy scenarios are developed. They are Reference Scenario (REF), Advanced Technology Scenario (ATS), and Net-Zero Scenario (NZS) as shown in Table. 4.1-2. REF simply follows the past 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. ATS is a scenario that aims at a harmonious accord of energy supply security, economic efficiency and environmental sustainability, or so called “3Es”.

It should be noted that NZS applies a backcasting approach, wherein zero emission in 2050 is a pre-determined condition rather than an estimated result, which differs from REF or ATS.

Table 4.1-2 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.

Note: For the purpose of calculation, NZS (Net Zero Scenario) 2050 is developed arbitrarily. Hence, Bangladesh is planning to adopt NZS (Net Zero Scenario) by 2070.

Source: IEPMP Study Team

Even in REF that follows the past trends, reduction of carbon emissions will still be pursued, though it will not significantly deviate from the historical trend. In terms of assumed technologies, moderate progresses will be observed in the efficiency improvement, cost reduction of energy supply, and adoption of low carbon technologies. But they will be on the extension of the past trend and would not see obvious acceleration despite the recent growing concerns on carbon neutrality.

In NZS, carbon emissions are set at net zero in 2050 and a backcasting approach is applied to find the pathway to 2050. Technology development and international cooperation should be pursued at an extreme pace. As shown in Table 4.1-3, energy conservation, electrification and hydrogen utilization have to be introduced at maximum in the industry sector. Thorough energy conservation and electrification must penetrate 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 (TRBSs). 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 assumes application of practicable and affordable technologies at maximum, while environmental regulations and targets will be enhanced. Technology development and international cooperation will show significant progress. Energy conservation and electrification will also be implemented across all the sectors. In the road sector, 40% of PLDVs and 10% of TRBSs will shift to EVs from conventional gasoline or diesel driven models.

Table 4.1-3 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: IEPMP Study Team

Table 4.1-4 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*), 50% hydrogen co-firing will start around 2040 (2045*). 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: IEPMP Study Team

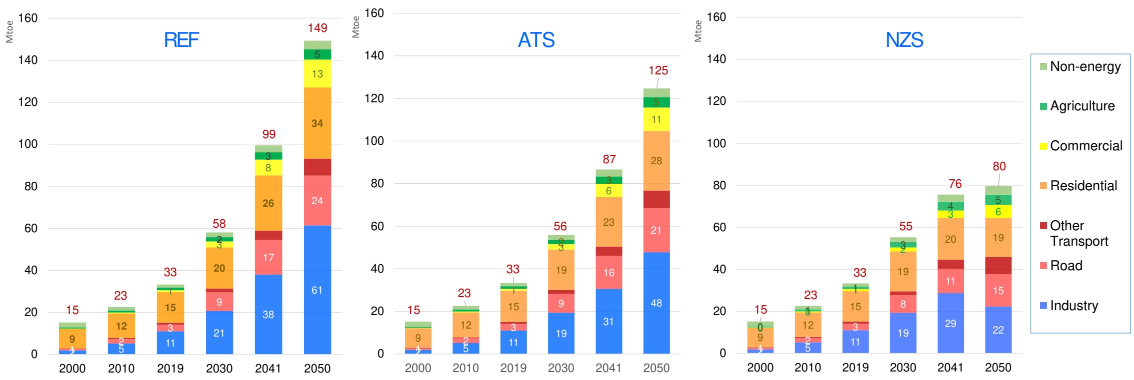
In the power sector, application of clean energies such as renewables, nuclear and decarbonization technologies including ammonia co-firing, hydrogen mono-firing and gas-fired power with CCS (Carbon dioxide Capture and Storage) will start in both NZS and ATS (Table 4.1-4). On the other hand, traditional captive power will decrease along with grid stabilization, while small amounts of high-efficiency co-generation systems will be introduced in some economic zones and large facilities through 2050 in ATS.

4.1.5 Preliminary Examination of Three Scenarios

A preliminary study was run to examine these 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. Energy intensity of GDP will keep decreasing in all three scenarios. 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 their achieving 1,300 US dollars (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.

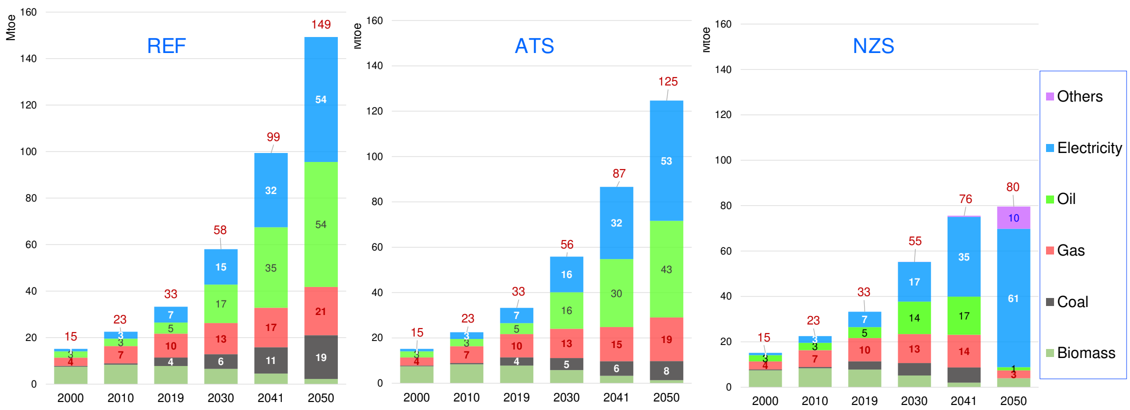
Among sectors, the industrial sector will be the largest demand sector for all three cases in both 2041 and 2050, reflecting the sustainable economic growth and expansion of the country's industrial activities (Figure 4.1-5). This suggests that the future energy demand growth of Bangladesh largely rests 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 along with rising living standards of the people during the entire period of this analysis, a steep demand increase is inevitable in these two sectors.



Source: Prepared by the IEPMP Study Team

Figure 4.1-5 Final energy consumption by sector

By energy source, electricity will be the largest energy source for ATS and NZS (Figure. 4.1-6). Besides electricity, a different mix of energy sources will be utilized in each scenario. In NZS, for instance, substantial amount of hydrogen and ammonia will be used through 2050 based on the assumption that hydrogen (and ammonia as its carrier) will be one of the major energy sources 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 IEPMP Study Team

Figure 4.1-6 Final energy consumption by source

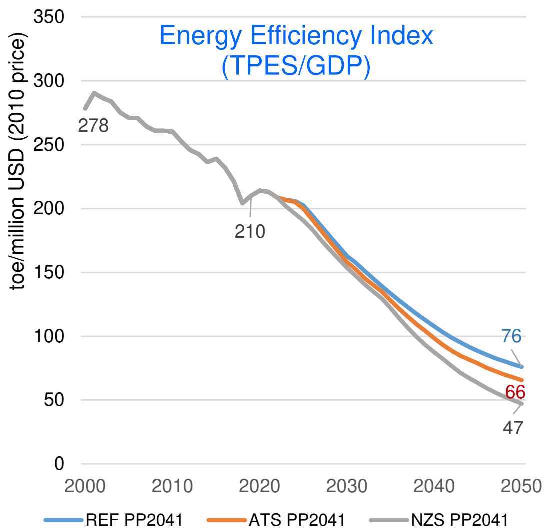
In terms of energy efficiency on the total primary energy supply (TPES) and carbon emissions, CO_2 intensity of a country can be observed as follows:

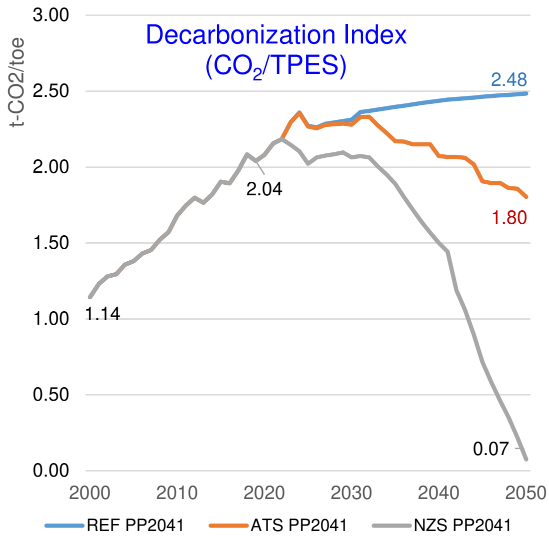
CO_2 Intensity: CO_2/GDP=(TPES/GDP) x (CO_2/TPES)

The energy efficiency index (EEI: TPES/GDP) declines along with technology progress and energy conservation efforts (Figure 4.1-7). It falls by 64% between 2019 and 2050 in REF (at 3.2% annual decline), 69% in ATS (3.7%), and 78% in NZS (4.7%). As a reference, India's EEI decreased 2.4% annually between 2010 and 2019, and China's EEI decreased 3.5% annually between 1996 and 2019 after achieving the US$1,300 (in 2010 price) of real GDP per capita, respectively, which is close to the present situation in Bangladesh. The estimated EEI improvement in ATS is almost the same as China's experience, and in NZS it is considerably greater than China's experience.

Energy related CO_2 emissions 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 a half of the Japan's emissions in 2019. In ATS PP2041, it will grow moderately to 305 million tons- CO_2, almost two thirds of that in REF. The emissions of NZS PP2041 are, by definition, almost zero in 2050.

Decarbonization Index (DCI: CO_2/TPES) follows very different paths in the three scenarios (Figure 4.1-7). 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 backcasting approach, it needs to drop sharply to achieve net zero in 2050, which would be difficult unless placing extreme stress on the economy.





Source: IEPMP Study Team

Figure 4.1-7 Comparison of Three Scenarios on Technology Development

It is not an easy task to reduce carbon emissions in the process of economic development. In Asia, no country, including Thailand, Indonesia, China, India, and Vietnam, has succeeded in reduction of DCI on average in the industrialization period after achieving US$1,300 (2010 price) of real GDP per capita. Bangladesh is determined to make contributions in addressing the global concerns on energy security and climate change in such a manner 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.

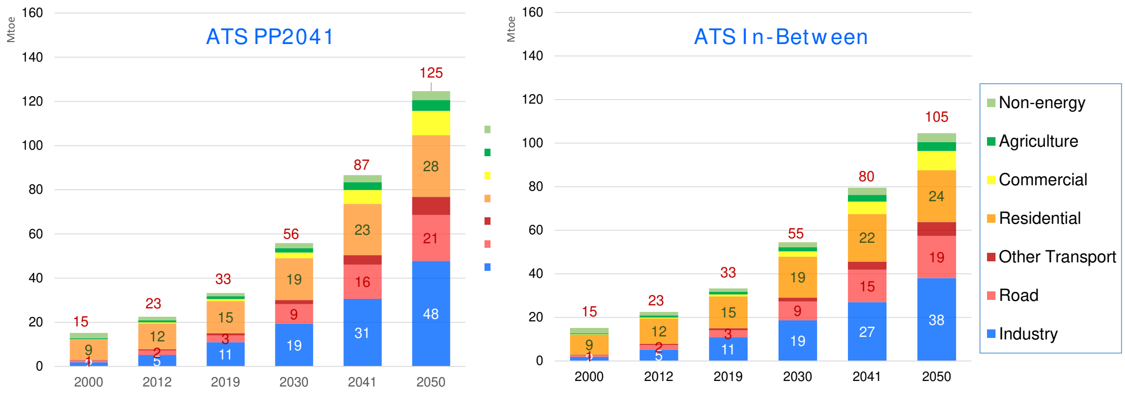
Based on the discussion above, the energy demand/supply forecast is run on the Advanced Technology Scenario (ATS) with two GDP projections of PP2041 Case and In-Between Case.

The Bangladesh government prefers the ATS In-Between case to be chosen as the basis for the Power Development Plan (PDP).

4.2 Long-term Energy Outlook

4.2.1 Energy Demand by Sector

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



Source: IEPMP Study Team

Figure 4.2-1 Final Energy Demand by Sector

Among sectors, the industry sector that 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 for household use will remain relatively slow. This is because inefficient traditional biomass, mainly firewood, will be replaced with modern energies such as electricity and LPG accompanying with significant efficiency improvements. Energy consumption in the commercial sector will grow fast to support modernization of life, but remains relatively small. Agriculture will continue to consume certain amount of energy for irrigation and agricultural machines. Non-energy consumption will also expand mainly as feedstock for fertilizers and petrochemical industries. Sectoral trends are analyzed as below.

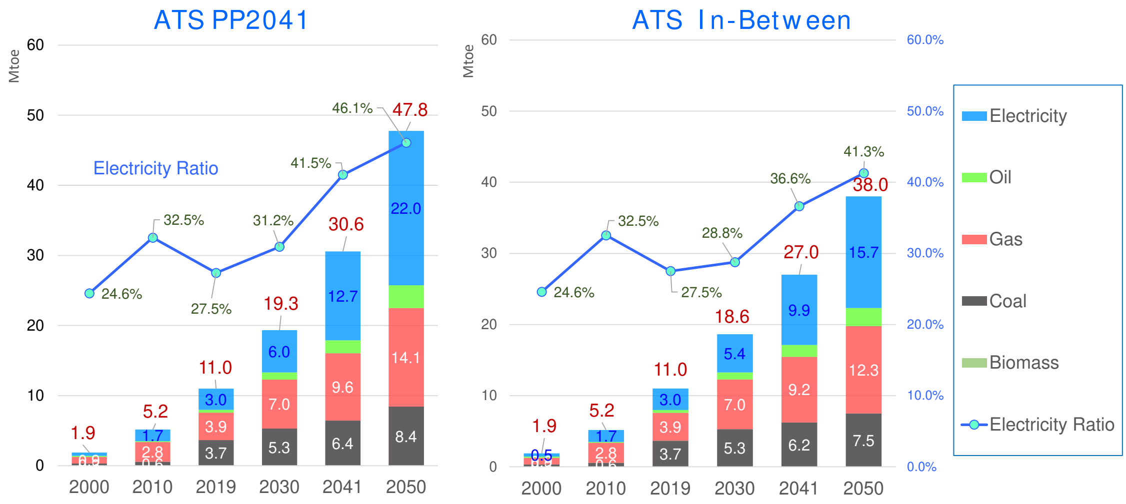
Table 4.2-1 Final Energy Consumption by Sector

ATS	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	2050
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: IEPMP Study Team

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 and steel by blast furnace, electricity will be the main energy source to drive the industry sector. 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 key energy sources. These fossil fuels will keep providing high temperature heat at relatively low costs.



Source: IEPMP Study Team

Figure 4.2-2 Industry-sector Energy Demand

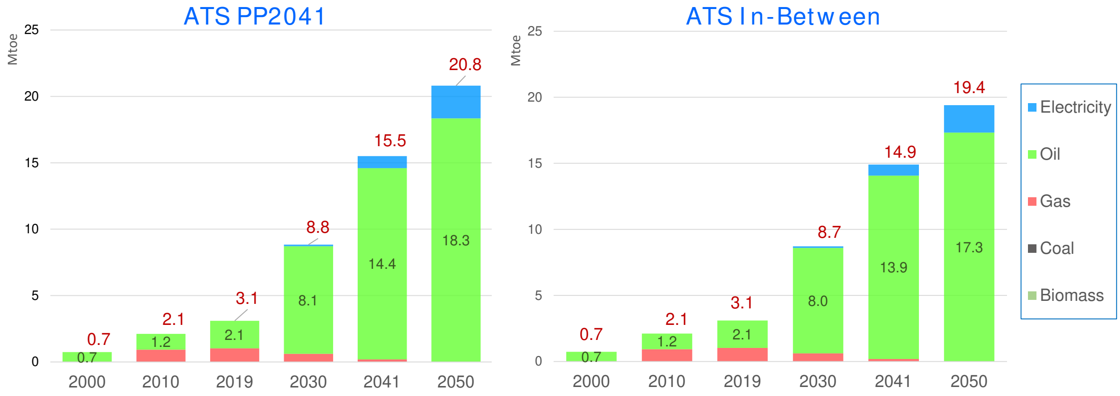
It should be highlighted here that coal will be the third largest energy source. This is because of its cost competitiveness compared to other energy options such as electricity supply from grid or natural gas.

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.

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 4.2-3). As the country's per capita income increases together with population, demand for mobility will grow fast and push up car ownership. This will be accelerated by switching from two-wheeled motorcycles to four-wheeled conventional cars.

In ATS, a growing number of EVs will penetrate the entire vehicle stock compared to REF, although the 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 at the Mirsarai Economic Zone will be expanded sooner or later to the maximum space capacity; the EVs produced there will become popular in the Bangladesh auto market.

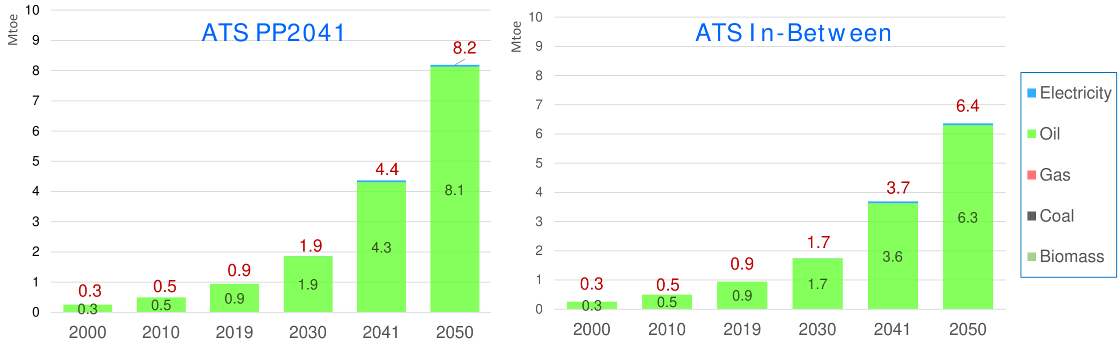


Source: IEPMP Study Team

Figure 4.2-3 Road-sector Energy Demand

3) Other Transport Sectors

Energy demand in the other transport sector is relatively small (Figure 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. Infrastructure 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 (MRT), high-speed railway, etc.



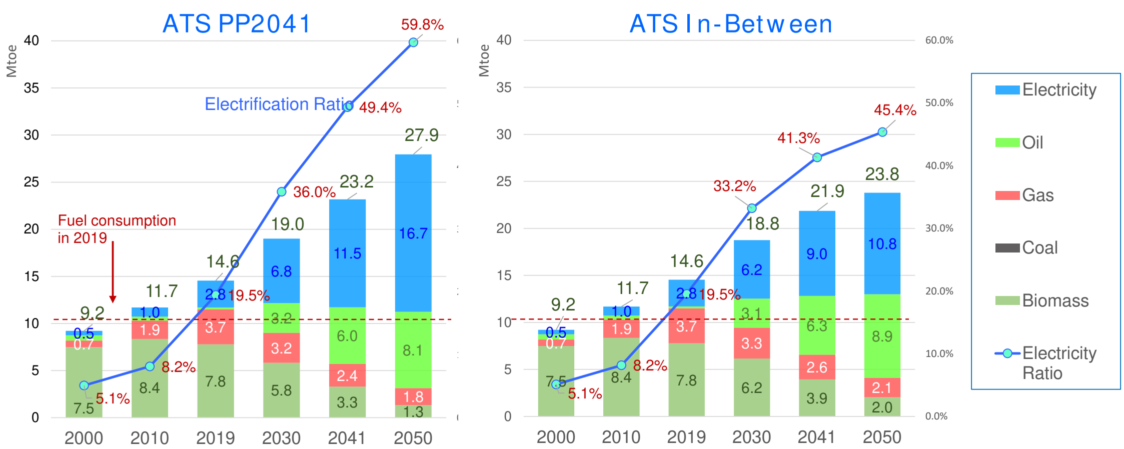
Source: IEPMP Study Team

Figure 4.2-4 Other-transport-sector Energy Demand

4) Residential Sector

In the residential sector, electricity will become the largest energy source. It will be the enabler for people to enjoy high-quality life with convenient and 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.

As for non-electricity energies for the residential sector, LPG, categorized as oil, and city gas will be used as the major energy source for cooking and hot water supply through 2050. Since the incremental demand for both natural gas and LPG most likely be imported in case no new major natural gas reserve discovery happens, their roles must be sorted out appropriately. Traditional biomass will rapidly decrease being replaced by electricity and LPG 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 same as shown in Figure 4.2-5.



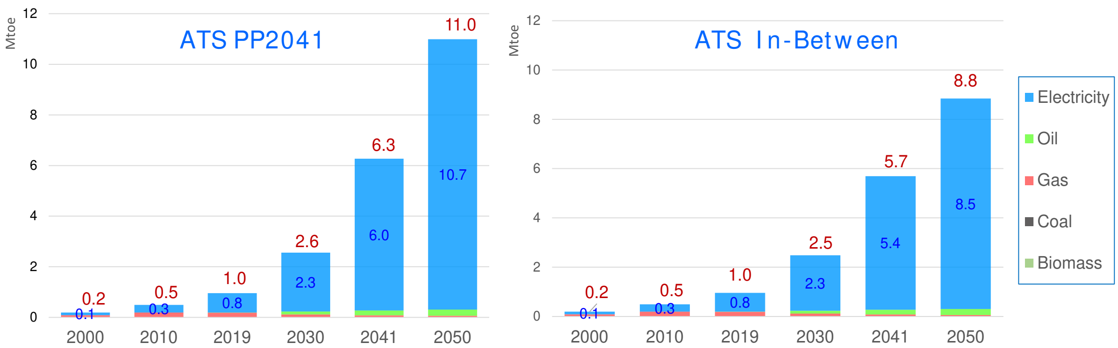
Source: IEPMP Study Team

Figure 4.2-5 Residential-sector Energy Demand

Energy conservation rate for the residential sector, when other conditions are held constant (without price effect, etc.), will be -13.1% (annual -0.5%) in 2050 compared with the demand estimated for REF. It is 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 performance of appliances.

5) Commercial Sector

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



Source: IEPMP Study Team

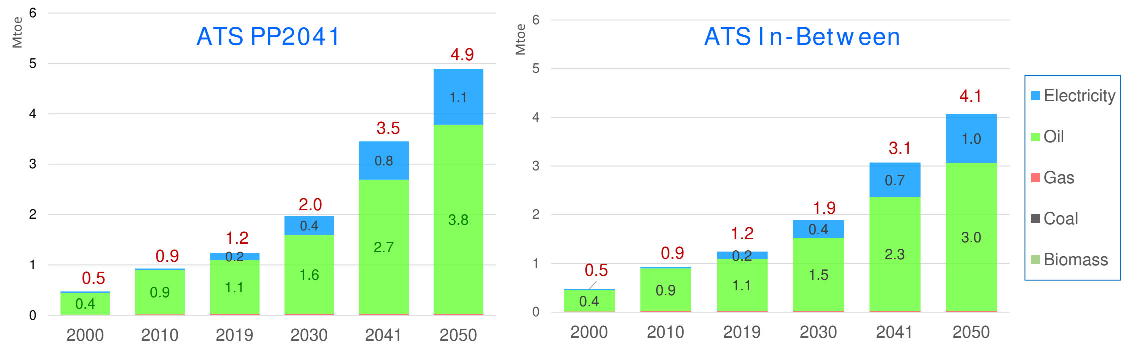
Figure 4.2-6 Commercial-sector Energy Demand

Energy conservation rate for commercial sector, when 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 residential sector, since energy conservation performance for commercial sector is mostly fixed at the time when building and facilities are built and thus remains challenging. 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.

6) Agricultural Sector

The size of 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 4.2-7). 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 solar PVs and connections to the grid system.

To rationalize the energy use in this sector, a nationwide irrigation system together with flood prevention measures may also be considered covering from the upstream to downstream of the water flow connecting users by water channels.

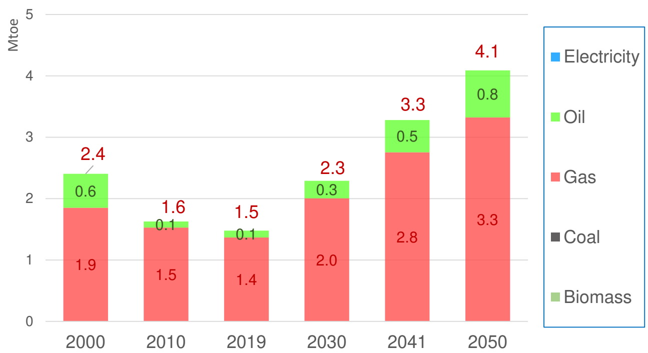


Source: IEPMP Study Team

Figure 4.2-7 Agricultural-sector Energy Demand

7) Non-energy Sector

Contrary to the declining trend in the last two decades, energy demand for non-energy sector will turn to grow again towards 2050. This demand growth will be generated mainly because the fertilizer industry will regain its production, while demand will also increase for naphtha in line with the increased use of chloroethylene as poly vinyl chloride (PVC) for building materials, and

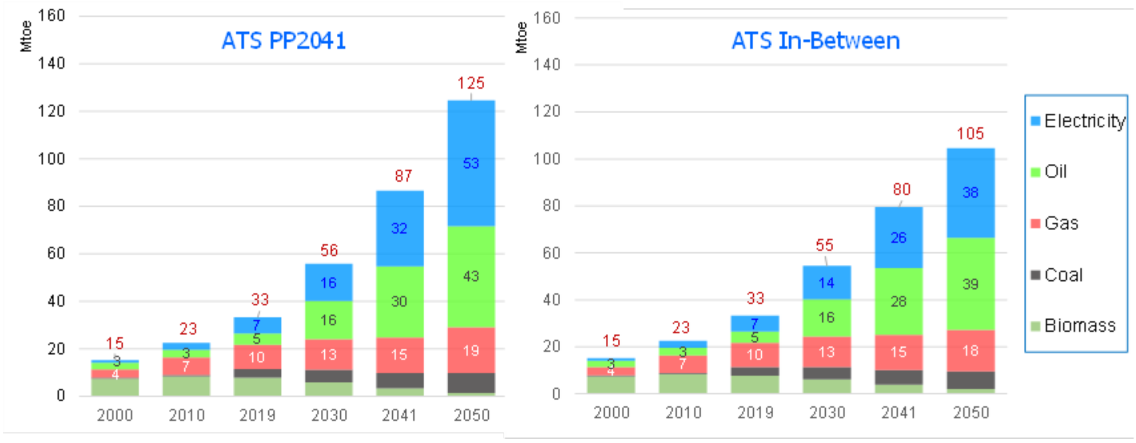


Source: IEPMP Study Team

Figure 4.2-8 Non-energy-sector Energy Demand lubricant oil for motor vehicles. Energy demand for non-energy sector will increase to around 4 Mtoe in 2050.

4.2.2 Energy Demand by Energy Source

The final energy consumption by energy source is summarized in Figure 4.2-9 and Table 4.2-2. 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: IEPMP Study Team

Figure 4.2-9 Final Energy Consumption by Energy

Table 4.2-2 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: IEPMP Study Team

4.3 Electricity Demand and Power Generation

4.3.1 National Power Demand

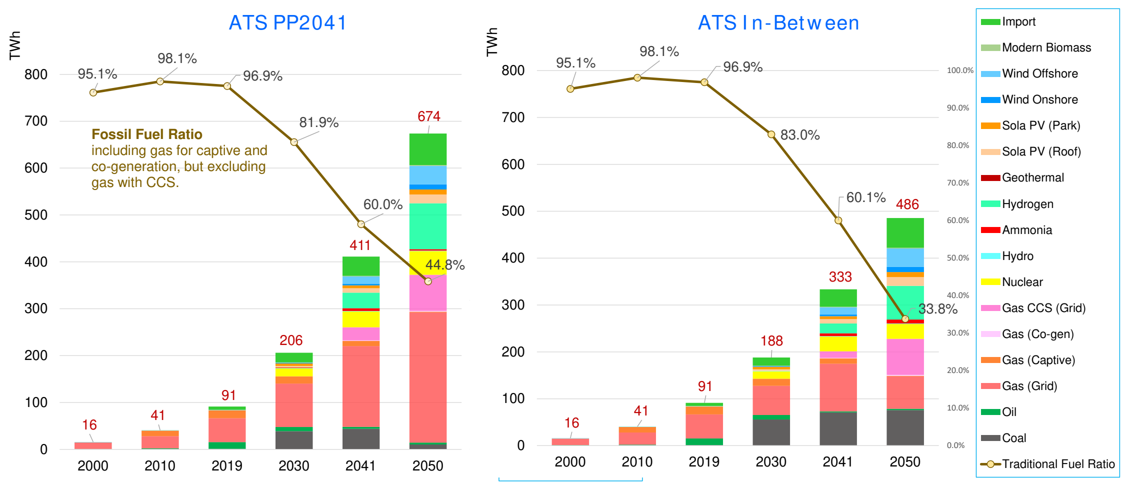
With high-speed industrialization and income growth, electricity demand will grow fastest among the energy sources. The requirement for power supply will expand 7.38-fold in PP2041 case between 2019 and 2050, and 5.32-fold in In-Between case. At present, 91.3% of the power supply comes from thermal power plants burning conventional fossil fuels such as coal, oil and natural gas. Only 1.3% is supplied by clean energy mainly solar PVs and 7.3% comes from import. In order to construct a low-carbon economy, every clean energy such as nuclear, hydro, solar 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% to about 40% in 2050.

Table 4.3-1 Outlook of Power Supply

	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
Traditional Fuel	83.4	155.7	232.5	295.4	91.3	75.6	56.6	43.8	5.8	3.7	2.2	3.54
Clean Energy	1.1	29.8	137.5	311.0	1.3	14.5	33.4	46.2	34.5	14.9	7.7	271.58
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
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
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
Traditional Fuel	83.4	142.8	187.1	150.9	91.3	76.0	56.1	31.1	5.0	2.5	-1.9	1.81
Clean Energy	1.1	27.6	109.1	271.3	1.3	14.7	32.7	55.9	33.5	13.3	8.6	236.93
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
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
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: IEPMP Study Team

Note: Net power generation is analyzed in more detail in Chapter 5 Power System Development Plan.



Source: IEPMP Study Team

Note: Net power generation is analyzed more in detail in Chapter 5 Power System Development Plan.

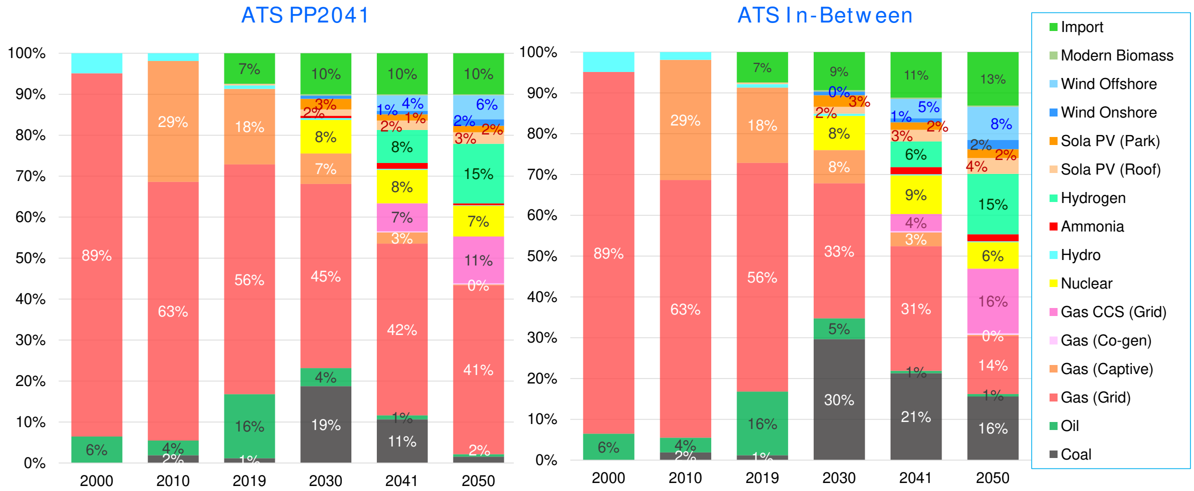
Figure 4.3-1 Power Generation

As shown in Figure 4.3-1, coal-fired power will introduce ammonia as a co-firing fuel, and gas-fired power will be replaced by hydrogen-fired one. Gas-fired power with CCS will be adopted as Bangladesh is endowed with suitable geological structures for underground storage of CO_2. Significant expansion of offshore wind is also expected as a 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.

4.3.2 Power Generation Mix

In the ATS PP2041 Case, the ratio of clean energy attains 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 neighboring countries and nuclear power also have considerable shares. In contrast, the share of renewable energies will be relatively small mainly due to the limited availability of suitable land areas. Coal-fired power remains more than 10% in 2041, but will almost disappear towards 2050.

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 backcasting approach. In terms of environmental sustainability, total renewable power capacity for ATS will achieve the NDC conditional target by 2030. Above all, achieving up to 40% of the clean energy ratio in 2041 will be consistent with the declaration made by the Prime Minister Sheikh Hasina at COP26 in 2021[27].



Source: IEPMP Study Team

Note: Net power generation is analyzed more in detail in Chapter 5 Power System Development Plan.

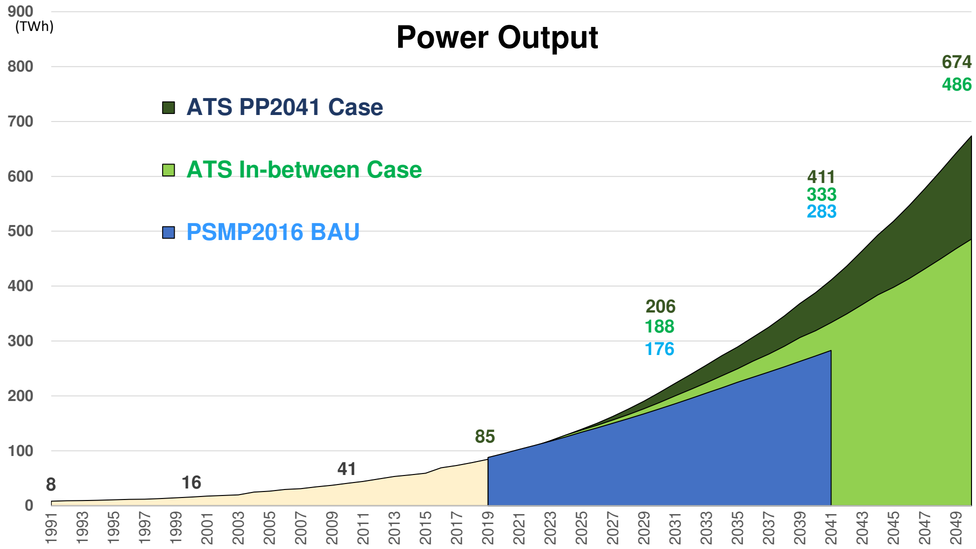
Figure 4.3-2 Power Generation Mix

4.3.3 Comparison with the Previous Power Plans

Power generation in ATS PP2041 and ATS In-between cases are roughly comparable to those of the past power system master plans as shown in Figure 4.3-3. Power generation of both cases are between that of the BAU of the Power System Master Plan 2016 and that of the base case of the Revisiting Power

[27] https://unfccc.int/sites/default/files/resource/BANGLADESH_cop26cmp16cma3_HLS_EN.pdf

System Master Plan 2016. Since the current economic situation is improving than that in 2016 when the PSMP2016 was published, this result will be more realistic.



Source: IEPMP Study Team

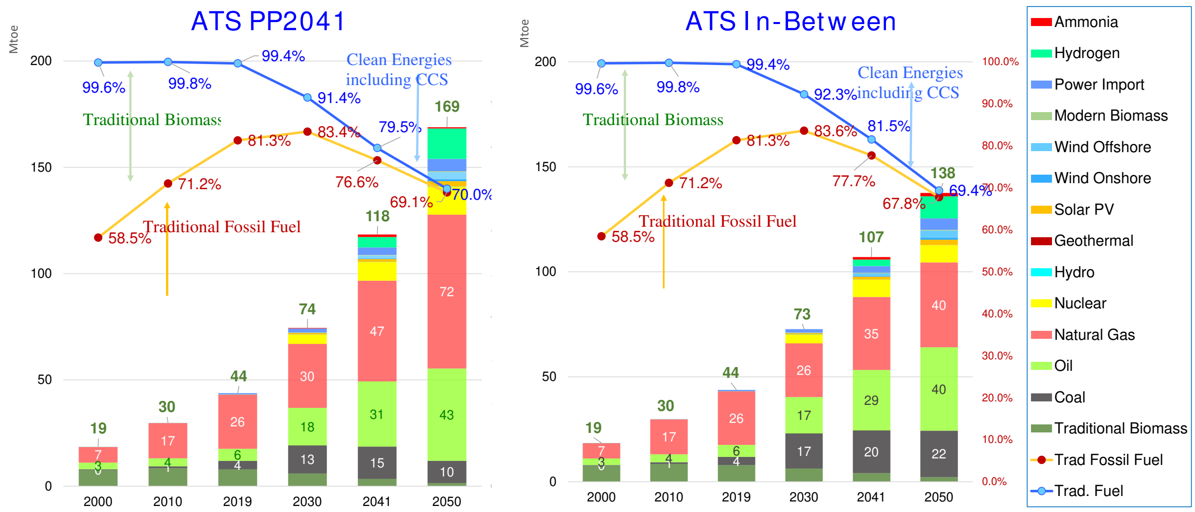
Figure 4.3-3 Comparison with the Previous Power System Master Plans

4.4 Primary Energy Supply

4.4.1 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 the power sector and the oil and gas sector (Fig. 4.4-1). 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. The size of TPES in 2050 is close to that of the United Kingdom in 2019. In the ATS In-between case, TPES will expand about three-fold to 138 Mtoe in 2050, which is close to that of Thailand in 2019.

To date, traditional biomass consumption mainly comprising 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. Meanwhile, with a view to constructing a low carbon economy and diversifying energy sources, clean energies such as nuclear, solar PVs, wind, CCS, ammonia and hydrogen will be introduced. The share of these clean energies will reach 20% by 2041 and 30% in 2050.



Source: IEPMP Study Team

Figure 4.4-1 Total Primary Energy Supply

Table 4.4-1 Total Primary Energy Supply

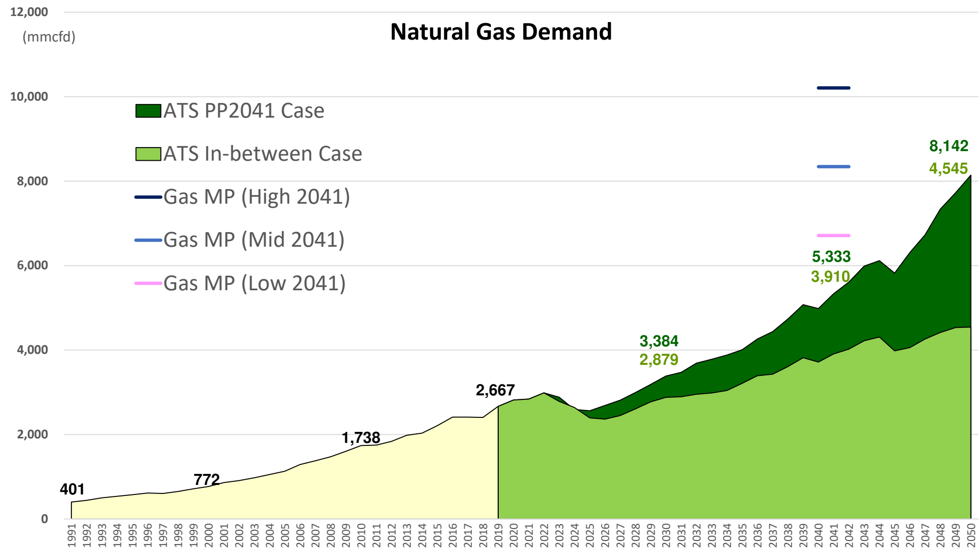
	Total Primary Energy Supply (million toe)				Composition				Average Growth Rate			2019 to 2050
	2019	2030	2041	2050	2019	2030	2041	2050	19-30	30-41	41-50	
PP 2041					%	%	%	%	%	%	%	times
Traditional Biomass	7.9	6.0	3.4	1.5	18.1	8.0	2.9	0.9	-2.5	-4.9	-7.3	0.19
Coal	4.0	13.2	15.2	10.5	9.0	17.8	12.8	6.2	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: IEPMP Study Team

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 by and large where traditional fossil fuels still play major roles.

4.4.2 Comparison with the Previous Natural Gas 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. Natural gas demand will keep growing, but the pace will slow down. The demand growth will be kept somewhat sustained. Various advanced technologies that substitute natural gas will become commercially available from the 2030s and onwards, and will gradually be adopted in Bangladesh.

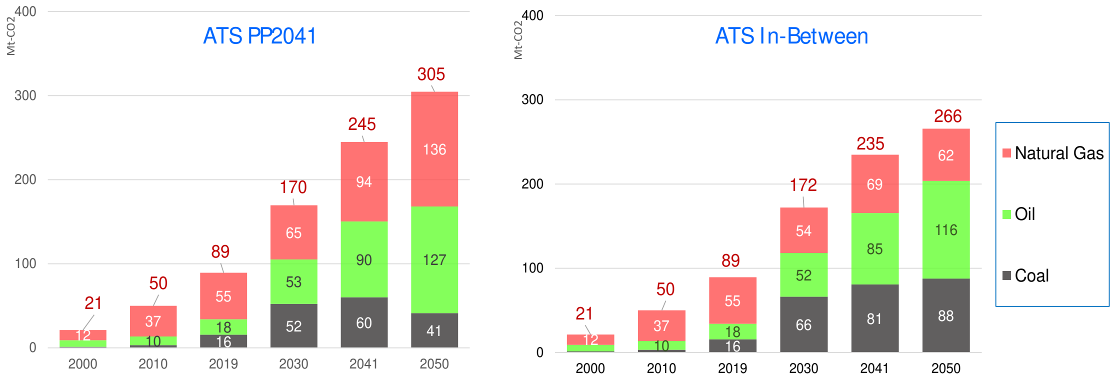


Source: IEPMP Study Team

Figure 4.4-2 Comparison with the Previous Natural Gas Plans

4.4.3 Energy-related CO_2

CO_2 emissions from energy use reflect the amount of fossil fuels in TPES. The emissions in ATS PP2041 will be much more moderate at 305 million tons-CO_2 in 2050 than in REF PP2041. Similarly, that of ATS In-between will be even lower at 266 million tons-CO_2 in 2050.



Source: IEPMP Study Team

Figure 4.4-3 Energy-Related CO_2 Emissions by Source

4.5 Points to Note

While it is quite a challenging target, the Advanced Technology Scenario (ATS) is a well-balanced scenario as the energy demand outlook on which Bangladesh designs 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 years to 2050 will be the 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 geopolitical tensions occurred since 2020 will be fugitive and would not affect the super long-term trends. On the other hand, with the backdrop of accelerating concerns on climate change, new technologies that we are yet to know may emerge much earlier. All in all, as future is uncertain and unpredictable; the adopted scenario must be examined and updated periodically in due course.

Chapter 5 Power System Development Plan

The PSMP2016, formulated in 2016, proposed a comprehensive energy and power development plan up to 2041. However, since the time of its formulation, movements aiming at a low carbon society has accelerated worldwide. In June 2021, the Bangladesh government cancelled construction plans for 10 coal-fired power plants. As PSMP2016 was already experiencing various revisions, it became apparent that a comprehensive review is necessary to properly incorporate recent movements. This chapter develops a power development plan up to 2050 taking into consideration the low carbonization movements, while following in principle the concept proposed in PSMP2016.

5.1 Priority Issues and Viewpoints

Based on a long-term demand forecast and a careful review on the appropriate reserve margin rate, lead time for construction of power plants and transmission facilities, and a timing when new low-carbon and decarbonization technologies can be applied, power system development plan is formulated in the IEPMP.

Since the late 2010s, domestic natural gas alone has become unable to meet the growing electricity demand brought by economic growth. Thus, several large-scale power plants using imported fuel such as coal and LNG have been newly built. Together with this, construction plans are underway for 400kV and 765kV transmission lines along the coast of the Bay of Bengal toward Dhaka, the demand center, from the power sources situated in the south. In addition, electricity import from the neighboring countries is also being planned.

An important change in this IEPMP is to take up low carbonization efforts, which are coming up as a global trend. At the same time, it is a crucial issue how to secure the primary fuel supply for electricity generation.

Under the above backdrop, the power development plan is formulated with major principles as follows:

a. Proactive introduction of clean energy

In keeping up with the global current toward low carbonization, clean energies (i.e., renewable energy, hydrogen/ammonia thermal power, thermal power with CCS, nuclear power, import of hydro power, etc.) are proactively introduced. The clean power generation ratio will attain 40%, the target for 2041, and will further increase from 2042 onwards.

b. Policy shifts on construction plans of coal-fired power plants

After formulating the PSMP2016, the Bangladesh government has cancelled construction plans for 10 coal-fired power plants observing its manifested implementation program in response to the world movements toward low carbonization. Some of the power plants have switched their primary fuel to LNG/Renewables.

c. Securing adequate supply reserve capacity

The reserve capacity is the power source whose value comes from its standing by function. Even when it is not used to generate electricity, it is necessary to incur the fixed cost according to the installed capacity. With this mechanism, a haphazard power development tends to exceed the appropriate reserve capacity causing an economic burden to the country. To improve the situation, a supply reserve capacity rate is proposed to maintain supply reliability for the users while minimizing the supply reserve capacity.

d. Renewable energy sources incorporated into supply capacity

In the traditional planning on electricity supply mix of Bangladesh, renewable energy other than hydropower has not been considered. Solar power, the main source of renewable energy in the future, cannot produce electricity in the evening when power demand reaches its peak in this country. However, the industrial structure of Bangladesh may change in the future and the power demand pattern may shift to a daytime peak type as seen in Japan, Thailand, and other developed countries. Therefore, due consideration should be given to renewable energies as prospective future supply sources.

5.2 Electricity Demand and Supply Requirement

5.2.1 Electricity Demand

Electricity demand based on the long-term energy demand outlook is described earlier in Section 4.2. It is a sum of the annual electric power consumption by each sector (consumers). In formulating a power system development plan, it is necessary to estimate the electricity demand (i.e., annual electric power amount and annual maximum electric power) at the generating end as well as the daily load curve for the daily operating status of each power plant.

When roof-top solar power generation increases in the future, its power output will not be included in the supply capacity on grid, but will be counted as a decrease in electric power demand, affecting the shape of the daily load curve significantly. This effect should also be considered when estimating the maximum power demand (MW) and the daily load curve.

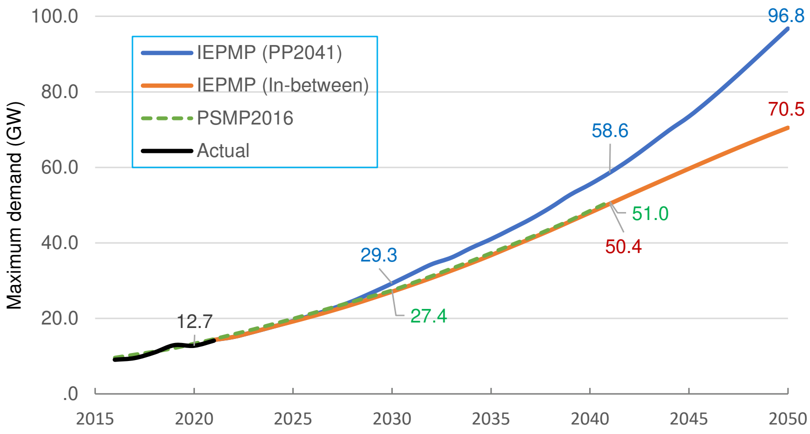
a. Maximum electric power demand (MW) forecast

The maximum electric power demand (MW) forecast for each year is obtained as per the electric energy demand (MkWh) forecast. Basically, the maximum electric power demand for each year is derived based on the estimated annual load factor, which is shown below.

Table 5.2-1 Maximum Electric Power Demand

	Maximum demand (MW)				Annual growth rate			
	2019	2030	2041	2050	’30/’19	’41/’30	’50/’41	’50/’19
PP2041	12,893	29,257	58,597	96,767	7.7%	6.5%	5.7%	6.7%
In-Between	12,893	27,087	50,364	70,512	7.0%	5.8%	3.8%	5.6%

Source: IEPMP Study Team



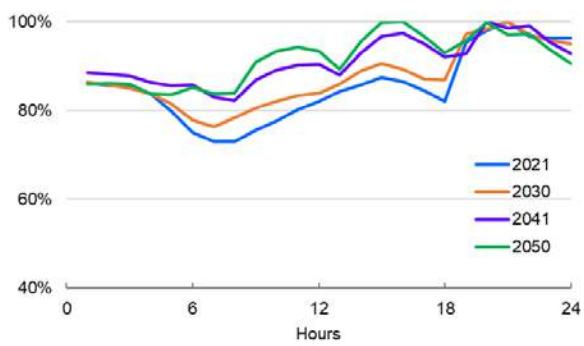
Source: IEPMP Study Team

Figure 5.2-1 Maximum Electric Power Demand

The maximum demand in 2050 will reach 97GW for the PP2041 GDP case and 71GW for the In-between case. Up to 2041, the In-between projection evolves similarly as the forecast in PSMP2016.

b) Estimation of daily load curve

In order to confirm the daily operation status of each power plant, daily load curves are estimated. Although accurate modeling of the future daily load curve is difficult, with expanding activities in commerce and industry in Bangladesh, it is expected that the current evening peak type load curve will gradually shift to a daytime peak type like Japan and other developed countries. Thus, the daily load curves of Japan, Singapore, Thailand, Vietnam, and India, which are having more advanced economic activities, are applied for estimation of the maximum electric power demand on typical days.



Source: Study Team

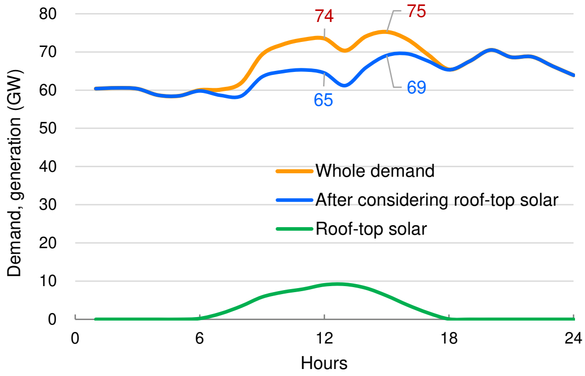
Figure 5.2-2 Estimation of daily load curve

From a geographical point of view, although Thailand is located at a lower latitude than Bangladesh and has a higher average temperature, not much difference is observed in the temperature during the high temperature period. Since they are under similar tropical savanna climate, the present shape of the load curve for Thailand is referred to in estimation of the shape of Bangladesh's daily load curve for 2050. The results are as follows. (Maximum demand day in April)

Daytime demand will gradually increase from 2021, and in 2050, the demand at 15:00 and the demand at 19:00 will become almost equal.

On the other hand, daytime demand will be greatly affected by roof-top solar, and the impact becomes particularly noticeable in later years. The impact on the maximum demand day in 2050 is shown in the right figure.

In 2050, the installed capacity of roof-top solar is expected to be 12 GW, and the demand during the daytime will decrease by about 10% due to roof-top solar.



Source: Study Team

Figure 5.2-3 Impact of Roof-top Solar on Daily Load Curve (2050)

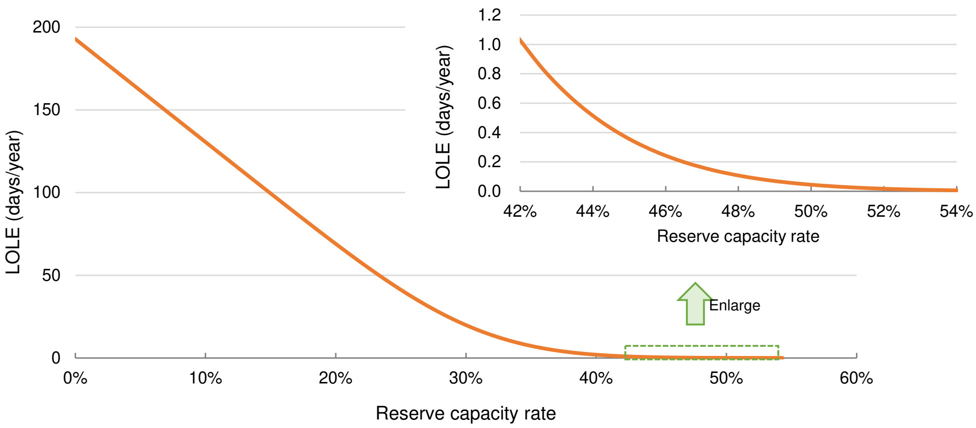
5.2.2 Supply reliability/reserve capacity

Optimizing the amount of reserve capacity and the frequency adjustment capacity is an important task in order to strike a balance between a stable supply of electricity and an inexpensive supply of electricity. To this end, it is necessary to secure a reserve capacity so as not to interrupt the supply as far as possible even in the event of unforeseen abnormalities such as unplanned outages of generators or errors in demand forecasts.

Increasing the amount of the supply reserve capacity improves supply reliability. But if it becomes excessive, recovery of the costs for power plant construction and O&M will be adversely affected leading to a risk of deteriorating the financial conditions of electric power companies. Eventually, the costs must be recovered with higher electric power tariffs, causing an economic burden on the customers of electric power. Therefore, the required supply reserve capacity must be estimated through an appropriate and transparent process.

a. Relation between LOLE and supply reserve capacity rate

The relationship between the supply reserve capacity and the Loss-of-Load Expectation (LOLE) based on the results of unplanned outages and the demand forecasting errors experienced in 2020 is shown in the chart below.



Source: Prepared by the IEPMP Study Team from various materials

Figure 5.2-4 Relationship between supply reserve capacity and LOLE

By increasing the supply reserve capacity, the value of LOLE gradually decreases, indicating that supply reliability improves. The graph shows that in an extreme case of not securing a supply reserve capacity, there will be a power shortage for about 190 days a year. According to this, the necessary reserve capacity rate to achieve the LOLE target value is roughly calculated as follows.

Table 5.2-2 Necessary reserve capacity rate

Target year	Target LOLE	Necessary reserve capacity rate
Present-2030	24 hours/year	Approx. 42% or more
2031-2041	12 hours/year	Approx. 44% or more
2041-2050	6 hours/year	Approx. 46% or more

Source: IEPMP Study Team

Currently, the reserve capacity rate of 50% or more is secured even considering the derated capacity due to the decline in power generation output. However, at the actual demand and supply situation, the expected supply reserve capacity rate may drop to below 10%, in which case LOLE will drop to about 130 days/year. (If the same supply and demand situation continues for one year, about four months will fall under power shortage conditions.)

In order to improve the above situation and maintain supply reliability within the target value of LOLE, it is not desirable to newly augment the reserve capacity. Rather, it will be more appropriate to reduce the unplanned outage rate of generators and reduce the reserve capacity required to achieve the LOLE target value.

According to the actual results in 2020, on average, generator outputs of about 2,200 MW and 2,000 MW could not be expected every day due to fuel constraints and forced outages of power generation facilities, respectively. On average, about 4,200 MW have been shut down unplanned. Considering the total power generation capacity as of the end of FY2020, the unplanned outage rate was about 20%.

b. Adequate reserve capacity rate

In the Revisiting PSMP2016, the target of reserve capacity rate was set at 25% through 2025, and then gradually lowered to 12% for the period from 2036 to 2041. PP2041 follows this target value and plans to aim for a reserve capacity rate of 10% to 15% in 2050. However, in order to satisfy this target, it is necessary to greatly reduce the unplanned outage rate of power generation facilities. Considering the fact that many of power generation facilities are dependent on IPP and the vulnerability of the fuel supply system, it would be difficult to significantly reduce the unplanned outage rate even in 2050. Under the circumstance, the following are proposed as the target of the reserve capacity rate in formulating the In-Between.

In order to reduce the reserve capacity rate as above while simultaneously maintaining the LOLE value as targeted, it is necessary to reduce the demand forecast error and forced outages of generators. Viewing the current status in Bangladesh, there may be a room for significant improvement in reducing forced outages.

Table 5.2-3 Target of Reserve Capacity Rate

	2030	2040	2050
Reserve capacity rate	30%	25%	20%
LOLE target (hours/year)	24	24	24
Unplanned outage rate	12% or less	11% or less	10% or less

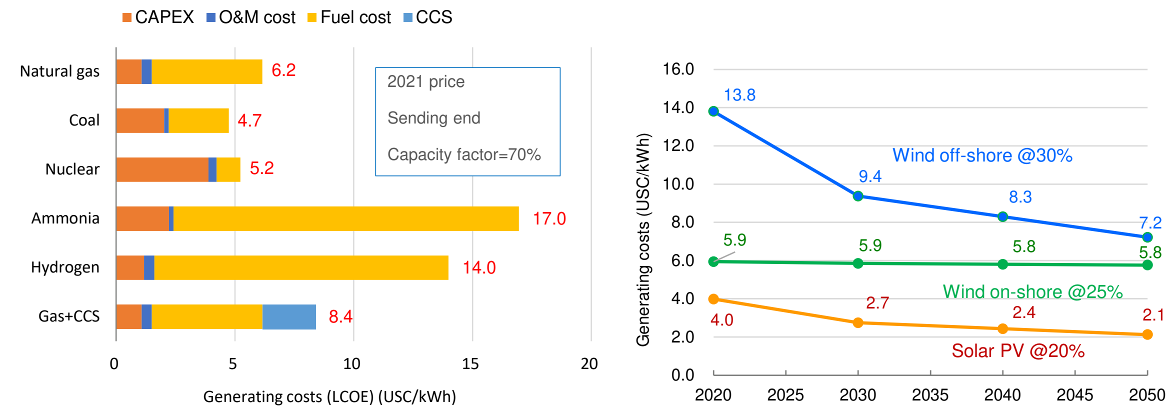
Source: IEPMP Study Team

To reduce the reserve capacity rate to 30% by 2030 and improve the LOLE value to 24 hours/year, calculation applying the 2020 data indicates that it is necessary to keep the forced outage rate to below 12% on average. It would be difficult to improve the forced outages caused by accidental failure of generators in a short period of time, but the overall goal may be achieved by eliminating forced outages due to fuel supply constraints. All power generation companies should strive to reduce forced outages and keep their rate below 12% on average by 2030.

5.3 Electricity Supply by Clean Energies

5.3.1 Cost comparison of power generation options

Generating costs of various power generation options are shown in Figure 5.3-1, where the generating costs of thermal power plants are calculated based on the projected crude oil prices in the future years. The generating costs of hydrogen-fired and ammonia-fired plants, as clean power source, are more than double those of the coal-fired and gas-fired plants. Comparing ammonia-fired and hydrogen-fired thermal power plants, hydrogen-fired plants have a higher thermal efficiency in power generation and lower fuel costs. If CCS is applied for gas-fired power plants, the cost will increase by US Cents 2.2/kWh.



Source: Prepared by the IEPMP Study Team from various materials (WEO2021: IEA etc.)

Figure 5.3-1 Generating costs of various power generation options

Among renewable energies, generating cost of solar power is the lowest, around US Cents 4.0/kWh in 2020, and is expected to decrease further in the future. That of offshore wind power generation in 2020 is very high at around US Cents 14.0/kWh, but is expected to decrease significantly in the future.

5.3.2 Renewable energy generation plan

Assumptions on renewable energy generation deployment are summarized in Table 5.3-1. which are considered in the power supply plan.

Table 5.3-1 Renewable energy generation deployment plan

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	By 2030: 49.6%	230	230	230

Source: IEPMP Study Team

Generation capacity that can meet the institutional and technical challenges is estimated for each power option, in particular after 2030. It is desirable to accelerate the efforts to address the challenges so that the capacity of renewable electricity generation will exceed these assumptions.

1) Solar PV

Amount of power generation by solar PV is estimated for the amount of large-scale solar PV plants

(Solar Park) and roof-mounted solar PV (Rooftop solar PV). They are expected to increase in Bangladesh in the future and are likely to account for a large proportion of the total solar PV installed in the country. On Solar Park, introduction plan up to 2030 is assessed by the IEPMP Study Team, and after 2030 Solar Park to be installed on the reclaimed river lands as mentioned in the Bangladesh Delta Plan are considered within a plausible extent.

Rooftop solar PV will be increasingly installed for self-consumption as well as selling electricity through the Net Metering System. It is considered as the easiest measures of introducing renewable energy in Bangladesh, as it is less susceptible to land issues and flooding risks.

2) Wind

For onshore wind power, a total of 5,000 MW is assumed to be installed on land along the Bay of Bengal, taking into account the wind resource availabilities in Bangladesh.

For offshore wind, it is assumed that 15,000 MW will be installed within the territorial waters offshore the Bay of Bengal by 2050. It is considered that there will be substantial challenges compared to other power sources described below.

3) Biomass (traditional biomass and waste-to-power)

For biomass power generation, it is assumed that waste-to-power generation plants and biogas power generation using manure in rural areas will be installed. Traditional biomass may also be considered as fuel for power generation where adequate conditions are prepared.

4) Hydropower

There is no plan to introduce any large-scale power plants through 2050.

5) Pumped storage power plant (PSPP)

In PSMP2016, nine PSPP candidate sites (installed capacity of each site is 500MW) were proposed in the Chattogram Hilly Area. Among them, No.17 site located in Thanchi Upazila, Bandarban District is considered as the most promising site.

PSPP is a power source that does not generate power by itself. It has the same function as a storage battery, and serves as a peak supply capacity for areas with low annual load factors. For this reason, low fixed costs are a condition. In general, it is desirable that the unit construction cost be USD 1,000/kW or less. A rough estimation of the unit construction cost for No.17 PSPP site is USD 1,200/kW or more, which is slightly higher than the standard unit cost that is generally thought to be economical.

However, the installed capacity could be increased to 900MW, while PSPP can provide a high speed and wide range of frequency control capacity. It is desirable to conduct a feasibility study for this site, including an economic evaluation of the frequency control function.

5.3.3 Nuclear

In Bangladesh, construction of the Rooppur Nuclear Power Plant (1,200 MW x 2 units) located 140 km west of Dhaka is underway, and is scheduled to start operation in 2025. The nuclear power development plan up to 2050 is shown below.

Table 5.3-2 Nuclear Development Plan

	2030	2041	2050
PP2041	2,400MW	4,800MW	7,200MW
In-Between	2,400MW	4,800MW	4,800MW

Source: IEPMP Study Team

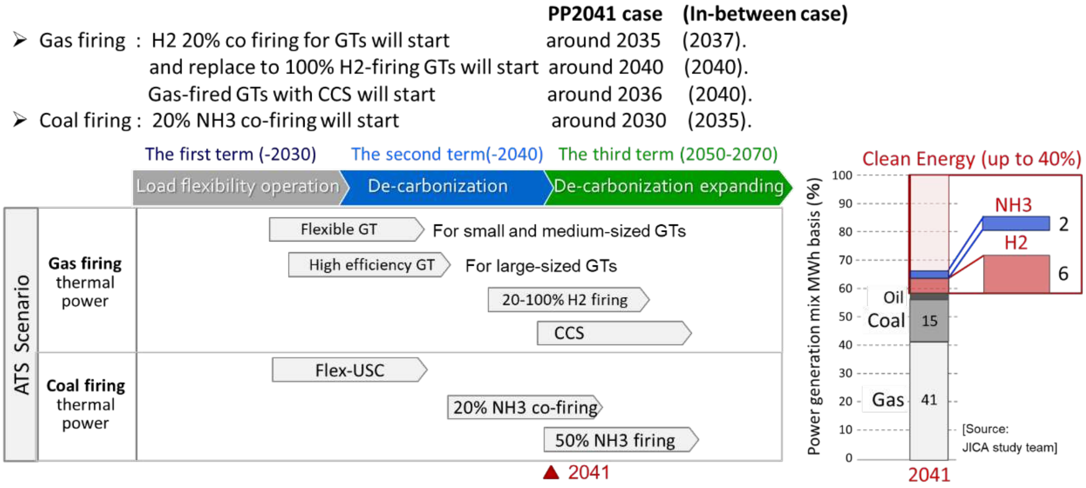
The Rooppur Nuclear Power Plant has a room for an additional 1,200MW x 2 units (total 4 units), but the next candidate site has not yet been decided. For this reason, if it becomes necessary to develop the fifth and subsequent units, a candidate site for a new location where a large-capacity unit such as Rooppur can be installed will be selected and a large-capacity unit will be built. If a promising candidate site cannot be found, one option is to install small capacity reactors (SMR: Small Modular Reactor) for the required capacity. However, SMR is still in the developmental stage, and it is desirable to select the introduction of SMR after fully confirming its safety and economic efficiency based on development trends and operating results of commercial SMRs around the world.

5.3.4 Thermal power generation systems contributing to clean energy

Figure 5.3-2 shows timeline for introduction of hydrogen (H_2) and ammonia (NH_3) co-firing in gas- and coal-fired thermal power systems.

The graph on the right shows the ratio of electricity generation in Bangladesh as of 2041, and the goal is to have up to 40% of electricity generated from clean energy sources. To achieve this goal, it will be necessary to introduce H_2 at 6% and NH_3 at 2%.

The left side of the chart shows the timing of the introduction of H_2 and NH_3 in gas- and coal-fired thermal power systems. Although it will be necessary to consider specific plants for application in the future, it will probably be necessary to apply gas-fired power plants with 20% hydrogen co-firing starting in 2037 and upgraded to 50% in 2045, gas-fired power plants with 100% hydrogen firing starting in 2040, and coal-fired power plants with 20% NH_3 co-firing starting in 2035 and upgraded to 50% in 2040. After 2037, introduction of CCS should also be considered to further reduce CO_2 emissions.



Source: IEPMP Study Team

Figure 5.3-2 Proposals for introducing H_2 co-firing and NH_3 co-firing

In order to achieve the clean energy goal, thermal power generation systems will be introducing H_2 and NH_3, which are known as clean energy fuels. In doing so, it is necessary to solve the problem of how to introduce H_2 and NH_3, which have higher fuel costs than natural gas and coal.

Table 5.3-3 shows the planned introduction of various thermal power generation systems (as of 2041). It shows the planned installation of large GTCC (gas turbine combined cycle), medium and small simple cycle GT (gas turbine), gas and oil fueled engines, and coal-fired USC (ultra-supercritical pressure thermal power plants), as well as the number of plants that use H_2 and NH_3.

Table 5.3-3 Introduction Plan of thermal power generation systems (as of 2041).

[The case for up to 40% clean energy]

Model	Gas ratio	H2 ratio	Coal ratio	NH3 ratio	Efficiency	Capacity/unit	Generation costs/unit	Number	Total capacity		Average generation costs	
	%	%	%	%	%	MW	US¢		MW		US¢	
Gas GTCC	100	0	-	-	61	840	6.2	38	31,920	36,960	7.3	6.9
	50	0	-	-	61	840	6.2	0	0			
	0	50	-	-	61	840	13.9	0	0			
	0	100	-	-	61	840	13.9	6	5,040			
USC	-	-	100	0	41	600	4.7	14	8,400	10,800	5.5	
	-	-	50	0	41	600	4.7	4	1,200			
	-	-	0	50	41	600	16.7	4	1,200			
	-	-	0	100	41	600	16.7	0	0			

[The case of only gas and coal without H2 &NH3]

Model	Gas ratio	H2 ratio	Coal ratio	NH3 ratio	Efficiency	Capacity/unit	Generation costs/unit	Number	Total capacity		Average generation costs	
	%	%	%	%	%	MW	US¢		MW		US¢	
Gas GTCC	100	0	-	-	61	840	6.2	44	36,960	36,960	6.2	5.8
	50	0	-	-	61	840	10.1		0			
	0	50	-	-	61	840	10.1		0			
	0	100	-	-	61	840	13.9		0			
USC	-	-	100	0	41	600	4.7	18	10,800	10,800	4.7	
	-	-	50	0	41	600	10.7		0			
	-	-	0	50	41	600	10.7		0			
	-	-	0	100	41	600	16.7	0	0			

Source: IEPMP Study Team

The balance of these thermal power generation systems is determined by prioritizing the generation efficiency of each thermal power generation system.

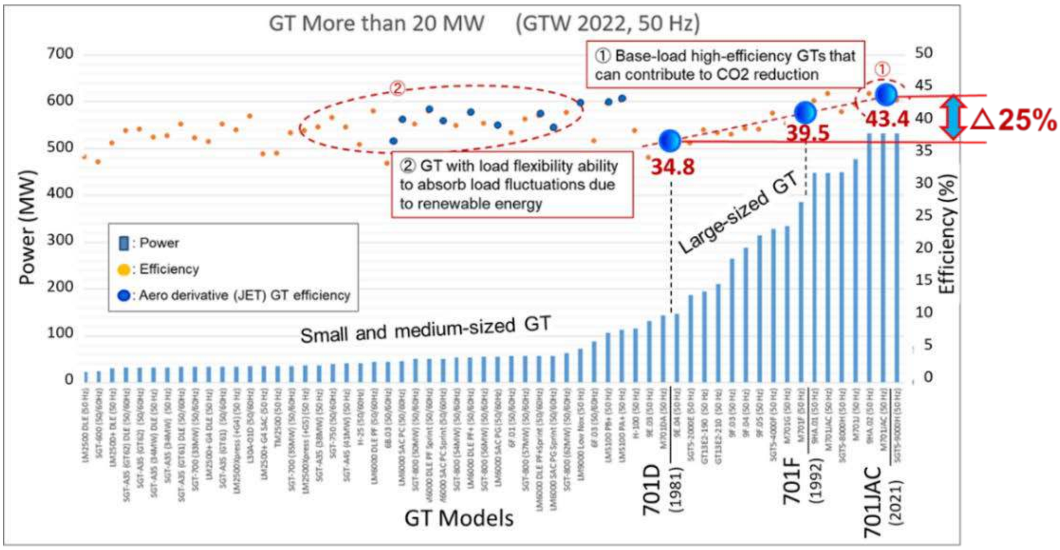
As a result, as of 2041, 6 units of GTCCs with 100% H_2 will be installed, while 4 units of coal-fired USCs with 50% NH_3 co-firing will be introduced.

The left chart shows the generation costs when H_2 is installed in GT and NH_3 is installed in coal-fired USCC, and the right chart shows the generation costs when H_2 and NH_3 are not installed. The generation cost will be US¢6.9/kWh and US¢5.8/kWh, respectively; the cost increase by adopting these fuels will be US¢1.1/kWh.

5.3.5 Gas Turbine (GT)

a. Trend of Gas Turbine (GT)

As shown in Figure 5.3-3 ①, the efficiency of large GTs has improved by about 25% over the past 20 years, reducing fuel costs and power generation costs by 25%. (e.g., Model 701D: 34.8% in 1981 701JAC: 43.4% in 2021). In addition, as shown in ②, small- and medium-sized simple-cycle GTs can play an important role as a load flexibility capability with high load changing rates. Thus, when moving toward a future target of up to 40% clean energy, load flexibility capability will play an important role in contributing to higher efficiency of gas turbines and stabilization of the power system.



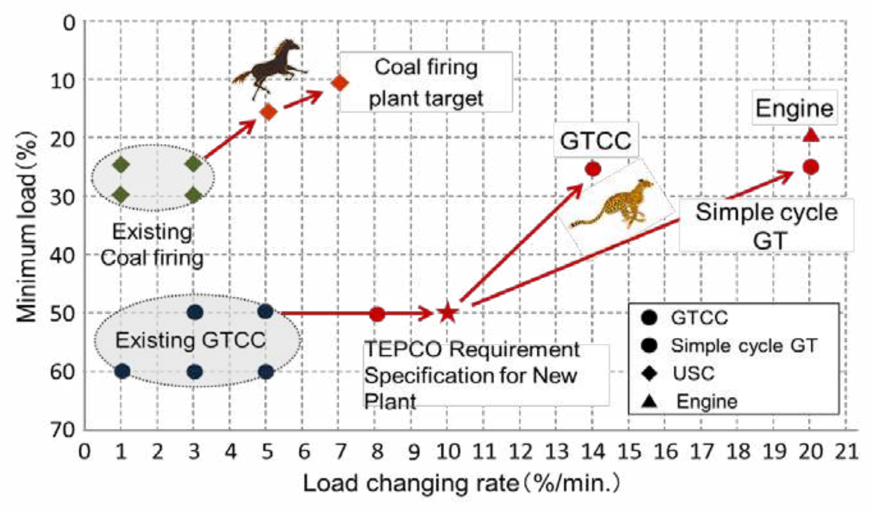
Source: IEPMP Study Team

Figure 5.3-3 Trend of gas turbine (GT).

b. Gas turbine with load flexibility function

Figure5.3-4 shows thermal power systems that can adapt to the era of RE expansion. The horizontal axis shows the load changing rate and the vertical axis shows the minimum load.

- USC: In existing USC, minimum load is around 30% and load changing rate is around 1%/min. The minimum load for latest USC is 15%, and the load changing rate is expected to be 5%/min.
- GTCC: Of the existing GTCC, minimum load is around 50% and load changing rate is around 8%/min. The minimum load for the future GTCC will be 25%, and the load changing rate 14%/min.
- Simple cycle GT: The load changing rate is expected to be 20%/min.
- Engine: The load changing rate is expected to be 20%/min. The minimum load is 20%.

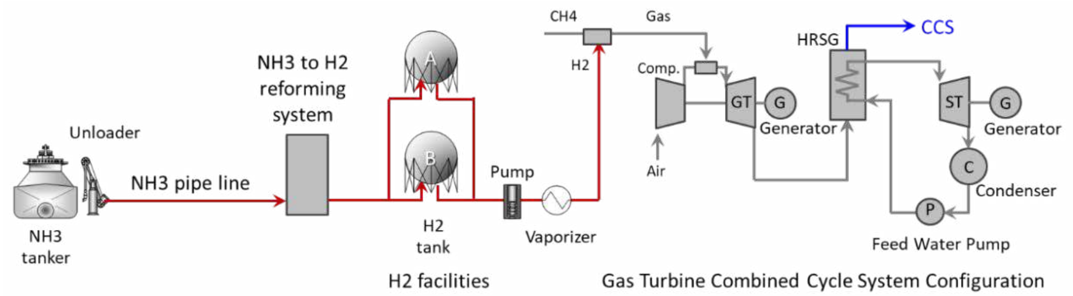


Source: IEPMP Study Team

Figure 5.3-4 Thermal power systems that can adapt to the RE expanding era

c. Gas turbine that can contribute to CO_2 reduction through H_2 co-firing

H_2 co-firing is possible in gas turbines using natural gas (CH_4) as the main fuel. Major gas turbine manufacturers around the world are working hard to develop H_2 combustion, and by 2030, commercial operation of large GTCCs will be possible. Demonstration tests have already been completed for small gas turbines, which are being developed ahead of other gas turbines, and they can be introduced around 2025.



Source: IEPMP Study Team

Figure 5.3-5 Diagram of the H_2 co-firing GTCC power generation system

Figure 5.3-5 shows a diagram of the H_2 co-firing GTCC power generation system.

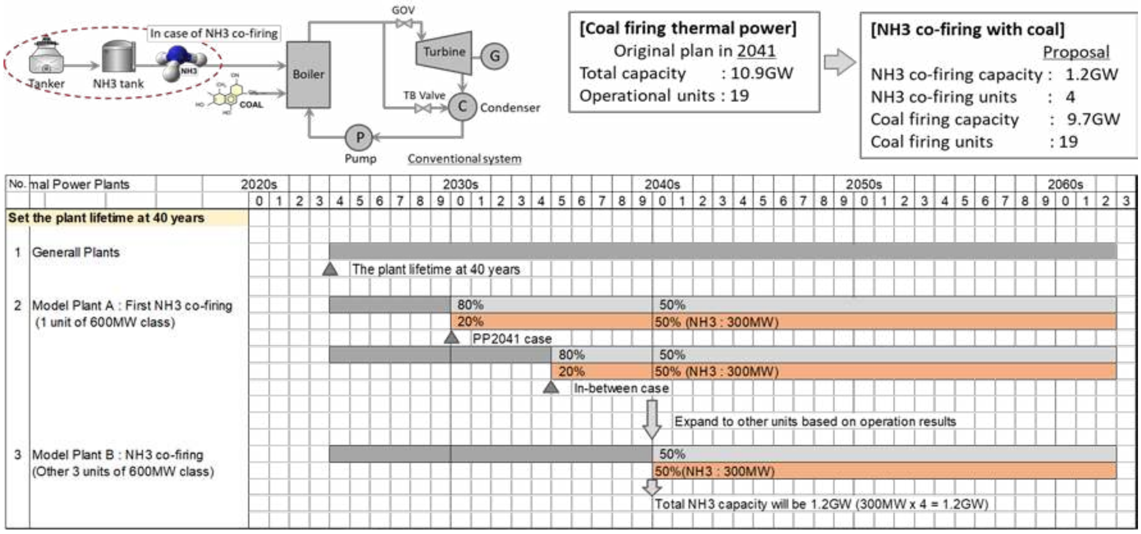
- Facilities shown in gray lines are GTCC systems fueled by natural gas.
- The red lines are facilities for H_2 co-firing. Liquefied NH_3 is imported from overseas because it is easy to transport. Liquefied NH_3 is transported to the power plant via pipeline. The NH_3 is then reformed to H_2 in the power plant and supplied as fuel for the gas turbine. (Future plan)
- The blue line is a facility to recover CO2 from the exhaust gas after the gas turbine has finished its work. The CO_2 captured here will be used in CCS (CO_2 Capture & Storage) to further reduce CO_2 emissions. (Future plan)

Thus, the GTCC system can be used as a large-capacity stable power source of a high-efficiency power generation system using gas fuel from the time of commissioning. After that, the system can contribute to CO_2 reduction by H_2 combustion, one of the clean energy sources, according to the needs of the times. In times when further CO_2 reduction is required, CCS can be introduced to achieve zero emissions.

5.3.6 NH_3 co-firing with coal

The global environment surrounding coal-fired power generation is becoming more and more challenging every year. Even thermal power generation systems will be required to contribute to CO_2 reduction in the future. In response to this, the IEPMP Study Team proposed the following targets for 2041.

"10.9GW of coal-fired power plants are expected to be in operation, of which 40% will be clean energy."



Source: IEPMP Study Team

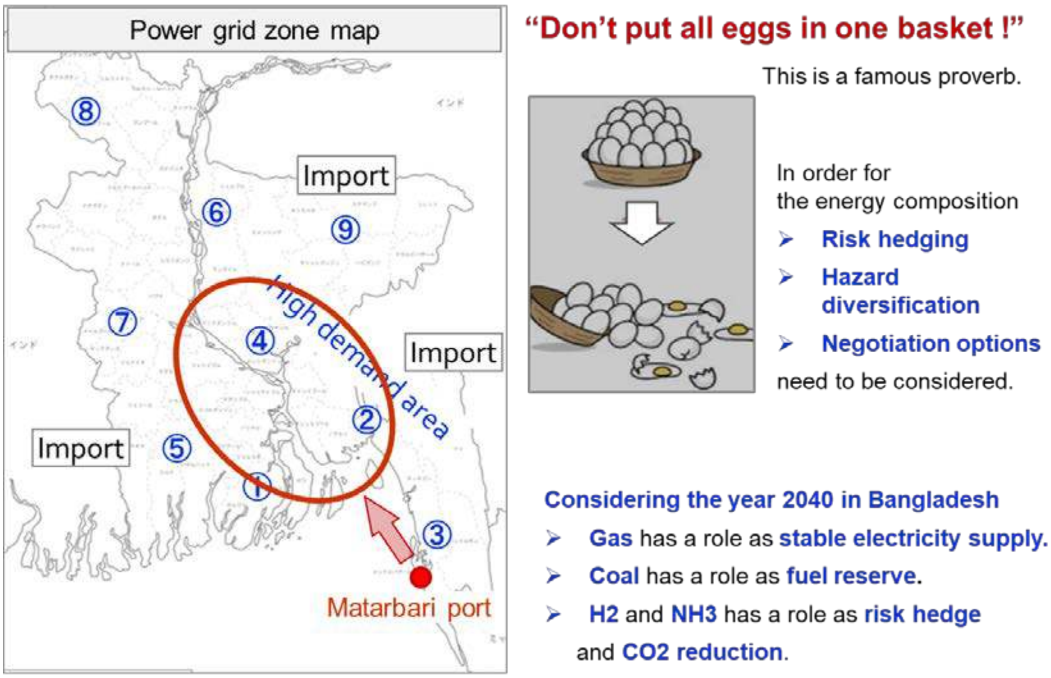
Figure 5.3-6 Timeline for introduction of NH_3 co-firing in coal-fired power plants.

In consideration of the above-mentioned circumstance, timeline for introduction of NH_3 co-firing at coal-fired power plants is shown in Figure 5.3-6.

- The IEPMP Study Team has recommended the life cycle of a coal-fired power plant as 40 years.
- NH_3 combustion will be introduced in coal-fired power plants to reduce CO_2 emissions. The first unit is targeted for 2030 (PP2041 case) or 2035 (in-between case).
- Eventually, the introduction of about six NH_3 co-firing units in a 600 MW class coal-fired power plant would contribute to achieving the up to 40% clean energy target.

5.3.7 Key words for achieving up to 40% clean energy in power generation

Figure 5.3-7 illustrates issues on electricity supply security. Given the geographical conditions of Bangladesh, future fuel procurement is likely to be concentrated in the Matarbari port. Under this backdrop, it is necessary to consider a power supply structure with a variety of fuels and fuel reserves to avoid security risks as much as possible. In this regard, it is important to work on a multi-fuel approach, including H_2 and NH_3



Source: IEPMP Study Team

Figure 5.3-7 Energy security considerations

To this end, it is important to consider the role of the innovative thermal power as follows:

a. Highly efficient GT

Highly efficient GTs have reduced generation costs and CO_2 emissions by 25% over the past 20 years. Furthermore, application of H_2-mixed combustion GT can contribute to the achievement of up to 40% clean energy in the power mix in 2041.

b. Energy Security

When considering the mix of thermal power supply, it is necessary to consider "risk hedging," "hazard diversification," and "negotiation options" for fuel procurement.

c. H_2 for GT, NH_3 for coal-fired power

The increase in the overall power generation cost by introducing H_2 to GT and NH_3 to coal-fired power plant is only US ₵ 1/kWh.

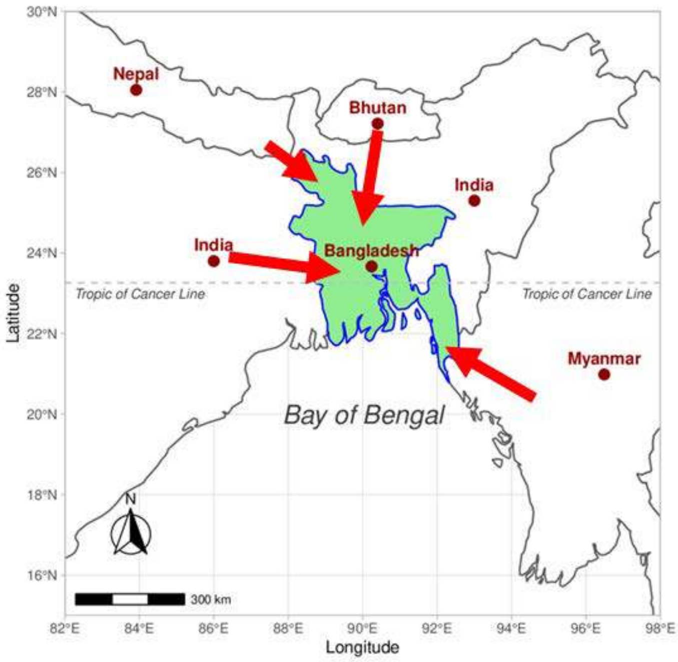
d. Establishment of a mechanism to prioritize the operation of H_2 and NH_3

In order to achieve the target for 2041, it is necessary to establish a mechanism to prioritize the operation of power generation systems that use H_2 and NH_3.

5.3.8 Electricity import

Bhutan, Nepal and the northeastern states of India have abundant hydropower potential. The purchase price of these electricity is assumed to be cheaper than other options that contribute to low carbonization. In order to realize power imports from such countries and regions, it is important to discuss with the transit country as well as the importing partner country.

Bangladesh shares a border with Myanmar. Myanmar also has abundant hydropower potential and is expected to be a power source that contributes to low carbonization. However, there are many thermal power plants planned around the area bordering Myanmar, and it is necessary to consider how to transmit the generated power to the Dhaka area, which is the demand center.



Source: PGCB

Figure 5.3-8 Cross border power trade with Neighboring countries

In importing power from other countries, risk of supply interruption caused by adverse relationships with them must be considered. Electric power, unlike other types of commodity, is technically easy to shut down which could be done even in minutes. Therefore, it is necessary to avoid excessive reliance on other countries in order not to place oneself in a serious situation. Specifically, the capacity of imported power from one country should be within the limit of generating reserve capacity and also 10% of all supply capacity in order to continue the supply in the event of supply interruption. In the case of Bangladesh, imported power from Bhutan and Nepal must be transmitted through India. Therefore, power imports from the neighboring countries should be kept within 10% of the whole supply capacity.

In general, demand equivalent to the peak load, defined as 95% or more of the maximum load, occurs for approximately 100 hours on 25 days a year, assuming 4 hours of daily peak hours. Since the system would tolerate 5% of the load shedding only during such limited peak hours, it is considered that power import through the Indian grid may be increased to 15% of the total supply capacity in Bangladesh.

The import volume at one interconnection point is determined by the amount of frequency fluctuation at the time of dropout. In a general grid, the frequency fluctuation at the time of dropout is less than 1 Hz up to about 10% of the demand, and it is possible to restore the standard frequency in a short time without collapsing the grid. In 2050, the maximum power demand is expected to be 70.5GW (In-Between) and the minimum demand is expected to be around 30GW. Therefore, if the primary reserve can be properly secured, up to about 3GW of imports can be allowed at one interconnection point.

In addition, in Bangladesh, demand is low in winter, and it is assumed that there will be excess capacity in supply capacity. On the other hand, in Nepal, Bhutan, and the northeastern states of India, where hydropower is the main source of power supply, winter is the dry season, and hydropower supply capacity drops dramatically, raising concerns about a shortage of supply capacity. If fuel shortages are resolved in the future, it is expected that electricity imports from neighboring countries will be curbed during the winter season, and if there is a surplus, electricity will be exported to these countries.

5.4 Power Source Development Plan

5.4.1 Power development plan (PP2041)

a. Overview of power development plan

The total capacity of existing power plants in operation (listed as "Existing" in the table 5.4-1 below) is 21.5GW in 2021, which will decrease to 6.7GW in 2041 due to the regular retirement of these power plants. After that, the capacity will gradually decrease, and by 2050, almost all power plants operating today will be retired.

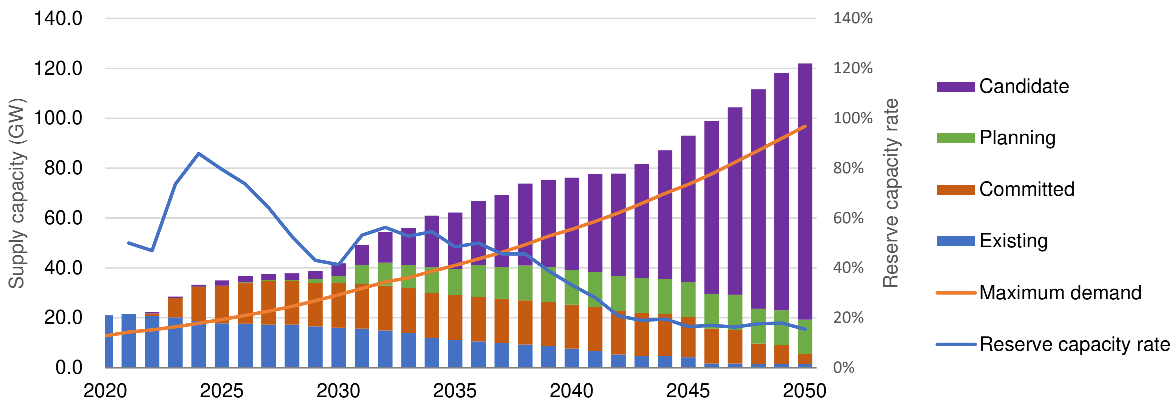
Table 5.4-1 Overview of Power Development Plan: PP2041

(Unit: GW)

	2021	2030	2041	2050	'21 - '30	'31 - '41	'42 - '50
Existing	21.5	16.0	6.7	1.4	-5.5	-9.4	-5.3
Committed	0.0	18.0	17.7	4.0	18.0	-0.3	-13.7
Planning	0.0	2.8	14.0	13.9	2.8	11.2	-0.1
Candidate	0.0	5.0	39.2	102.7	5.0	34.2	63.5
Supply Total	21.5	41.8	77.6	122.0	20.4	35.8	44.4
Maximum Demand	14.3	29.3	58.6	96.8	15.0	29.3	38.2
Reserve capacity	7.1	12.1	16.5	14.9	5.0	4.4	-1.5
Reserve capacity rate	50%	41%	28%	15%			

Source: IEPMP Study Team

Therefore, in order to fill the gap between the steadily increasing electricity demand year by year and the ever-decreasing capacity of existing power sources, it is necessary to steadily develop new power sources. As for new power sources, the so-called "Committed" power sources, which are under construction or have reached the stage of power purchase agreements, alone are insufficient, so it is also necessary to consider potential power sources ("Planning", "Candidate") as an additional supply capacity. An overview of the power development plan in PP2041 is shown below.

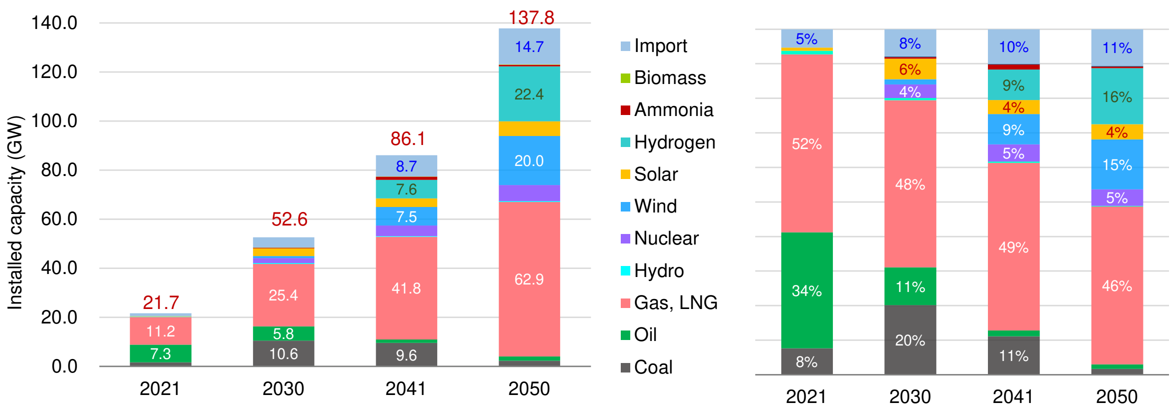


Source: IEPMP Study Team

Figure 5.4-1 Overview of the power development plan: PP2041

In the 2020s, there are many "Committed" power sources, so the reserve capacity rate exceeds 60%. During the 2030s, the reserve capacity rate will remain at around 50% due to restraints on the development of candidate power sources ("Planning", "Candidate") for additional supply capacity. After 2040, most of the new developments are "Candidates" whose locations are yet to be specified. By adjusting with the amount of new development, the reserve capacity rate will be reduced to the target value of about 15%.

The composition of the installed capacity according to this plan is shown below.



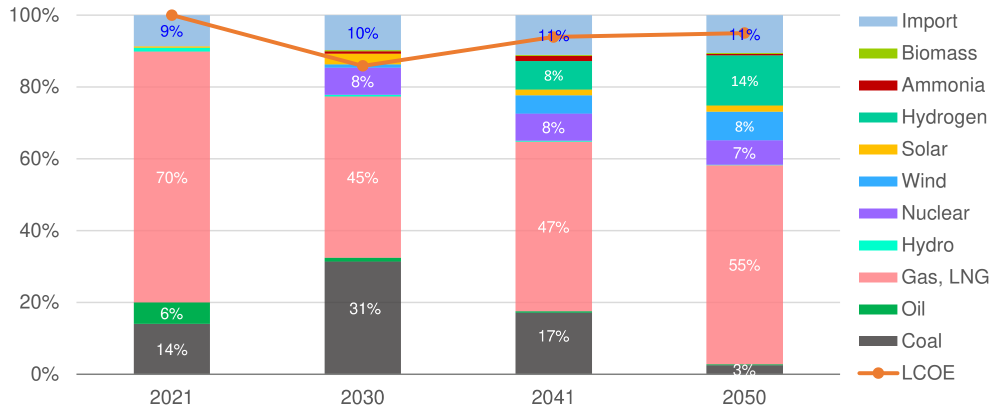
Source: IEPMP Study Team

Figure 5.4-2 Composition of the installed capacity: PP2041

Gas-fired thermal power accounts for the majority of the power source composition, and always has a share of more than 1/3. Oil-fired thermal power, which currently accounts for 34% of the total, will gradually decline due to retirement, and will be around 1% in 2050. Coal-fired thermal power currently accounts for 8%, and will increase to 20% in 2030, but will drop to 2% in 2050 with gradual retirement. Towards 2050, the ratio of wind power and hydrogen-fired thermal power will increase, and the composition ratio in 2050 will be 17% and 19%, respectively.

b. Supply cost

Supply cost and the composition ratio of generated power is shown below. The supply cost is an indexed value with the current (2021) figure set at 100.



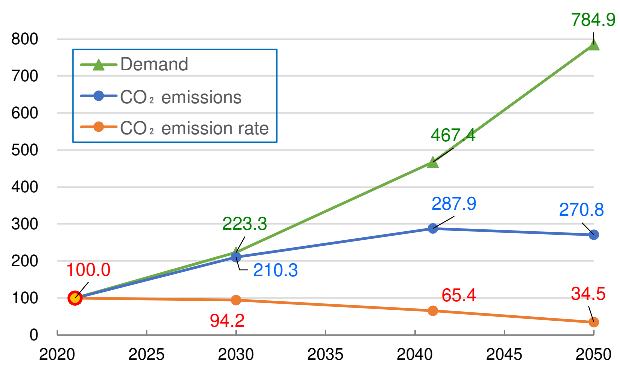
Source: IEPMP Study Team

Figure 5.4-3 Supply cost and the composition ratio (PP2041)

The supply cost will drop to around 80 points in 2030 and then rise, but will remain below the current level. At present, the composition of gas-fired power plants with high fuel cost is high. But in 2030, it will decrease sharply, and instead, the composition of coal-fired power plants with lower fuel cost will increase. As a result, the supply cost in 2030 will drop by about 20 percentage points from the current level. Towards 2050, the composition of coal-fired power with lower fuel cost will decrease, while that of hydrogen-fired power and gas-fired power with CCS, which have high generating costs, will increase. However, most of the gas-fired power plants that will be newly developed after 2030 will be the latest combined-cycle models with significantly higher thermal efficiency than the power plants currently in operation. Therefore, even after 2040, supply costs will remain at a slightly lower level than at present.

c. CO_2 emissions

Changes in CO_2 emissions in the power sector are shown in Figure 5.4-4. All data are indexed with the present (2021) as 100. CO_2 emission rate will gradually decrease due to the increase in renewable energy and hydrogen-fired thermal power, which do not emit CO_2 at all, and it will drop to less than half of the current level in 2050. However, electricity demand will increase about 8 times from the current level, so CO_2 emissions will increase about 2.5 times from the current level.

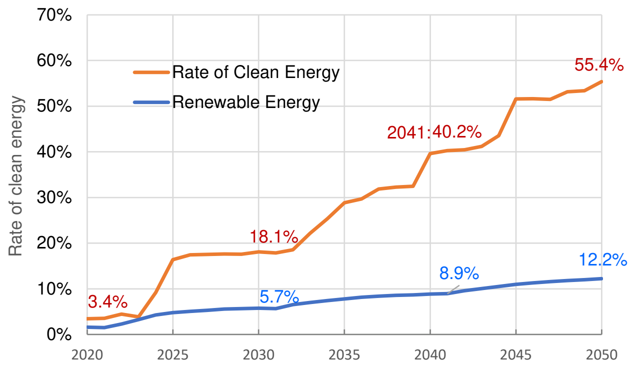


Source: Study Team

Figure 5.4-4 Changes in CO_2 emissions in the power sector (PP2041)

Changes in the clean energy ratio are shown in Figure 5.4-5. The "Clean energy" refers to a power source that does not emit CO_2 at all, including renewable energy (solar, wind, hydropower), nuclear power, ammonia-fired, and hydrogen-fired thermal power.

Currently, it is very small at about 4%, but it will gradually increase with the development of clean power sources. It will achieve 40% or more in 2041, the target year, and will gradually increase thereafter, reaching about 55% in 2050.



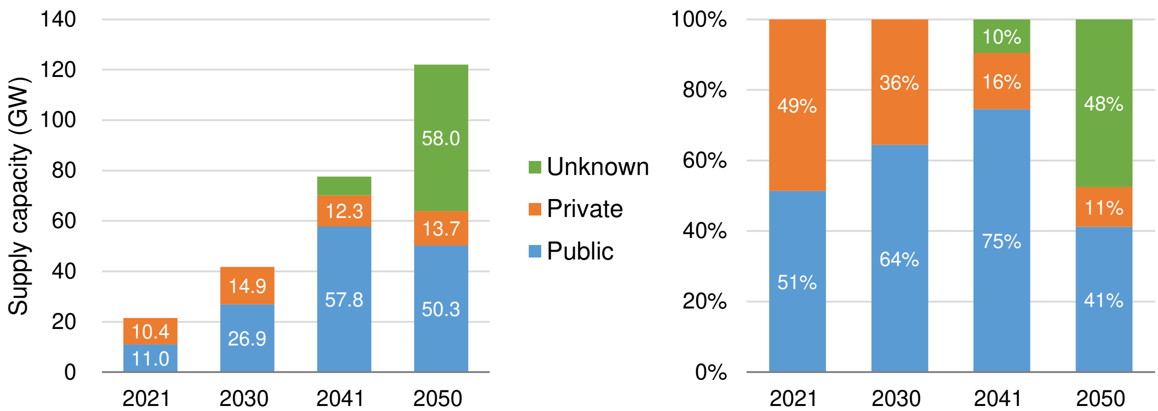
Source: Study Team

Figure 5.4-5 Changes in the clean energy ratio (PP2041)

d. Public-Private Ratio of Power Development

In general, the ratio of public and private sectors in power generation capacity is set by the government and/or its regulatory bodies from the following three perspectives, i.e., ensuring healthy competition in terms of price and efficiency, maintaining supply-demand balance and stable supply, and ensuring the national energy security.

The ratio of installed capacity in the public and private sectors is currently about 50% and about the same. Until around 2040, the power generation facilities of government-affiliated power generation companies other than BPDB, which belong to the public sector, will increase, and in 2041, the ratio of public sector will exceed 70%. After that, the development of power plants for which the business entity has not been decided will increase. However, even if all these developments are entrusted to the private sector, it is possible to secure a public sector ratio of around 40% in 2050.

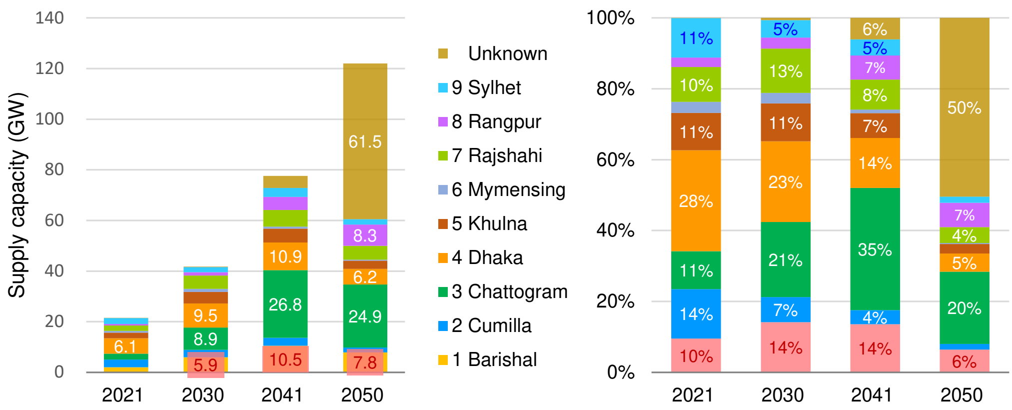


Source: IEPMP Study Team

Figure 5.4-6 Ratio of installed capacity (Sector wise: PP2041)

e. Location of power plants

The breakdown of supply capacity in each region is shown below.



Source: IEPMP Study Team

Figure 5.4-7 Breakdown of supply capacity in each region (PP2041)

Currently, the ratio is high in the Dhaka, Cumilla, and Sylhet regions, which are close to domestic gas production areas. However, in the future, the ratio of Barishal and Chattogram regions will increase, as they are located in the coastal areas with advantages in supply of imported fuels.

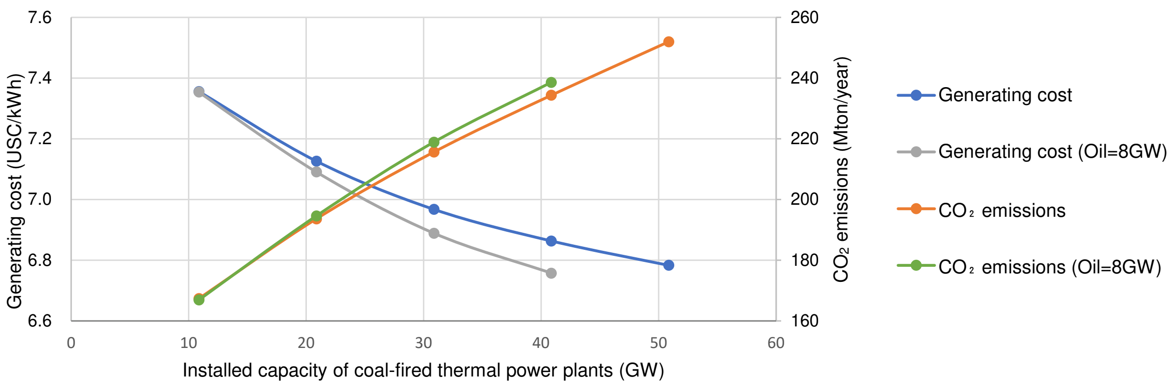
After 2035, the number of power plants whose locations are yet to be determined will increase, reaching 61 GW (50% of the total) in 2050. These power plants need to be decided from the viewpoints of the supply and demand balance in each region, the availability of fuel, and the cooperation with construction of transmission and transformation facilities (especially the backbone system).

5.4.2 Power development plan (In-Between)

a. Power source mix in 2050

Maximum power demand at In-Between in 2050 is 70.5GW, and in order to secure 20% of reserve capacity, supply capacity of about 84.6GW is required. The installed capacity includes renewable energy (26.2GW) such as solar and wind power, which can hardly be expected to supply power during the evening peak hours, bringing the total installed capacity to 110.8GW. Of this, 45.5GW (41%) will be imported electricity, hydropower, nuclear power, and renewable energy, and the remaining 65.3GW will be covered by thermal power.

Then, an analysis is conducted to find out an effective combination of fuel sources among thermal powers. Since ammonia and hydrogen are known to be expensive, they are excluded from this analysis, and the three-element combinations of coal-fired, gas-fired, and oil-fired power are examined. Figure 5.4-8 shows changes in power generating cost and CO_2 emissions when the installed capacity of oil-fired power is fixed at 0GW and 8GW and the ratios of coal-fired power and gas-fired power are changed.

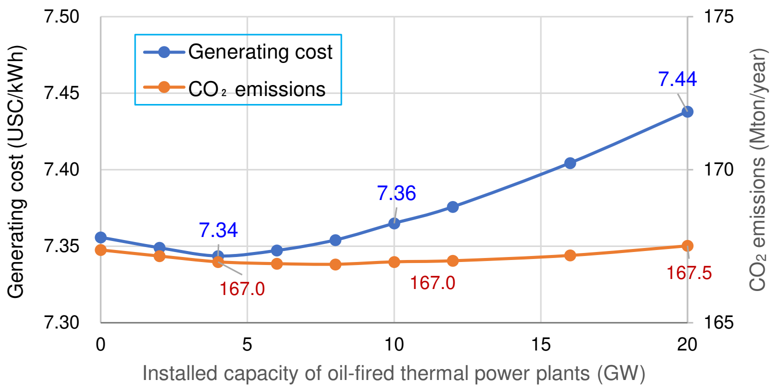


Source: IEPMP Study Team

Figure 5.4-8 Relationship between coal-fired power plant capacity and power generating cost

When the amount of coal-fired power increases, power generating cost gradually declines, while CO_2 emissions gradually increase. If the installed capacity of oil-fired power were 8GW, the power generating cost will be slightly lower compared with the case with no oil-fired power plants. There is almost no difference in CO_2 emissions depending on the installed capacity of oil-fired power plants.

Figure 5.4-9 shows the case when the installed capacity of coal-fired power is fixed at around 10GW and composition ratios of oil-fired and gas-fired power are changed.



Source: Study Team

Figure 5.4-9 Oil-fired power plant capacity and power generating cost

In the range where the installed capacity of oil-fired power is up to about 10GW, power generating cost decreases slightly. Oil-fired power has high fuel costs, but fixed costs are lower than gas-fired power. Thus, it has an advantage in areas where the operating rate is extremely low and plant is used as a peak supply capacity. It is economical to develop oil-fired power up to 6GW or about 5% of the total capacity. However, there is no significant difference within the range of 2GW to 8GW.

Based on these results, a comparative evaluation is conducted for two scenarios as explained below in order to optimize the power mix in 2050.

Table 5.4-2 Composition ratio of each scenario

	Least cost		Fuel diversification	
	kW	kWh	kW	kWh
Gas/LNG	34%	32%	27%	30%
Coal	20%	32%	10%	17%
Import	12%	14%	14%	16%
Nuclear	4%	7%	4%	7%
Liquid Fuel	6%	0.8%	6%	0.8%
Hydro	1%	0.2%	1%	0.2%
Hydrogen	0%	0%	10%	10%
Ammonia	0%	0%	5%	5%
RE	23%	14%	23%	14%
Total	100%		100%	

Source: IEPMP Study Team

The results of the scenario comparison are shown below.

Table 5.4-3 Results of scenario comparison

	Least cost	Fuel source diversification
Generating cost	USC 7.1/kWh	USC 8.3/kWh
CO_2 emissions per year	198 Mton	96 Mton
Clean energy ratio	33.8%	66.2%
Continuously suppliable days	39.5 days	32.4 days

Note: Continuously suppliable days are the number of days that only stockpiled fuel can supply when the use of import port is unavailable (assuming 80% of the storage capacity remains).

Source: IEPMP Study Team

In the "Least cost" scenario, power generating cost is significantly lower than "Fuel source diversification" scenario. However, even in 2050, the clean energy ratio is 33.8%; far below the target value of 40% in 2041. In addition, CO_2 emissions are more than double that of the "Fuel source diversification" scenario, and it cannot be adopted from an environmental point of view.

The "Fuel source diversification" scenario is inferior to the "Least cost" scenario in terms of power generating cost. However, because of the diversification of fuel sources, the plan is well-balanced in terms of cost, environment and energy security.

In view of the above analysis, it is considred efficient to aim for the composition ratio of the "Fuel source diversification" scenario in 2050, which is the optimal power source composition, when formulating the power development plan up to 2050.

The basic concept for formulating a power source development plan is shown below:

a. The "Fuel Diversification" scenario is the optimized scenario for the power development planning. So, the fuel composition ratio indicated in the "Fuel Diversification" scenario will be achieved in 2050.

b. The power generation projects that are under construction and/or in the public tendering stage have been considered as the "Committed" power plants.

c. Renewable energies are considered to be developed as much as possible based on the potential and development schedule.

d. On introduction of ammonia/hydrogen-fired power generation and CCS, the following amount and timing are considered in view of the technology progress expected at present.
   - 20% ammonia co-firing in coal-fired power plants: from 2035 onwards
   - 20% hydrogen co-firing in gas-fired power plants: from 2037 onwards
   - Hydrogen-fired power plants: from 2040 onwards
   - CCS in gas-fired power plants: from 2040 onwards

e. Requirement for new capacity ("Candidate" and "Planned") has been calculated to meet the target of reserve capacity rate shown in Table 5.2-3.

The power development plan formulated based on the above is discussed below.

b. Overview of the power development plan

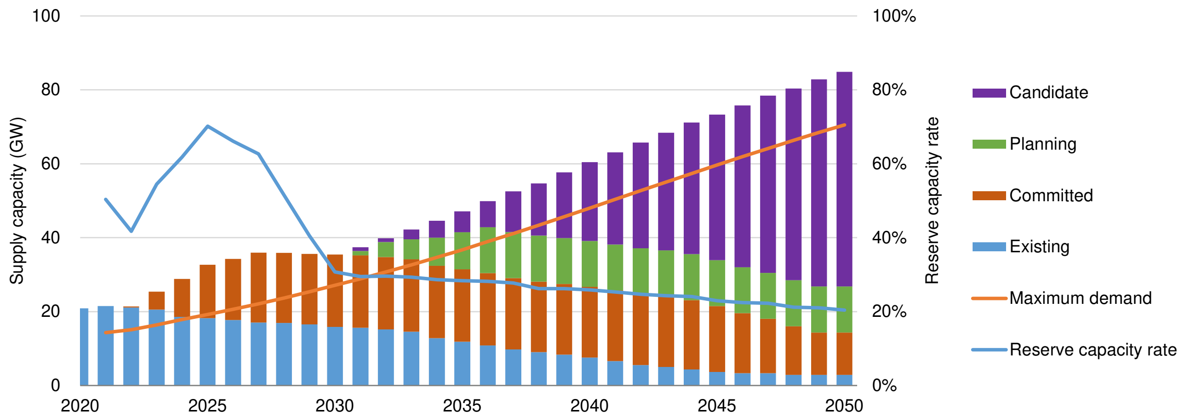
The total capacity of existing power plants in operation ("Existing") is 21.5GW in 2021, which will decrease to 6.6GW in 2041 and 2.9GW in 2050 due to the regular retirement of these power plants.

Therefore, in order to fill the gap between the steadily increasing electricity demand year by year and the decreasing capacity of existing power sources, it is necessary to steadily develop new power sources. As for new power sources, so-called "Committed" power sources, which are under construction or tendering stage, alone are insufficient, so it is also necessary to consider potential power sources ("Planning", "Candidate") as additional supply capacity. An overview of the power development plan in In-Between is shown below.

Table 5.4-4 Overview of Power Development Plan: In-Between

(Unit: GW)

	2021	2030	2041	2050	'21 - '30	'31 - '41	'42 - '50
Existing	21.5	15.8	6.6	2.9	-5.7	-9.2	-3.7
Committed	0.0	19.6	19.1	11.5	19.6	-0.5	-7.6
Planning	0.0	0.0	12.5	12.5	0.0	12.5	0.0
Candidate	0.0	0.0	25.0	58.1	0.0	25.0	33.2
Supply Total	21.5	35.4	63.1	84.9	13.9	27.7	21.8
Maximum Demand	14.3	27.1	50.4	70.5	12.8	23.3	20.1
Reserve capacity	7.2	8.3	12.8	14.4	1.1	4.4	1.6
Reserve capacity rate	50%	31%	25%	20%			

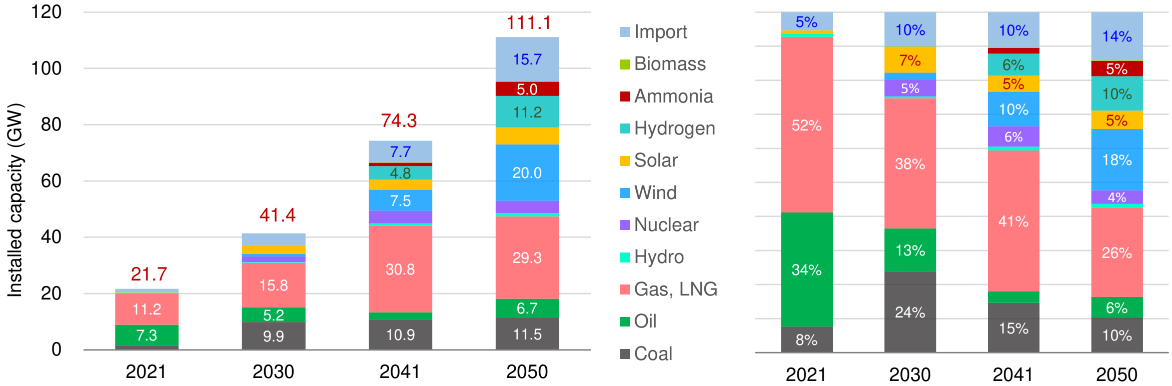


Source: IEPMP Study Team

Figure 5.4-10 Overview of the power development plan (In-Between)

In the 2020s, there are many "Committed" power sources, so the reserve capacity rate exceeds 60%, which greatly exceeds the target value shown in Table 5.4-2. In the 2030s, the reserve capacity rate will remain at around 30% due to restraints on the development of candidate power sources ("Planning", "Candidate") for additional supply capacity. After 2040, most of the new developments are "Candidates" whose locations are yet to be specified, and by adjusting the amount of new development, the reserve capacity rate will be reduced to the target value of about 20%.

The composition of the installed capacity according to this plan is shown in figure 5.4-11 below. Gas-fired thermal power accounts for the majority of the power source mix, and has a share of 40% or more up to 2041. Oil-fired thermal power, which currently accounts for 34% of the total, will gradually decline due to retirement, but with a certain amount of new development, it will be about 6% in 2050. Coal-fired thermal power currently accounts for 8%, and will increase to 24% in 2030. But there is almost no additional capacity to be developed after that, and the ratio will gradually decline to 10% in 2050. Towards 2050, the ratio of wind power and hydrogen-fired thermal power will increase, and the composition ratio in 2050 will be 18% and 10%, respectively.



Note: In 2050, approximately half of gas/LNG-fired thermal power (17.6GW) will implement CCS.

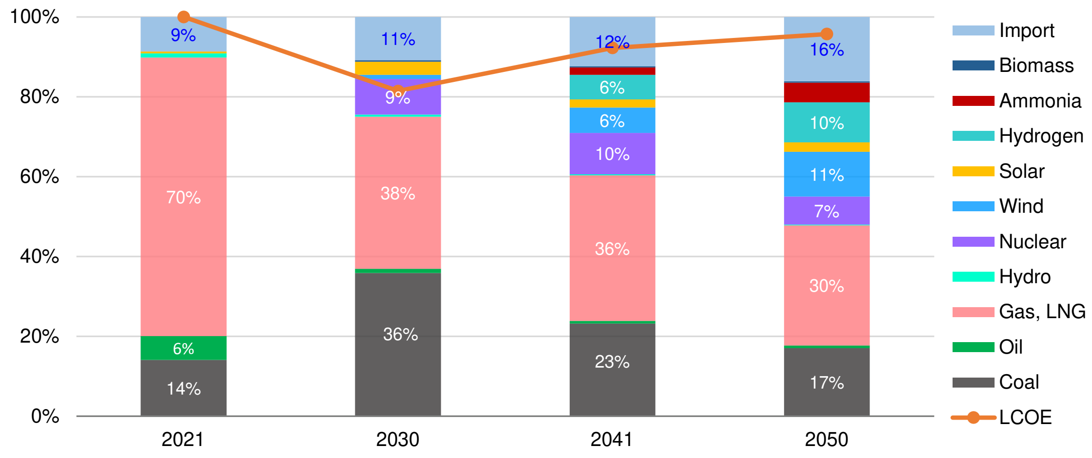
Source: IEPMP Study Team

Figure 5.4-11 Composition of the installed capacity (In-Between)

c. Supply cost

Supply cost and the composition ratio of generated power are shown in Figure 5.4-12. The supply cost is an indexed value with the current (2021) figure set at 100.

The supply cost will drop to around 80 in 2030 and then rise, but will remain below the current level. At present, the composition of gas-fired power plants with high fuel cost is high. But in 2030, it will decrease sharply. Instead, the composition of coal-fired power plants with low fuel cost will increase. As a result, the supply cost in 2030 will drop by about 20 points from the current level. Towards 2050, the composition of coal-fired power with low fuel cost will decrease, while that of hydrogen-fired power and gas-fired power with CCS, which have high generating costs, will increase. However, most of the gas-fired power plants to be newly developed after 2030 will be the latest combined-cycle power models with significantly higher thermal efficiency than those currently in operation. Therefore, even after 2040, supply costs will remain at a slightly lower level than that at present.



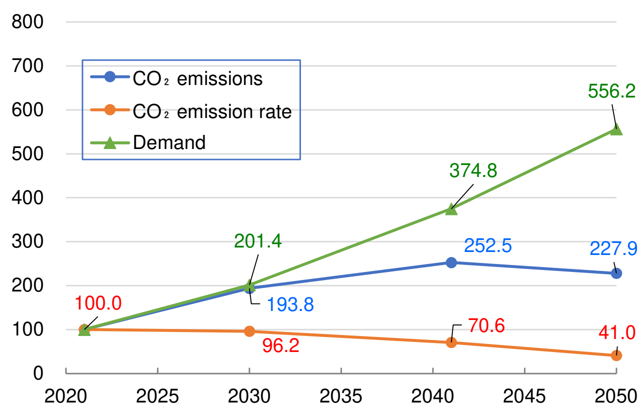
Source: IEPMP Study Team

Figure 5.4-12 Supply costs and the composition ratio (In-Between)

d. CO_2 emissions

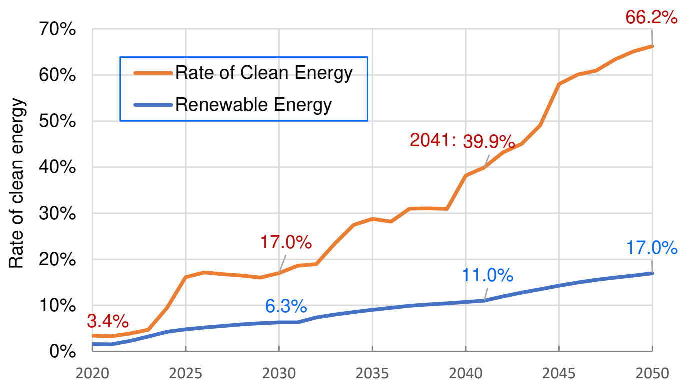
Changes in CO_2 emissions in the power sector are shown in Figure 5.4-13. All data are indexed with the present (2021) as 100.

CO_2 emissions rate will gradually decrease due to the increase in renewable energy and hydrogen-fired thermal power, which do not emit CO_2 at all, and it will drop to less than half of the current level in 2050. However, electricity demand will increase about 6 times from the current level, so CO_2



Source: IEPMP Study Team

Figure 5.4-13 Changes in CO_2 emissions in the power sector (In-Between) emissions will increase about 2 times from the current level.



Source: IEPMP Study Team

Figure 5.4-14 Changes in the clean energy ratio (In-Between)

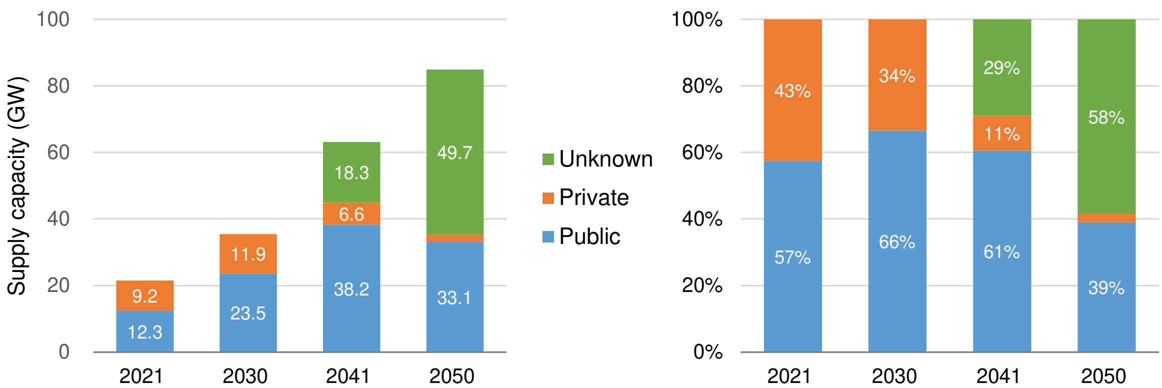
Changes in the clean energy ratio and renewable energy ratio are shown below. The "Clean energy" refers to a power source that does not emit CO_2 at all, and includes renewable energy (solar, wind, hydropower), nuclear power, ammonia-fired, and hydrogen-fired thermal power.

Currently, it is very small at about 4%, but it will gradually increase with the development of power sources that do not emit CO_2 at all. In 2041, the target year, it will be about 40%, and it will gradually increase thereafter, reaching more than 60% in 2050.

e. Public-Private Ratio of Power Development

The ratio of supply capacity in the public sector and private sector is shown in Figure 5.4-15 below.

In general, the ratio of public and private sector at power generation capacity is set by the government or its regulatory bodies from the following three perspectives, i.e., ensuring healthy competition in terms of price and efficiency, maintaining supply-demand balance and stable supply, and ensuring national energy security.



Note: Excluding solar and wind

Source: IEPMP Study Team

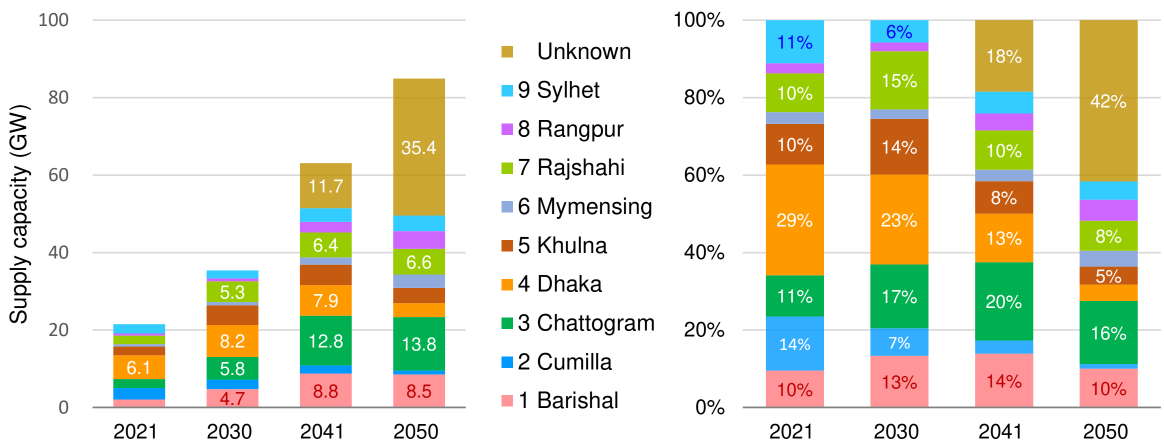
Figure 5.4-15 Ratio of supply capacity (Sector wise: In-Between)

The ratio of installed capacity in the public and private sectors is currently about 50% and about the same. Until 2030, the power generation facilities of government-affiliated power generation companies other than BPDB, which belong to the public sector, will increase. After that, the development of power plants for which the business entity has not been decided will increase. However, even if all these developments are entrusted to the private sector, it is possible to secure a public sector ratio of around 40% in 2050.

f. Location of power plants

The breakdown of supply capacity in each region is shown in Figure 5.4-16.

Currently, the ratio is high in the Dhaka, Cumilla, and Sylhet regions, which are close to domestic gas production areas. However, in the future, the ratio of Barishal and Chattogram regions will increase, as they are located in coastal areas having advantages in the supply of imported fuel.



Note: Excluding solar and wind. Candidate projects are counted as Unknown.

Source: IEPMP Study Team

Figure 5.4-16 Breakdown of supply capacity in each region (In-Between)

Transmission planning based on the imbalance between supply and demand in each region is discussed in Section 5.5, Transmission System Planning.

After 2035, the number of power plants whose locations have not been determined will increase, reaching 42% of the total in 2050. These power plants need to be decided from the viewpoint of the supply and demand balance in each region, the availability of fuel, and the cooperation with construction of transmission and transformation facilities, especially the backbone system.

For many of these “Unknown” sites, replacement of existing facilities will be considered. If a new power plant is to be constructed on the same site after the site has been cleared, there will be a period of at least three years during which no power can be generated. Therefore, it is desirable to construct a new power plant on idle land within the existing site and clear the existing facilities after the construction is completed. However, if there is not enough idle land within the existing site, one way to secure idle land is to relocate facilities that are not directly related to power generation (for example, training facilities, workshops, and company housing etc.) outside the site.

g. Issues in Power Development Plan

(1) Diversification of supply sources

In this plan, gas and LNG will have a share of more than 30% until 2041 in both power generation capacity and the amount of power generated. As domestic gas production is declining in recent years, LNG import needs to be increased as discussed in Chapter 6. It should be noted that locations for deepwater ports to receive ocean-class LNG carriers are limited in Bangladesh, and that LNG storage tanks are very costly for storing LNG in large quantities. To enhance energy security at an affordable cost, diversification of fuel sources should be considered with due cautions on overdependence on LNG import.

(2) Ensuring fuel supply security

Coal-fired power plants have advantages in terms of fuel supply security, for large stockpiles can be secured relatively easily. However, there is a potential risk of restrictions imposed on the movements of coal fuel in the future due to environmental concerns. In order to avoid supply disruptions due to fuel shortages in such situations, co-firing of ammonia in coal-fired power plants will enable power generation to continue even in the event of shortage in either fuel.

In preparation for a case of gas supply shortage, it is necessary to accelerate exploration and development of indigenous gas resources and, at the same time, to consider installation of power plants that can be run by other fuels such as HSD, hydrogen, etc.

(3) Securing peak supply capacity

It is desirable to secure about 20% of the total installed capacity as peak supply capacity. Basically, the gas turbine, which is a power source with low fixed cost, will be the peak supply capacity, but because the HSD fuel cost is high, HSD-fired gas turbine will cost more than the combined cycle even at a load factor of 5%.

The role of each power generation facility changes over time. Even if it was the latest combined cycle facility at the beginning of operation, the priority of operation was lowered as new equipment was introduced. Facilities with significantly lower thermal efficiency than state-of-the-art equipment will change their roles from base to middle, and finally to peak supply capacity. In this way, it is conceivable that outdated combined-cycle facilities will be responsible for peak supply capacity. So, it is not always necessary to develop 20% of the total development capacity as peak supply capacity.

(4) Securing frequency control capacity

In order to secure the frequency control capacity, it is desirable to introduce facilities such as hydropower (including pumped storage hydro), gas turbines, and engines that have a high load change rate. In particular, with introduction of renewable energy such as solar and wind power, whose output is affected by weather conditions and whose power generation is difficult to control, fluctuations on the supply side will tend to increase. As a result, the importance of frequency control capacity is increasing. It is desirable to promote introduction of power generation equipment with a large frequency control capacity as far as economic efficiency permits. All the users of grid shall obey the grid code for the discipline of the national grid.

5.5 Transmission System Plan

5.5.1 Key Issues of Transmission System Planning

Regarding the transmission system planning, the following three points are important and priority issues.

(1) Increase of South to North Power Flow
(2) Reliability improvement of supply network to Capital Dhaka
(3) Interconnection

Appendix D contains a review of the past plans and the situation surrounding the future transmission system that serve as the background for these key issues, as well as a list of referenced reports and a map showing the zones that indicate the area, and an outline of 230 kV, 400 kV, and 765 kV backbone transmission networks for different timelines.

5.5.2 Increase of South to North Power Flow

1) Overview of the issue

In the future, with increasing fuel imports for power sources, large-scale power plants will often be located in coastal zones of Barisal and Chattogram that receive fuel. Surplus power generated in Barishal & Chattogram Zone will need to be transferred to other deficit Zones, particularly around Dhaka.

There are difficulties in constructing additional 400 kV or 765 kV transmission lines from Barishal Zone to Dhaka because of a need for crossing a wide river and high cost associated with it. On the other hand, construction of a new transmission line from Chattogram Zone to Dhaka faces a technical difficulty of ensuring Right of Way (RoW) through the narrow corridor of Feni area between the coast and the border, and the river crossing section at Munshiganj, Narayanganj area.

The power generated in Barishal & Chattogram Zone will be transmitted to Dhaka after subtracting the power consumed locally. Therefore, the required capacity of transmission lines from Barishal & Chattogram Zone to Dhaka will become less if the local demand increases in the future.

2) Outlook for transmission capacity considering difficulty of transmission line construction

First, regarding the transmission line from Barishal to Dhaka, a 400 kV d/c transmission line is currently being constructed and another 400 kV double circuit transmission line is planned. Considering the future generation plan in Payra, another Padma River crossing (3rd) line may have to be constructed after the 2nd 400 kV line. In consideration of the difficulties being faced during the construction work of the 7 km-long Padma River crossing and to reduce the impact on Padma River navigation with a fewer number of lines, one 765 kV large-capacity transmission line could have been planned rather than the 2nd 400 kV lines construction. However, it has been decided that the second transmission line is to be built at 400kV.

Next, at present Chattogram-Feni-Dhaka direction has one 132 kV double circuit, and one 230 kV double circuit transmission line from Chattogram to Dhaka passing through Feni District. Besides these, Maunaghat-Meghnaghat 400 kV double circuit transmission line which is under construction is also passing through Feni as the third line in this zone. During the construction of this third line, managing RoW was challenging in various areas, especially, in the 20 km narrow corridor in the Feni area. Therefore, it will be very challenging to construct the proposed Chattogram-Feni-Dhaka 765 kV transmission line as the fourth line within this region by ensuring the necessary RoW. It should be noted that the RoW required for a 765 kV line is 116 meters as per Electricity Rules 2020.

Based on the above, transition of the transmission capacities from the Barishal & Chattogram zones to Dhaka is summarized in Figure 5.5-1. The capacities shown in the figure are, in the sense of the upper limit, the conductor capacity of the total facilities during N-1 contingency. It is assumed that it is possible to operate without imbalance for each transmission route, and that constraints such as stability can be addressed. However, inter-zone power transfer capability shall be assessed in detail considering thermal capacity, voltage regulation, N-1 contingency and stability limit.

3) Zone-wise demand forecast

Zone-wise demand forecasts are extrapolated to 2050 with reference to the zone-wise distribution of the latest zone-wise demand forecasts by each distribution company and compiled by BPDB (See Appendix D). The results are used in Figure 5.5-1.

According to report (1), after Bangladesh becomes a developed country by 2041, it is forecasted that industrial demand will grow in economic zones other than Dhaka. The impact of this, however, would not be significant according to the demand forecasts by respective distribution companies.

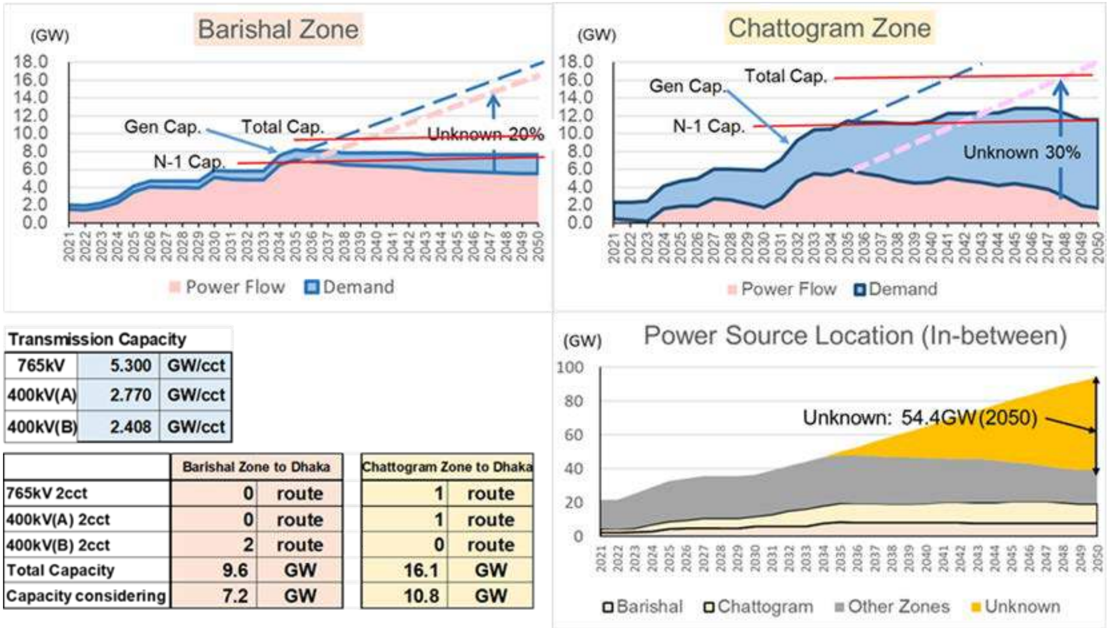
4) Power source site plans other than ZONE 1 and 3 (consistency with gas pipeline plans)

In order to locate a power source outside of Barishal & Chattogram Zones, it is necessary to transport fuel from these zones to outside areas. A gas-fired power plant consumes a large amount of gas, so it is necessary to build a gas pipeline system to serve as the backbone. The pipeline plan is described in Chapter 6. By utilizing these pipelines, gas-fired power plants of around 20-30 GW can be located in the areas other than Barishal & Chattogram Zones.

5) Countermeasures to cope with increasing power flow from south to north

Figure 5.5-1 shows the transmission line capacity based on the above mentioned plan and the yearly transition of the power flow from each zone obtained subtracting the forecasted local demand from the generation capacity planned for each zone.

Through 2030, by the time when sites of the power sources are almost fixed, capacity of the currently planned transmission lines will be able to accommodate the increasing power flows. However, in the Barishal zone, the second transmission line is decided to be not of 765kV but 400kV in capacity, so the transmission capacity is near the limit. The third 400kV d/c transmission line will become necessary pending the power development plan after 2030. In the Chattogram zone, transmission capacity will likely be secured through 2040, provided that a 765kV transmission line be constructed as planned. Even so, depending on the locations of unknown power sources after 2030, further transmission line construction may be required. It is desirable to conduct a feasibility study on the future transmission line route to Dhaka. The study may also require a re-examination of the national regulations on RoW for transmission lines, which means the possibility to reduce the current figures from 116meters to 765kV transmission lines for RoW considering the global experience.

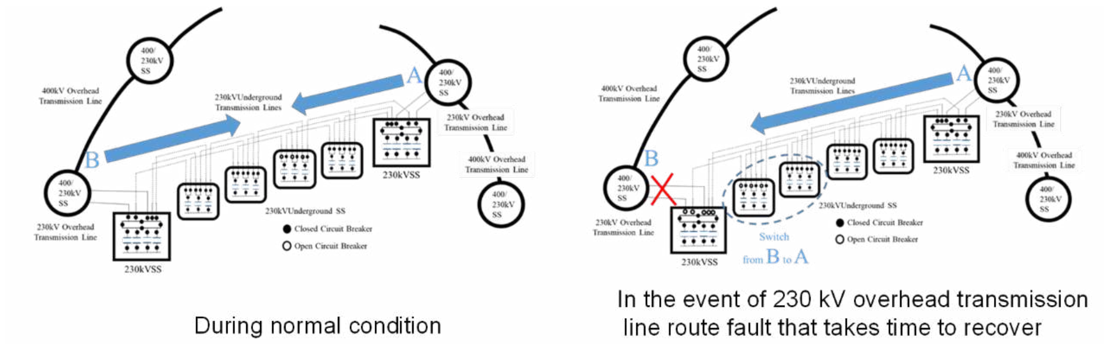


Source: IEPMP Study Team

Figure 5.5-1 Transmission Capacities vs. Power Flows:
Barishal & Chattogram Zones to Dhaka

5.5.3 Reliability improvement of supply network to Capital Dhaka

In the Dhaka area where central state organs and facilities are concentrated requiring high reliability on power supply, construction of a 230 kV underground system will be the core policy on the transmission system. A sample design consistent with the city planning is developed using a Geographic Information System (GIS) as follows.

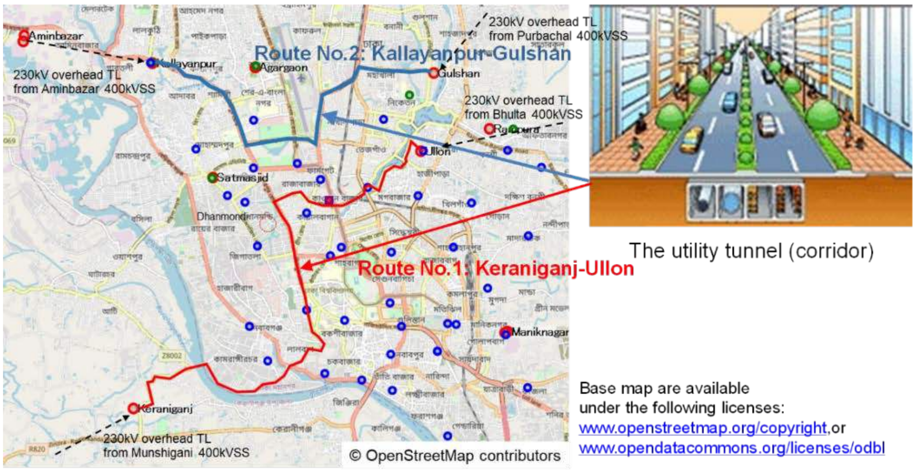


Source: IEPMP Study Team

Figure 5.5-2 Basic design of the 230 kV underground system

In underground systems, the transmission capacity of cables is significantly lower compared with overhead lines. Hence, it is important not to mix the overhead and the underground systems; the capacity of the transformer that supplies the 132kV system should match the cable capacity. For 230kV cables, 600MW per circuit is the normal limit. Unlike overhead lines, underground lines are not affected by the external environment such as lightning, so the probability of fault occurrence is low. On the other hand, once a fault occurs, it takes time to recover. Considering these characteristics, underground system will be efficient with unit connection as shown in Figure 5.5-2.

Since the underground cable route will be built under the trunk road, it is necessary to take consistency with the Dhaka city plan (road plan). Figure 5.5-3 shows an example of a route connecting Keraniganj-Ullon and Kallayanpur-Gulshan. For connection to these substations from the 230kV buses of the Dhaka outer ring 400kV substations, 230kV overhead transmission lines are used. Cable routes are selected considering the locations of 230kV/132kV substations so that four substations can be connected to each route as shown in the figure. Detailed feasibility study shall be conducted for any proposed project.

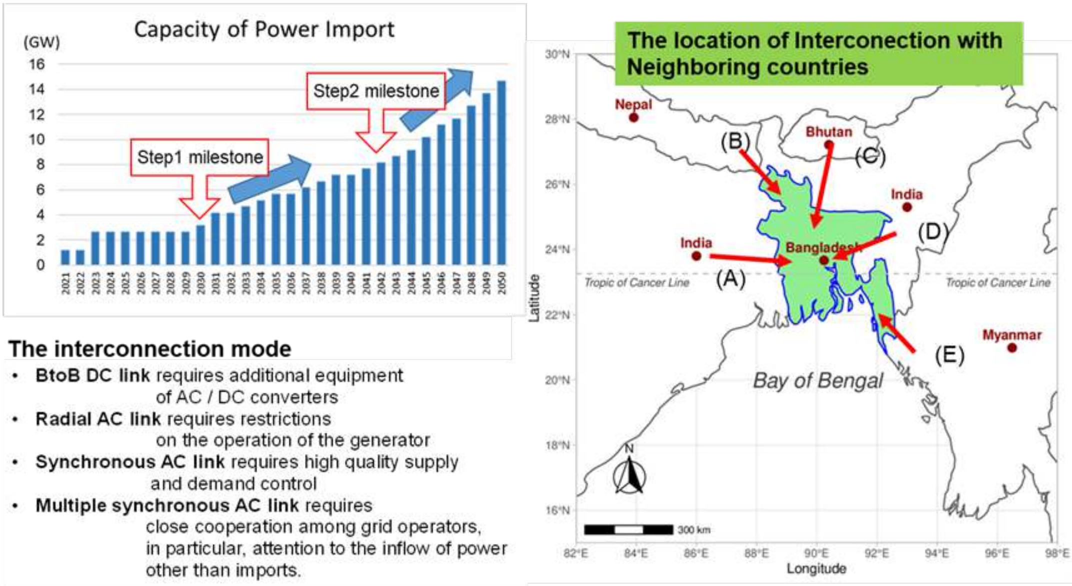


Source: IEPMP Study Team

Figure 5.5-3 Example of 230kV underground cable routes

5.5.4 Interconnection

Sharing the borders mostly with India, there are two asynchronous interconnections through a Back-to-Back HVDC station and a radial interconnection with Power System of India at present. Bangladesh can also have a cross-border interconnector with Myanmar in the future. And, although it does not share borders with Nepal and Bhutan, they are sufficiently close to connect with dedicated lines. These interconnections are important options in terms of security and reliability of power supply in Bangladesh. The mode and interconnection points could be identified through detailed technical, financial, and environmental studies.



Source: IEPMP Study Team

Figure 5.5-4 Power Import and Interconnection

According to the power source plan, power import requirement will increase in 2030 and onward. It will be necessary to implement certain interconnection projects. In particular, it is important to prepare the first step for interconnection toward 2030 and the second step for enhancement around 2040.

1) The first step milestone

From the aspect of reliability and security, it is important to diversify interconnections with respect to partner countries and modes. Since there is not enough time until 2030, however, it is necessary to narrow down promising candidates and conduct detailed studies.

Hydroelectric power generations in Nepal and Bhutan, which are clean energy, have been raised as specific candidates for power import as these countries are parted from Bangladesh by a narrow corridor of India. In order to import power from Nepal and Bhutan, transmission line routes and options for their mode of operation need to be finalized through financial viability and environmental impact assessments followed by detailed power system studies. However, both of the following modes of operation may be considered:

(a) Radial AC link (Construction of a dedicated transmission line from Nepal or Bhutan) and
(b) Synchronous AC link .

Both modes are considered to be realized at (B) or (C) in Figure 5.5-4. It is important to discuss both modes at the same time in order to reach an agreement among countries.

2) The second step milestone

The operational flexibility of Synchronous AC link is considered essential in the first step interconnection project. If power export is also to be implemented through the same point, although it is not included in the current power supply plan, Synchronous AC link should be selected instead of Radial AC link. As such, realization of Multiple synchronous AC links may have the challenge for the second step.

Advanced technologies are required to control the power flow through each Synchronous AC link. Then locations of the interconnection point will have to be determined by performing technical study to find the best interests of Bangladesh. Synchronous AC links between neighboring countries may be established in different voltage levels i.e., 765 kV, 400 kV or any other voltage level justified technically, economically, and environmentally.

The most important thing to watch out on the Multiple synchronous AC links is the inflow of power other than the intended import into the Bangladesh grid. Synchronous AC links located at (A) or (D) in Figure 5.5-4 are difficult to avoid the inflow of power between east and west of India into the Bangladesh grid. In that sense, Multiple synchronous AC links are considered suitable for the location such as (B) and (C), where the power flow directions are the same, North to South. These directions will also mitigate the problem of Increasing South to North Power Flow, the first issue of Bangladesh transmission planning.

5.5.5 Power System Operations

1） Issues on frequency quality

As frequency quality is improving in recent years and fluctuation range is becoming smaller, there is still a fluctuation of about ±0.5 Hz. Presently, the duration frequency is controlled within the specified range remains at about 70%. To improve the power system operations, it is necessary to improve facilities and operation procedures with an in-depth review. Issues and countermeasures are discussed in detail in Appendix D.

a. Individual demand data and meteorological data are not collected accurately, and thus Energy Management System (EMS) demand forecast is functioning with reduced accuracy. Accuracy needs to be improved.
b. Generator control is done not by EMS but by telephone command from NLDC operator. To improve frequency quality, it is important to connect NLDC and each power plant online for efficient data exchange.
c. NLDC must be equipped with a facility for predicting the output of renewable energy.
d. There is a shortage of FGMO power plants that provide primary control reserves.
   Although there are 27 power plants capable of supplying primary control reserves, fuel shortages and technical problems prevent all generators from operating with FGMO. According to the NLDC, a primary reserve capacity of 350-400 MW is not sufficient as the reserve capacity to maintain the control range in the grid code at all times.
e. AGC is not utilized and secondary reserve capacity is not secured.
   The primary control capability means that each power plant automatically adjusts its output sharply. But AGC that automatically changes the output of each power plant at an early stage, which is a function to complement it, is not used.
f. It is necessary to secure tertiary reserve capacity and reserve capacity to meet future demand increase. It is important to align the future power supply plan with the transmission plan so as to continuously secure a certain level of reserve and adjustment capacity.

g. NLDC needs to have proper tools and facilities for establishing appropriate control and authority over all users (generators and loads) of the national grid. Establishment of automatic frequency control (Primary, Secondary & Tertiary Control) and voltage control are necessary for the system stability. For the grid discipline all the users of the national grid must strictly observe the Grid Code. The Bangladesh Energy Regulatory Commission (BERC) shall monitor the enforcement of the grid code. There may have to be a mechanism for procuring necessary reserve for the frequency control.

2) Voltage operation issues

a. Low voltage phenomena during peak hour is observed in the areas with insufficient base load generation. All power plants basically need to run in voltage control (AVR) mode. Introduction of adequate reactive power compensation facilities is also required.
   It is necessary to install a phase-advancing capacitor at the trouble-prone locations. In addition, when any renewable energy power source is installed, the system voltage tends to rise. So, it is necessary to carefully avoid an excessive investment.
b. Overvoltage occurs due to sudden drop in the power demand while voltage adjustment is done in time. In addition to tap control of transformers, future expansion of renewable energy will become possible by adopting EMS with functions that automatically control the terminal voltage of generators and by turning on and off of phase-modifying equipment, or by installing automatic voltage control devices. It is also effective for changes occurring in a short period of time that increase with time.

3) Issues related to organizational structure

It is necessary to promote use and automation of EMS in both frequency operation and voltage operation. In addition, further efficiency and productivity improvements are required by promoting DX. In view of the cases in Japan, it is important to develop human resources and secure sufficient personnel in the following two areas:

a. Supply and demand system design
b. Power supply system and DX capabilities

Future-oriented human resource development and review of the organizational structure are also issues to be addressed.

4) Measures to prevent wide-area blackout incurred by large-scale nuclear plants

The Rooppur nuclear power plant with 2 units will generate 2,400 MW of electricity, 1,200 MW from each unit. The first unit is currently planned to start test operation in October 2023 and the second unit will start commercial operation by 2024 (these plan will be delayed). From the grid point of view, loss of a large scale unit will bring about severe impacts, especially to cause low frequencies and leading to a wide-area blackout. One of the effective solutions is to utilize an under-frequency load shedding (UFLS) which is a protection relay at substations as a countermeasure to mitigate the impact when the nuclear plant dropped suddenly during its operation. A study on installing UFLS with proper placement and adequate capacity should be implemented immediately to prepare them ready at the start-up of the first nuclear plant. Another effective measure is a special protection scheme (SPS) which detects an accident and takes the emergency control basically in a predetermined way, even when the UFLS scheme cannot be brought in time to prevent a wide-area blackout.

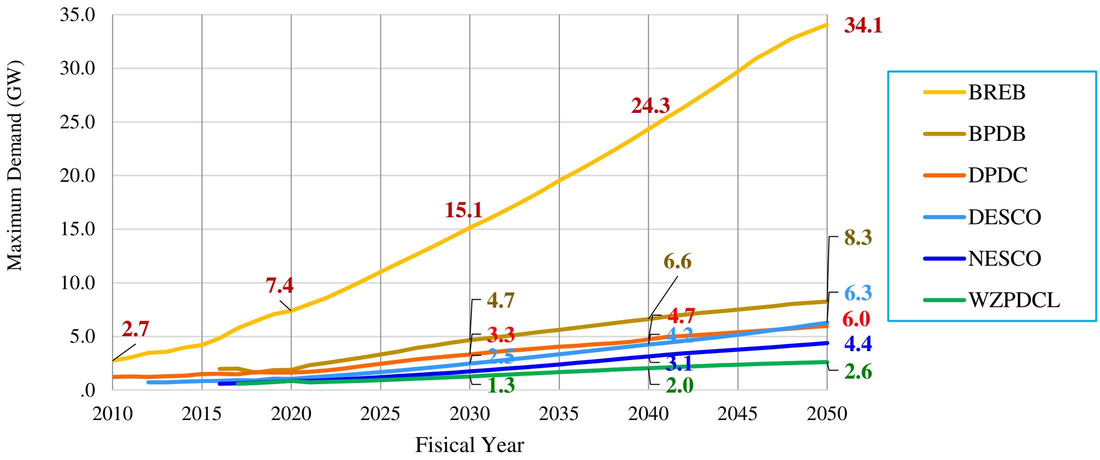
5.6 Distribution System

5.6.1 Conceptual Distribution System Planning

This section focuses on the current status and preliminary study of both urban and rural distribution networks. In-depth study should be accomplished under the Detailed Distribution Master Plan (DDMP) in due course.

1) Demand Outlook

Presently, six utilities in Bangladesh are responsible for management and supervision of the distribution network, according to their institutional positions and responsible 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).



Source: Listed Utility Companies

Figure 5.6-1 Maximum Demand Outlook at 33kV level by Distribution Company

Electricity demand is increasing at all utilities and expected to keep high growth rates further. DESCO, covering the northern part of the capital city of Dhaka, has seen an average annual growth of 6% over the last 10 years, while DPDC at 3%. Both DESCO and DPDC expect high demand growth of almost 10% over the next several 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 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, accounting for 80% of the country, has seen an average annual demand growth of about 10% in the past 10 years. Although the demand growth will slow down after 2025,the demand will still grow to 1.9 times today by 2030 and 4.3 times by 2050. The BPDB area, with a recorded annual 5% demand increase in recent years, is expected to see a 10% increase in coming years. Afterward, growth will slow down and demand is expected to expand 3.5 times today by 2050. The NESCO area has seen relatively high growth rate, annual 5.9%, in the last few years, and is expected to gradually slow down and to expand 5.1 times today by 2050. The WZPDCL area has seen an annual 4.4% demand growth, and this will continue for a relatively longer period, though gradually slow down to expand 3.6 times today by 2050.

The number of customers is also increasing fast in the BREB area by an annual 10%, in the DESCO area close to 10% and in the WZPDCL area 8%. On the other hand, the growth in the DPDC area is at about 7%, which is somewhat lower than that in the DESCO area.

2) Outline of Facilities

Each utility's equipment consists mainly of 33kV or 11kV as medium-voltage lines and 230/400V as low-voltage lines. The 33kV lines are mainly used to supply power from 132/33kV substations to 33/11kV distribution substations or as interconnected lines between 33/11kV distribution substations. The 11 kV lines are mainly used to supply electricity from 33/11kV distribution substations. In addition to the 33/11kV distribution substations, they have jurisdiction on management of 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 11kV or less account for 80% of the total, and the underground rate is about 40%. By voltage, the undergrounding rate of 33kV medium-voltage lines is 85% while that of 11kV medium-voltage lines is 31%, indicating that 33kV medium-voltage underground lines are 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 operating scales, taking approximately 60% of the total electricity sales, slightly more than 70% of the installed transform capacity, and approximately 80% of customers.

As for distribution losses, those of DESCO, DPDC and BPDB, which cover the urban areas, are in the range of 5.6 % to 6.7 %, while those of utilities in charge of rural area, i.e., WZPDCL, NESCO and BREB, are 7.9 % to 10.5 %. The average length of distribution lines for 33kV and lower voltages is relatively longer in rural areas than in urban areas, contributing to greater losses.

The amount of renewable energy sources (RES) installed in rural areas appears smaller compared with urban areas mainly because they are scattered as small off-grids.

The GIS (Geographic Information System) has been installed or is being installed at most power distribution companies, and SCADA is being installed at DESCO, DPDC and NESCO while others are planning to install. Utilities are planning to introduce smart grid systems as well. For example, DPDC is preparing for introduction of Distribution Management System (DMS) along with a smart grid project. BPDB and DESCO are also planning to introduce it. BREB has completed a related F/S, and is considering a full-scale introduction of the same. Prepaid meters are also being introduced one after another led by DESCO, followed by DPDC, WZPDCL, NESCO, BREB and BPDB.

5.6.2 Challenges in the Network Operation

Comments and ideas on important issues are obtained by interviews with electricity distribution companies as discussed below. For details, please refer to Appendix D.

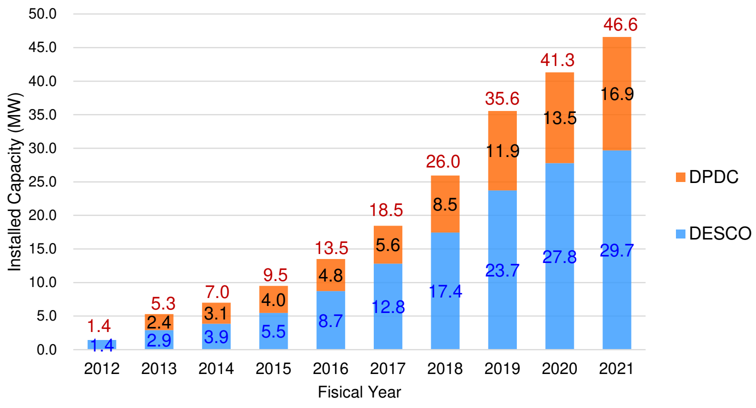
Demand forecast is a challenge in the urban areas. It is necessary to review how individual companies are working on it. Automated systems being introduced will make a significant contribution to improving the operational efficiency through collaboration with other systems. However, utilization of such data for system collaboration is still under study. In addition, relevant advice on the cyber security is sought for. It is also recognized that there are many challenges in underground cable construction. Human resource development and clarification of the role of each jurisdiction area are also mentioned.

In the rural areas, improving supply reliability is a major issue. In particular, the improvement on SAIDI (System Average Interruption Duration Index) and SAIFI (System Average Interruption Frequency Index) is a pressing issue. Maintenance of distribution facilities and control of dropping voltage in the long lines, response to natural disasters, and aging of facilities are mentioned as issues. Long-lasting power outages are occurring due to transformer failures caused by lightning, and to breakage of lines by fallen trees caused by cyclones, and contact with trees and wildlife. Regarding Renewable Energy Systems (RES) connections, study on the impact of connection on the system and establishment of guidelines are mentioned.

5.6.3 Introducing Renewable Energy Sources

The global trend toward a low-carbon society is driving introduction of RES. Distributed solar power facilities with high capacity may increasingly be connected to the country's distribution network system in a short period of time. Figure 5.6-2 shows the installed renewable energy sources in the DESCO and DPDC areas, which have jurisdiction over the capital city of Dhaka. In addition, 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. Furthermore, another 30MW solar generation is supposed to be connected to the NESCO's grid in the future.

The RES in Bangladesh mostly consists of solar PVs with net metering. Some are connected to the grid, while others are small and off-grid. 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 RESs support policies such as the FIT system. In order to realize the maximum grid connection of RESs, it is necessary to prepare for the establishment of grid connection conditions and the improvement of grid reliability.



Source: DESCO, DPDC

Figure 5.6-2 Rooftop Solar Installations

5.6.4 Distribution Plans in Dhaka area

1) Measures for RES connections

To realize a low-carbon society, it is necessary to maximize the amount of RES connections. When RES connection increases, power flow on the distribution network becomes very complicated making it difficult to manage the voltage and the current. In Japan, widespread voltage flurries are also experienced caused by inverters attached to RES to prevent independent operation. Based on these cases, IEPMP Study Team recommends to adopt the following measures.

a. Development of technical requirements for RES connections
b. Installation of sensors for gaining power data in medium-voltage lines
c. Introduction of voltage control equipment to medium-voltage lines
d. Introduction of Distribution Management System (DMS) to obtain power data
e. Remaining proper voltage by optimal control of line equipment based on DMS results

2) Measures for Improving of Reliability

Japanese power companies have historically improved reliability of electricity supply by introducing insulated wires, lightning protection equipment, Distribution Automation System (DAS), preventive maintenance, and accident detection technologies. In addition, multi-division and multi-connection (MDMC: Multi Divided and Multi Connected) distribution line system configuration is adopted, in which one distribution line is divided into several sections by a division switch where these sections are connected to other distribution lines. The MDMC contributes to improvement of supply reliability by enabling separation of the fault sections while transmitting to sound ones smoothly. Reliability improvement also allows the maximum use of the RES power. Furthermore, it is made possible to quickly and automatically separate a fault section and re-electrify sound sections by utilizing combined system with DAS and MDMC. Main measures to improve reliability are as follows:

a. Insulation covered wires (in practice)
b. Lightning resistant equipment
c. Introduction of DAS

d. Introduction of MDMC configuration
e. Hybrid Overhead/Underground equipment combination
f. Improvement on fault point probing technology

3) Operational Efficiency Measures

For efficient operation, utilities in developed countries including Japan are working on acquisition and analysis of data such as voltage, current and power factor. They try to optimize the configuration of the distribution line systems to minimize losses and to reduce duration of outages. Digitizing information on operation and facilities is a key to achieve these objectives. Introducing high-speed communication technologies also support them. In addition, in order to promote hybrid overhead/underground distribution system, it is necessary to follow international standards along with improved technologies to support construction of facilities, measurement technology specific to the system and technologies on the underground configuration. The following measures are proposed to improve operational efficiency of facilities.

a. Introduction of smart meters and data operation with management technology
b. Improvement of communication environment
c. Facility management using GIS (Geographic Information System)
d. Data management integrated with DMS, DAS, SCADA and distribution simulation software
e. Underground related technology (system configuration, equipment configuration, construction technology, and measurement technology)
f. Ensuring cyber security at GIS, SCADA, DAS, DMS etc. systems

Meanwhile, demand side management (DSM) is also an effective measure for effective use of facilities. In areas where a large amount of RES, mainly PV (Photo Voltaic), is connected to the grid, it is reported that net electricity demand, or total demand derived from difference between the actual electricity consumption and the amount of RES output deviates greatly from expected one depending on the time of day.

When massive PV is connected to the grid, the amount of electricity consumption during the day time is compensated by the 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 profile is called a duck curve as it resembles the shape of a duck. It is thought that shifting the peak demand by adopting electricity billing systems such as Time-of-Use Tariff, 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 Tariff systems
d. Use of water heaters and air conditioning systems with ice storage
e. Introduction of batteries and electricity storage equipment

5.6.5 Distribution Plans Outside of Dhaka Areas

Likewise with recommendations for distribution plans in Dhaka areas, it is necessary to consider introduction of mini-grids or stand-alone grids outside of the Dhaka area. For short term, configuration of mini-grid or independence grid system should be studied for connection or evaluation of the impact on the system demand. For long term, upgrading of the distribution system should be considered in relation to increasing mini-grids or stand-alone grids to appropriately manage their impact.

5.7 Power Policy

5.7.1 Power Trading

In Bangladesh, BPDB purchases electricity from generation companies as a single buyer and sells it to distribution companies on bulk electricity tariff. Distribution companies then sell electricity to final customers on retail electricity tariff. As the electricity consumption is expected to increase robustly , this market structure may need to be reviewed and upgraded from time to time in order to rationalize the electricity supply system while securing stable supply at affordable prices. Low carbonization is another important issue in considering this.

The Bulk Electricity Tariff that BPDB receives from distribution companies and the Retail Electricity Tariff that distribution companies receive from final customers are approved by BERC. Since the Bulk Electricity Tariff is low compared to the bulk supply cost that BPDB pays, as a single buyer, to generation companies, BPDB's expenditure keeps exceeding its revenues.

The government has set out a policy of gradually increasing the retail electricity tariff while taking into account the burden on low-income customers, as well as the bulk electricity tariff. Thus, retail electricity rates were increased by 5.3% on average in December 2017, and again by 5.3% in March 2020. The bulk electricity tariff was also increased by 8.4% in March 2020. The bulk tariff has been increased 19.92% from December 2022.

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 the related facilities, reform management of companies and fine tune the retail electricity tariff.

Current bulk electricity tariff and retail electricity tariff are below the level to compensate the wholesale supply cost. In the course of market liberalization, it is necessary to assure a healthy situation where the cost is properly recovered with liberalized market prices.

5.7.2 Demonstration test of ammonia co-firing

An ammonia co-firing at coal-fired thermal plant is planned to start from 2035. Combustion tests of ammonia co-firing in coal-fired power plants have already been conducted in Japan. However, if full-scale co-firing operation is to be implemented in Bangladesh, it is essential to conduct a demonstration test to evaluate the combustibility at the actual power plant in Bangladesh to identify issues and solutions, including fuel supply method.

5.7.3 Master plan for hydrogen/ammonia fuel supply system

Hydrogen power generation is regarded as a promising means of decarbonization technology, and hydrogen co-firing at gas-fired plant is set to start in 2040. However, studies are yet to be conducted on the hydrogen fuel supply system.

Many hydrogen-fired plants are planned to start after 2040, but their locations are yet to be determined. In site selection for these plants, there are many issues to be examined such as land acquisition, procurement of fuel, regional electricity supply/demand balance and feasibility of constructing transmission lines. In particular, as hydrogen fuel will most likely be imported, hydrogen power plants will be located in coastal areas. This would cause a large imbalance in the regional electricity supply/demand balance, requiring many additional transmission lines.

It is desirable in principle to locate power plants near the demand center with a capacity to meet the demand. In Bangladesh, electricity demand is concentrated in the Dhaka region, and hence it is preferable to build power plants nearby. For this reason, fuel supply pipelines must be built from the coastal area where imported fuel is received. To establish a rational fuel supply system, a comprehensive pipeline plan should be established examining optimum distribution of power plants and fuel supply system.

5.7.4 Electricity import and transmission plan

Low carbonization can be achieved at a lower price by importing hydroelectric power from Bhutan and Nepal than using decarbonized fuels such as ammonia and hydrogen. This beneficial option should be pursuit proactively. Then, since Bangladesh does not share border with Bhutan and Nepal, power transmission lines must go through India. So far, it has been agreed with India that interconnection will be implemented synchronously, and construction will be carried out by SPV (Special Purpose Vehicles) formed by a joint venture between the two countries. It is essential to push forward the dialogue with three countries among Bhutan, India and Nepal as there are many issues to be solved before reaching the final decision.

5.7.5 Sites for CCS

In this Master Plan, CCS for gas-fired thermal power plants is scheduled to start in 2040. Enough time is available to establish the implementation plan. Nevertheless, it is desirable to start preliminary studies on suitable sites and technologies for CCS. Today CCS projects are coming up worldwide. It is important to monitor progress of these projects to accumulate information as the basis for the study to establish an efficient plan.

5.7.6 Improvement of frequency quality

In introducing large scale nuclear power plants and AC synchronized interconnection with neighboring countries, it is also necessary to keep the fluctuation within ±0.2Hz as opposed to the present level of about ±0.5Hz. To achieve this, it is necessary to work comprehensively on the measures given below.

a. Sophistication and accuracy improvement of demand forecast and power generation plan
b. Securing primary, secondary and tertiary reserves
c. Sophistication and on-line systemization of SCADA/EMS
d. Consolidation of regulations and rules including strengthening the authority of NLDC and building effective relationships among relevant players
e. Establishing proper institution and appropriate compensation payment for securing reserve capacity

To improve the frequency quality, it is recommended to establish a comprehensive collaboration system to discuss and decide plans, policies and rules with participation of not only PGCB and NLDC, who are directly in charge of the system operation, but also all stakeholders who are engaged in power generation, distribution and retail as well as regulatory bodies and government agencies. To this end, a study working group may be formed, who will also support inter-government talks with India, Nepal and Bhutan on grid synchronization and power imports.

Chapter 6 Primary Energy Supply Plan

6.1 Requirement for Primary Energy Supply

The total primary energy supply (TPES) plan to accommodate the increasing energy demand of Bangladesh is summarized in Table 6.1-1. TPES is a sum of i) each demand sector's final energy consumption, which is elaborated in Chapter 4, excluding secondary energies such as petroleum products and electricity, 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.

Table 6.1-1 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

In the course of economic development, 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 fossil fuels such as coal, oil and gas will keep steady increase 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 follows keeping the second position mainly due to increasing demand for motor fuel. Coal consumption may remain in a relatively small quantity, though domestic coal supply is expected to play a role to strengthen national energy security.

Along with the country's commitment to cope with 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 Sheikh Hasina at COP26 in 2021[28].

It will be a great 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 supply and utilization of conventional fuels such as coal, oil and natural gas, substantial investment must be made steadily mobilizing a huge amount of funds. In addition, new energies should also be introduced proactively and at a high speed albeit some of them are still in their infancy. To enable this, not only the required 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 will be discussed in Chapter 7.

6.2 Natural Gas

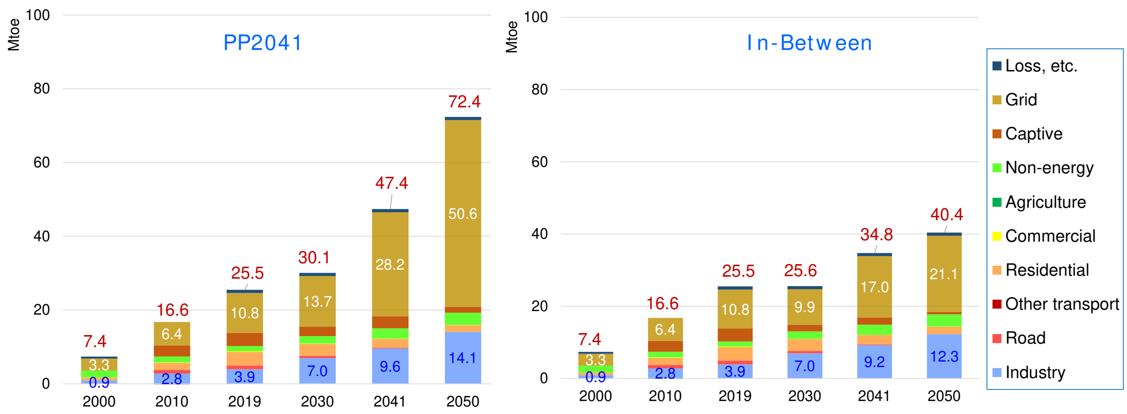
6.2.1 Natural Gas Demand Outlook

Natural gas demand is forecast to increase fast. 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 industry sector. This is because the high economic growth will be driven by accelerating industrial development and the high-tech sophisticated future industries will be mainly powered by electricity. In addition, natural gas is preferred among fossil energies as a low carbon fuel.

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. With improving energy efficiency of gas appliances, this movement will be even accelerated.

In addition, in 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 fine tune the fuel requirement of other fossil power plants, particularly imported LNG and coal.

[28] https://unfccc.int/sites/default/files/resource/BANGLADESH_cop26cmp16cma3_HLS_EN.pdf



Source: IEPMP Study Team

Figure 6.2-1 Natural Gas Demand Outlook

As Bangladesh pushes forward modernization of the country, traditional biomass notably firewood used at household will be replaced by gas fuels. Under the present policy, the rapidly increasing demand for modern fuel is being supplied with LPG, which causes serious problems. A huge number of LPG cylinders must be delivered in the congested metropolitan areas which is sprawling along with urbanization. To avoid worsening traffic congestion and ensure safety, it will be more prudent to consider rehabilitation and new construction of city gas systems in the metropolitan areas together with overall city development plans. This issue must be investigated more in detail on the technical and socio-economic aspects of various options so as 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 petrochemical industries.

All in all, natural gas requirement will exceed 5.3 billion scfd in 2041 in the GDP PP2041 case, and 3.9 billion scfd in the In-Between case.

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 6.2-1. 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 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 6.2-1 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

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 6.2-1A 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 6.2-1).

Table 6.2-1A Adjusted Natural Gas Demand Outlook (PP2041 case)

	Total Primary Energy Supply			Composition			Average Growth Rate			2022 to 2050
	2030	2041	2050	2030	2041	2050	22-30	30-41	41-50	
PP 2041	Mmtoe	Mmtoe	Mmtoe	%	%	%	%	%	%	times
Industry (incle. Tea)	9.5	12.1	16.6	24.1	21.3	20.3	3.4	2.2	3.6	2.29
Transport (CNG, etc.)	0.8	0.3	0.1	1.9	0.6	0.2	-5.1	-7.2	-8.7	0.13
Residential (Domesctic)	2.7	1.9	1.3	6.9	3.4	1.6	-2.5	-3.0	-4.2	0.40
Commercial	0.2	0.1	0.1	0.4	0.2	0.1	-3.1	-2.0	-2.0	0.52
Agriculture	-	-	-	-	-	-		-	-	-
Non-Energy (Fertilizer, etc.)	2.4	3.1	3.7	6.1	5.5	4.5	3.6	2.5	1.9	2.06
Power	24.0	39.1	59.9	60.6	68.9	73.2	1.0	4.6	4.8	2.70
Grid	18.7	34.5	56.7	47.3	60.7	69.4	1.8	5.7	5.7	3.51
Captive	5.3	4.6	3.2	13.3	8.2	3.9	-1.7	-1.2	-4.2	0.52
Loss, etc.	-	-	-	-	-	-		-	-	-
Total	39.5	56.8	81.8	100	100	100	1.2	3.4	4.1	2.27
billion scfd	4.45	6.40	9.21	(NCV @ 8,600kcal/m3)						

Note: "Agriculture", "Losses, etc." and "Others" are omitted since there is no such categories in given actual data in 2022.

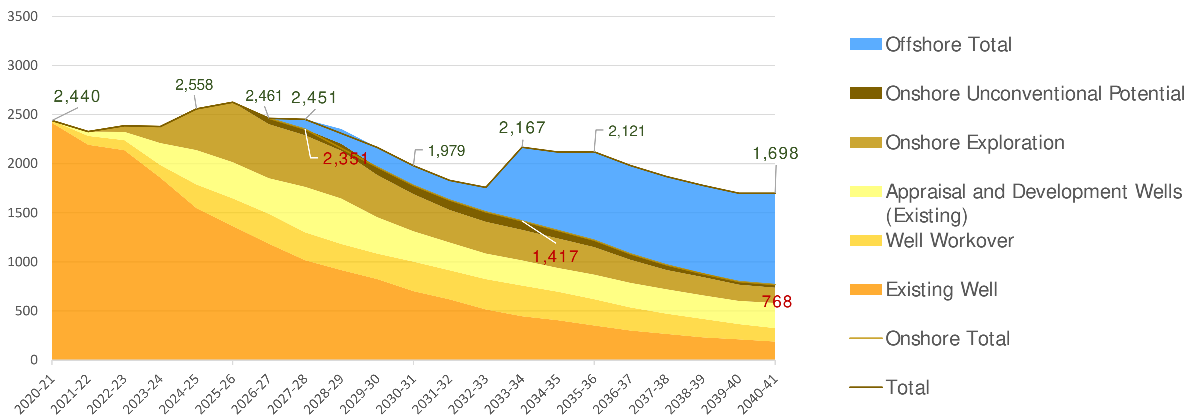
Source: IEPMP Study Team

6.2.2 Domestic Natural Gas Production

Domestic natural gas production is forecast by Petrobangla as shown in Figure 6.2-2. Gas production is projected to decrease from the present 2.4 billion scfd to 1.7 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 trend, but far less enough to reverse it.

Table 6.2-2 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



Note: Natural gas production up to 2040 (FY2040-41) is made by Petrobangla, and the trend is extended to 2050 by the IEPMP Study Team.

Figure 6.2-2 Forecast of domestic gas production

Gas production is also expected from offshore shallow and deepwater blocks. Gas has already been discovered and produced from shallow offshore but the deep offshore still remains as frontier. Vigorous exploration activities are required to identify the hydrocarbon resources in the offshore Bangladesh. Such activities will require sophisticated technology and huge amount of fund. Thus, they may be ranked as high-risk potentials. However, getting offshore gas will significantly improve the gas supply scenario.

With regard to the natural gas potential, experts of International Oil Companies (IOCs) 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.

To establish high-quality exploration and development programs, introduction of cutting-edge technology and enhancement of interpretation and evaluation capabilities of the national companies are required. At the same time foreign investment by the IOCs are equally important especially for offshore hydrocarbon exploration and development programs.

6.2.3 LNG import plan

Under the circumstance that indigenous gas production would not be able to suffice the demand, the balance must be made up. The answer is LNG (liquefied natural gas). Today, international LNG market is established worldwide and developing fast especially in Asia. Bangladesh started import of LNG in 2018 facing insufficient natural gas production. To support economic development of the country, LNG import will increase inevitably in the decades to come.

1) LNG import plan

Table 6.2-2 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, 11 million tons (Mt) in 2030, 25 Mt in 2040 and 49 Mt in 2050 for the PP2041 GDP case and 7 Mt in 2030, 16 Mt in 2040 and 22 Mt in 2050 for the In-Between case, respectively. However, if exploration on the high-risk potential resources were not successful, additional import of

LNG will become necessary on top of these projections by 7.1 Mt in 2040 and 9.4 Mt in 2050. In line with the increasing requirements, LNG import facility as well as gas transmission system must be reinforced simultaneously.

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 an FOB basis.

Table 6.2-3 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

To accommodate the increasing requirement for LNG import, the country will need to introduce additional LNG receiving terminals beyond the current plan. As shown in Figure 6.2-4, it will be after 2045. If the high-risk production potential would not materialize, LNG import facility must be expanded much earlier, and around 2040. Since about 5 years are necessary to develop and execute a new plan, such decision may need to be made around 2035 in the earliest case. 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.

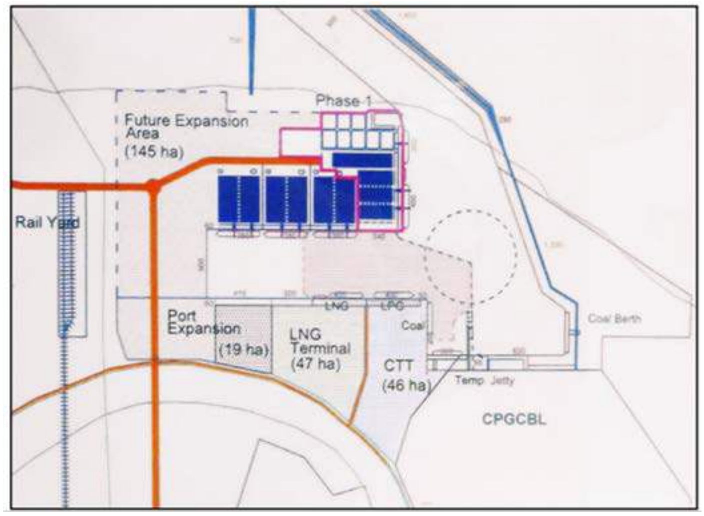
Simultaneously, natural gas pipelines must be strengthened to accommodate the increased demand, especially increased LNG import and transmission.

2) LNG Import Terminal

Table 6.2-4 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



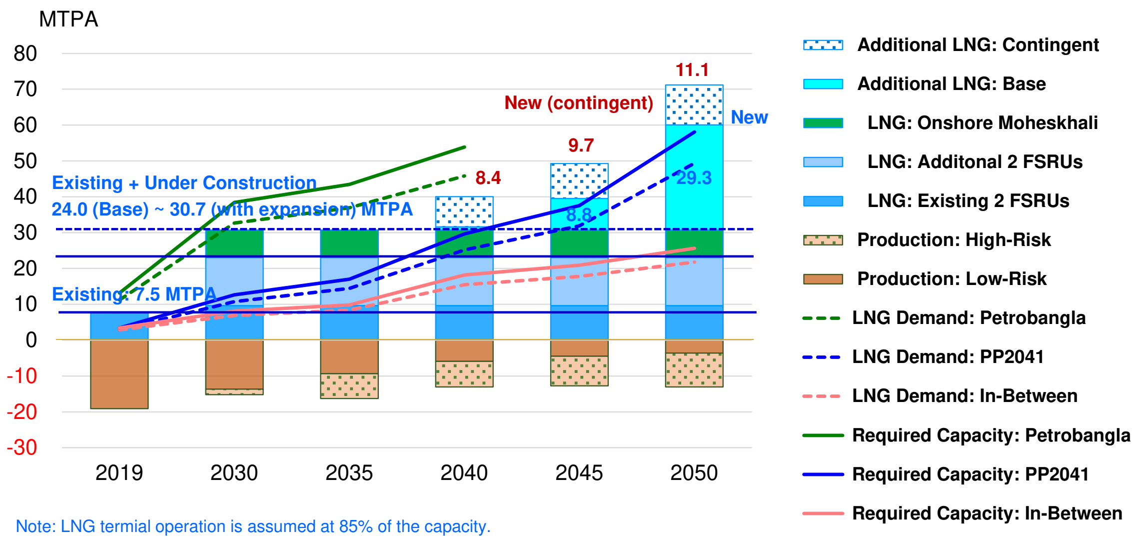
Source: RPGCL

Figure 6.2-3 Matarbari Port Development Plan

Presently two floating storage and regasification units (FSRUs) are in operation in southeastern part of Bangladesh offshore Moheskhali; their expansion is being considered pending gas demand trend. In addition, preparation is being made to introduce two more FSRUs and one onshore LNG terminal as shown in Table 6.2-4. Located at estuaries of big rivers, very shallow water areas are extending to 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 the case of a lease contract, 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 flexible operation with sufficient tank capacity 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 be of long life and will 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 requirement increases 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.

As LNG demand increases, supply scheduling will become more seriously affected by hourly, daily, and seasonal fluctuations of gas demand. As international LNG SPAs are generally rigid providing only limited tolerance for lifting adjustment, demand fluctuation must be absorbed on the LNG buyer’s side. It will become increasingly difficult to cope with demand fluctuation only with FSRUs with limited capacity. To secure sufficient operational flexibility, it is necessary to construct an onshore terminal with greater LNG storage capacity and an additional pipeline to timely send out gas.



Source: IEPMP Study Team

Figure 6.2-4 Requirement for LNG Import Terminals

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 the high-risk potential would not materialize, such consideration must be advanced by 5 years or so. Requirement for LNG import terminals[29] is illustrated in Figure 6.2-4 based on the gas demand projection and natural gas production as shown in Table 6.2-2.

In case gas production from the high-risk potential were not materialized, LNG import capacity needs to be expanded at 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 at around 2035. On one hand, if natural gas demand evolves along with the projection for the In-Between case, such a 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.

3) Cross border LNG import

Due to lack of deepwater ports in Bangladesh, import of vaporized LNG via pipeline is being considered. Feasibility of this plan is yet to be examined, while, likewise with electricity, well-designed international connection is expected to enhance stability of the entire gas supply network.

[29] Calculated applying an annual average re-gas availability at 85%, according to the information provided by Petrobangla.

6.2.4 National Gas Pipeline Network Plan

Currently, the JICA Technical Cooperation Project W/G (Gas Technology Project) is working on improvement of the gas supply 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 pipeline loops with multiple input points to stabilize gas supply in the central area around Dhaka and the western region.

The draft plan presently considered by the project team is shown in Figure 6.2-5. 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, when the Matarbari onshore LNG terminal will be 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[30].

Source: IEPMP Study Team

Figure 6.2-5 National Gas Pipeline Network Plan (Draft)

To provide a resilient gas system, a 36-inch loop will be built in the central metropolitan area around

[30] International LNG contracts usually allow only limited tolerance for lifting. LNG buyers are supposed to manage overall gas procurement by themselves and cope with their demand fluctuation by their own responsibility.

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 and the pipeline connecting to the western loop are 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.

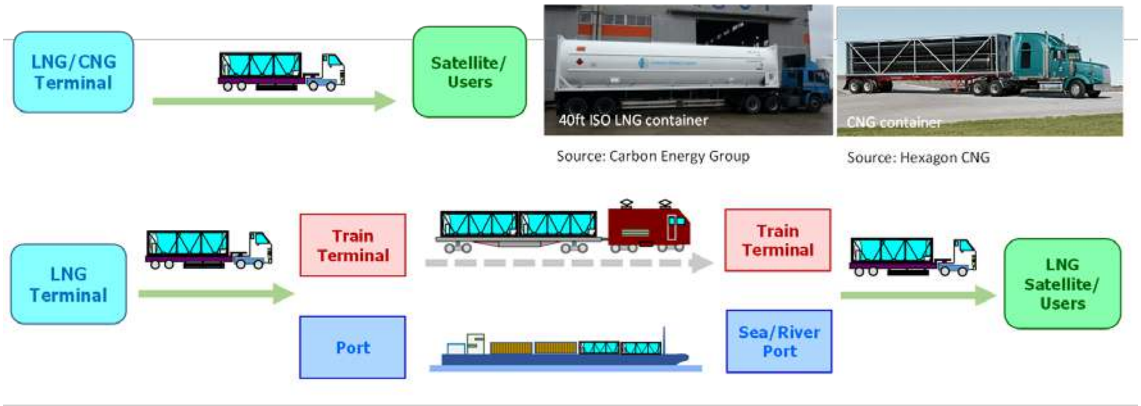
In order to properly manage the entire system as described above, it is necessary to have a centralized operation center such as a Gas Dispatch Center. It will monitor, direct and control operation of the entire gas system. To enable this, it is necessary to install gas metering systems at custody transfer 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[31] 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 supply of gas 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 pipeline connection is impracticable.

For example, LNG is filled in 40-ft containers (18 tons of LNG each) at an onshore LNG terminal, and transported by trailers, railways or river barges as shown in Figure 6.2-6. This system is beneficial as it does not require 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 trunk pipeline, CNG will be more advantageous than LNG because vaporization system is not necessary. However, the CNG approach may be limited to small-medium size users as high-pressure gas storage in a large quantity is difficult. Depending on the demand size, laying a branch pipeline may be practical for a large gas user. If necessary, feasibility of such system may be examined in the course of national gas system development.

[31] For example, the existing pipeline from Moheskhali to Bakhrabad is designed to accommodate 1,700 MMscfd. However, without proper operation system, present gas flow is less than 1,000 MMscfd on average. The gas flow system must be reviewed and upgraded to maximize the flow capacity.



Source: IEPMP Study Team

Figure 6.2-6 Virtual Pipeline by LNG

6.2.5 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 6.2-2, outlook of indigenous gas production is particularly important for the country as the deficit must be made up by import. Though the global market is developed today, LNG import means straight outflow of foreign currencies giving substantial burden on the economy. On the other hand, by increasing domestic production, gas supply will be more stabilized, economy will be stimulated with investment and technologies will be accumulated. Introduction of modern technology and exploration fund that are not available in Bangladesh is a key to success in enabling development 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.

Present gas system in Bangladesh is laden with problems on its relatively outdated designs. Gas leakages observed in many points of the system must be fixed in view of safety, economy and global climate change. Proper and complete measuring and control system must be built in the system for efficient system management.

Modernization of the city gas system, in particular on measuring and pricing, is essential to revitalize the gas business and to promote rationalization of metropolitan development. Because of the problems facing the obsolete system, city gas is being phased out. However, it requires a huge number of LPG cylinders to be delivered or increased electricity consumption in the residential and commercial sectors. In this regard, it is necessary to consider the policy on appropriate distribution of cooking fuel among city gas, LPG and electricity.

6.3 Petroleum Products

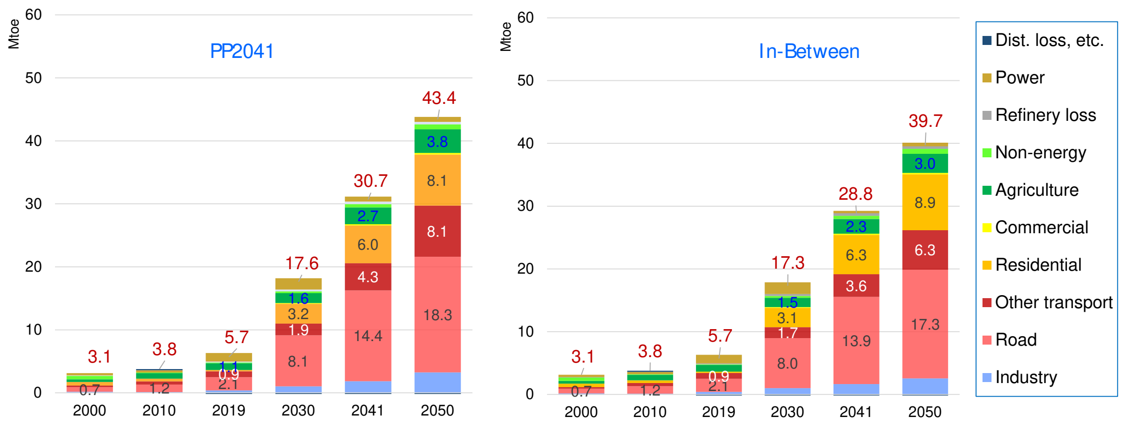
6.3.1 Oil Demand Outlook

Consumption of petroleum products is forecasted to expand 7.6-fold between 2019 and 2050 for the PP2041 GDP case and 7.0-fold for the In-Between Case as shown in Table 6.3-1. 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 6.3-1 Oil Demand Outlook by Sector

	Total Primary Liquid 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	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)							

Source: IEPMP Study Team



Source: IEPMP Study Team

Figure 6.3-1 Oil Demand Outlook by Sector

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. 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 of life. Fuel switching is expected to improve domestic air quality and hence people's health condition. For 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 herein.

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.

Depending on the future transport system and the choice of cooking fuel, consumption of petroleum products is projected to expand greatly and how to supply them, in adequate quantity and quality, is the issue for the oil sector. Also an important issue for consideration is whether they should be supplied by expansion of the domestic refining capacity or by import of products.

6.3.2 Breakdown of Petroleum Demand

Bangladesh Petroleum Corporation (BPC) expects petroleum demand of its marketing companies from 2022FY to 2031FY as shown in Table 6.3-2.

Table 6.3-2 BPC's Demand Outlook

million tons

	2022FY	2023FY	2024FY	2025FY	2026FY	2027FY	2028FY	2029FY	2030FY	2031FY
Gasoline	0.8	0.8	0.8	0.9	0.9	1	1	1.1	1.2	1.2
Kerosene, Jet A-1	0.5	0.5	0.5	0.6	0.6	0.6	0.7	0.7	0.8	0.8
Diesel	4.9	5.3	5.8	6	6.3	6.6	7	7.4	7.9	8.4
HSFO and others	0.9	0.8	0.7	0.8	0.8	0.8	0.8	0.8	0.8	0.9
Total	7.1	7.4	7.8	8.3	8.6	9	9.5	10	10.6	11.3

Taking into account that 1.4 million tons of LPG was imported by private companies in 2021, Fuel Oil (Furnace Oil) imported by Independent Power Producers (IPP), and the above outlook of BPC up to 2030, breakdown of the demand till 2050 are forecast as shown in the Table 6.3-3.

Table 6.3-3 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: IEPMP Study Team

The sales volume of the three marketing companies under the umbrella of BPC (Padma Oil Company Ltd., Jamuna Oil Company Ltd., and Meghna Petroleum Ltd.) will be 10.6 million tons in 2030, increasing to 32.6 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 4.5 million tons in 2030 and will phase out before 2040.

6.3.3 Supply Plan of Petroleum Products

Along with progress in expansion of refineries and installation of Single Point Moorings (SPMs), supply capacity of petroleum products will expand to 17.5 million tons by 2030 including LPG import. Main expansions expected are; a) 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, b) 4.5 million tons per year by the new SPM for petroleum products to start in December 2023 which are being constructed together with the SPM for crude oil handling, and c) 1.0 million tons per year by construction of an LPG import terminal. In the north of the country, import of petroleum products from Numaligarh Refinery Limited of India via India Bangladesh Friendship Pipeline (IBFPL) has already been commissioned in March, 2023.

Table 6.3-4 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: IEPMP Study Team

Once the SPM currently under construction at 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, 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, Chittagong-Dhaka Pipeline (CDPL) and jet fuel pipelines toward Dhaka and Chittagong airports will start operation at the end of 2024 and 2025, respectively. Approximately 40% of the petroleum demand is concentrated in the Dhaka region. In line with the start of the CDPL, it is necessary to increase the capacity of connected oil depots and also to construct new regional oil depots.

Table 6.3-5 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 2023	0.033
CDPL	2.7	End of 2024	0.35
JETA1	0.9	June 2024	0.037
JETA1-2 (SAIA)	0.4	End of 2025	0.02
ERL-2	3.0	Dec 2028	2.20

Source: IEPMP Study Team

By 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 for the two SPMs, their storage capacities and the route of the product pipelines to cover the regional oil demand.

6.3.4 Points to Note

Petroleum demand is expected to increase further beyond 2030; at a rate of 1.28 million tons per year or 25.6 kbd between 2030 and 2050. Against this backdrop, expansion of the national refining capacity is projected with 10 million tons per year or 200 kbd as the ERL Unit-3 with a high cracking capacity to concentrate on production of lighter products. This plan aims to maintain a certain degree of independence on product supply. In addition to the economics, issues on security, flexibility and resilience of the petroleum supply system should be considered to strike a sound balance between the domestic refinery and product import with a deliberate study.

In consideration of the increasing demand in the western regions and improvement of supply security through dispersion of refineries, the Study Team considers that the location of the new refinery should be decided carefully while present candidate sites are Moheskhali and Payra.

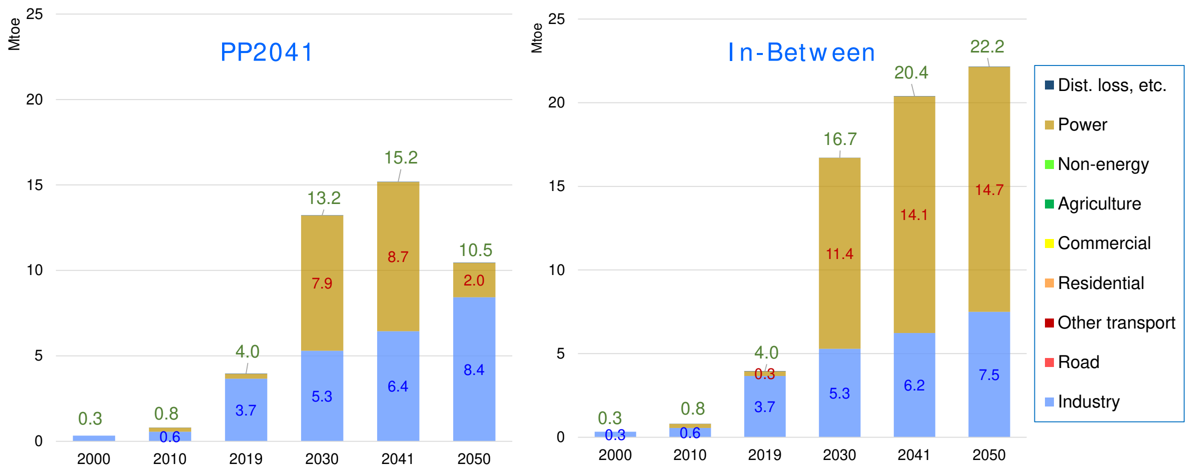
In this plan, after construction of the Moheskhali LPG import terminal with a handling capacity of 1.0 million tons per year, LPG import is projected to grow significantly. This is mainly caused by increasing use of LPG for cooking. As discussed earlier, it is necessary to consider the appropriate distribution of cooking fuel among city gas, LPG and electricity evaluating pros and cons of them.

6.4 Coal At present, domestic natural gas is positioned as the main base power of Bangladesh, but its production is anticipated to decline in the decades to come. Consideration on an appropriate balance between the imported and the domestic coal is required as some amount of coal-fired power plant will remain for a certain period as the primary energy of the base power.

6.4 Coal

6.4.1 Coal Demand Outlook

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



Source: IEPMP Study Team

Figure 6.4-1 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. Later, coal consumption for power will begin to decrease in the early 2040s. On the other hand, if economic growth would be dull like in In-Between case, introduction of innovative fuel would delay, and coal would be used continuously. Nevertheless, the total GHG emissions will be substantially lower compared with the PP2041 case as shown in Figure 4.4-3 due to slower energy demand growth.

Table 6.4-1 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

At present, ammonia co-firing and CCS, both technologies for reducing GHG emissions, are still in their infancy. Selection of low carbon technologies must be investigated carefully including the technologies yet to emerge, and an appropriate guideline for use of coal as one of the primary energies must be set out in consideration of economics, energy security and environmental considerations. The potential of CCS technology should also be confirmed with systematic assessment.

Coal-fired power plants expected to be in operation during the project period are listed in Table 6.4-2 with features on operational parameters. Note that the total Installed Capacity and Annual Consumption totals are indicative figures, as the operating periods are different.

Table 6.4-2 Coal-fired power plants and coal consumption

No.	Name of the Power Plant	Installed Capacity (MW)	Ownership	Plant Efficiency (Gross) (%)	Load Factor (%)	Calorific Value of designed coal (HHV, kcal/kg)	Annual coal consumption (1,000t/y)
1	Barapukuria 250 MW (1st & 2nd Unit) (BPDB SBU)	250	BPDB	32.0%	50%	6,130	480
2	Barapukuria Replace	600		41.0%	70%	6,130	1,259
3	Barapukuria 275 MW (3rd Unit) (BPDB)	274	BPDB	32.0%	50%	6,130	526
4	Payra, Potuakhali 1320MW CFPP (1st Phase)	1,320	BCPCL (NWPGCL)	41.0%	70%	5,050	3,362
5	Maitri Super Thermal PP (Rampal)	1,320	BIFPCL	41.0%	70%	5,500	3,087
6	Payra, Patuakhali 1320MW CFPP (2nd Phase)	1,320	BCPCL (NWPGCL)	41.0%	70%	5,050	3,362
7	Matarbari 1200 MW USC CFPP (Unit-1)	600	CPGCBL	41.3%	70%	4,700	1,630
8	Matarbari 1200 MW USC CFPP (Unit-2)	600	CPGCBL	41.3%	70%	4,700	1,630
9	Patuakhali 1320 (2x660) MW USCPP (Phase-1) (Unit-1)	660	RNPL	41.0%	70%	5,000	1,698
10	Patuakhali 1320 (2x660) MW USCPP (Phase-1) (Unit-2)	660	RNPL	41.0%	70%	5,000	1,698
11	Barishal 307 MW CFPP	307	IPP	41.0%	70%	5,000	790
12	Chittogram 2 x 612 MW CFPP (S.Alam Group)	1,224	IPP	41.0%	70%	5,000	3,149
13	Dhaka Orion	635		41.0%	70%	5,000	1,634
14	Moheskhali 1200 MW USCPP (ECA)	1,200		41.0%	70%	5,000	3,087
15	Matarbali 1200 MW USC CFPP (Phase 2: Unit 3&4)	1,200	CPGCBL	41.3%	70%	4,700	3,261
	Total	12,170					30,652

Note: Coal consumption is estimated on imported coal heat value basis.

Source: IEPMP Study Team

6.4.2 Coal Supply

1) Domestic Coal Production

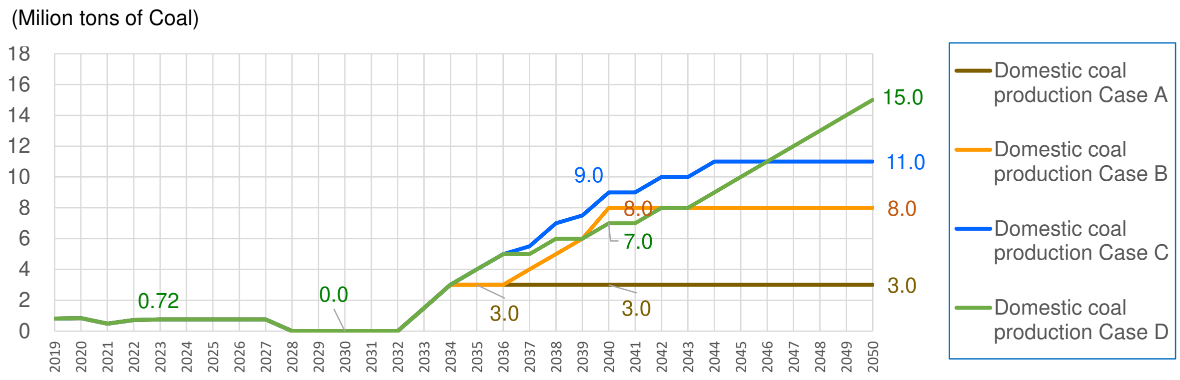
On indigenous coal production, four scenarios are considered on a variety of possibilities of seven coal mines as shown in Table 6.4-3. Case-A and -B are stagnant scenarios that new coal mines will be relatively limited. Case-C and -D consider more utilization of domestic coal. The most important point is the F/S of open-pit mining at the Barapukuria coal mine, the results of which will determine the direction of coal development in Bangladesh for the future. If open-pit mining becomes technically, cost-effectively, and socially and environmentally feasible, both the amount of coal production and the mining rate will be greatly improved.

Table 6.4-3 Case Study on Coal Production

	Project	Case-A	Case-B	Case-C	Case-D	Production start
1	Barapukuria U/G	Production	⇨ Same	⇨ Same	⇨ Same	Producing
2	Dighipara U/G	Feasible >> Production	⇨ Same	⇨ Same	⇨ Same	2033
3	Khalashpir U/G	FS >> Not Feasible	FS >> Feasible >> Production	⇨ Same		2037
4	Jamalganj U/G	FS >> Not Feasible	FS >> Feasible >> Production			
5	Barapukuria O/C	FS >> Not Feasible	⇨ Same	FS >> Feasible >> Production	⇨ Same	2035
6	Phulbari O/C				FS >> Feasible >> Production	2045
Outpot (mt)	2019	0.8	0.8	0.8	0.8	
	2022	0.7	0.7	0.7	0.7	
	2030	0.0	0.0	0.0	0.0	
	2041	3.0	8.0	9.0	7.0	
	2050	3.0	8.0	11.0	15.0	

Note: Assume coal production continue until 2050 in both existing and new mines.

Source: IEPMP Study Team



Source: IEPMP Study Team

Figure 6.4-2 Coal Production Outlook by Scenario

The scenario sequence of the above assessment is as follows:

1) Expansion of the Barapukuria coal mine and development of the Digipara coal mine will be implemented.
2) F/S on open-pit mining in the Barapukuria coal mine and the Khalashpir and pre-F/S of Jamalganj coal field will be conducted
3) If the F/S on open-pit mining at Barapukuria is not favorable, development of the Khalashpir coal mine may be considered.
4) If the F/S on open-pit mining at Barapukuria is favorable and the open-pit development is implemented, development of the Khalashpir coal mine is not necessary.
5) Development of an open-pit mine at Phulbari will be considered after the Barapukuria coal mine starts production by open-pit mining.

2) Coal Supply Balance and Import

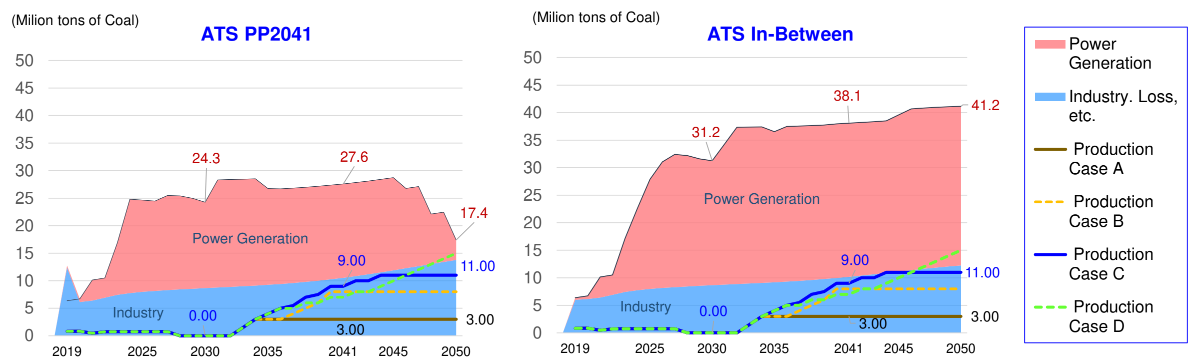
The above study result is summarized in Table 6.4-4 and Figure 6.4-3. Under the PP2041 demand projection with vigorous economic growth, introduction of new energies will progress fast in the power generation sector, and coal consumption may start decreasing in the 2040s. If domestic coal utilization would be stagnant as in Case-A, coal import needs to be continued. On the other hand, with coal mine development as in Case-C, coal import may almost cease by 2050.

Table 6.4-4 Demand/Supply Balance of Coal

	Million tons of coal				Compared with 2019		
	2019	2030	2041	2050	2030	2041	2050
Coal Demand (6,505 kcal/kg equiv.)							
PP2041	6.1	21.6	24.8	17.1	15.5	18.7	11.0
In-Between	6.1	27.3	33.3	36.2	21.2	27.2	30.1
Domestic Production (6,505 kcal/kg equiv.)							
Case A	0.8	0.0	3.0	3.0	-0.8	2.2	2.2
Case-C	0.8	0.0	9.0	11.0	-0.8	8.2	10.2
Coal import (5,000 kcal/kg equiv.)							
PP2041							
Case-A	6.9	28.1	28.3	18.3	21.2	21.5	11.4
Case-C	6.9	28.1	20.5	7.9	21.2	13.7	1.0
In-Between (5,000 kcal/kg equiv.)							
Case-A	6.9	35.5	39.4	43.1	28.6	32.5	36.3
Case-C	6.9	35.5	31.6	32.7	28.6	24.7	25.9

Source: IEPMP Study Team

In contrast, without utilization of domestic coal, significant amount of coal needs to be imported causing a greater foreign currency outflow.



Source: IEPMP Study Team

Figure 6.4-3 Demand/Supply Balance of Coal

Pros and cons of domestic and imported coals are summarized in Table 6.4-5, where underlined parts indicate advantageous features.

Table 6.4-5 Comparison of Domestic and Imported Coal

Evaluation Item	Domestic Coal	Imported Coal
1. Charcoal quality	6,500 kcal/kg	About 5,000 kcal/kg
2. Price	Stable	Unstable
3. Source of supply	Time and initial investment are required to develop new coal mines.	There are many overseas coal-producing countries. Investment in new coal mine development will be decreasing.
4.Transportation infrastructure issues	When supplying power plants that use imported coal, it is necessary to establish a transportation infrastructure from the coal-producing area to the supply site.	Large ship + barge transportation in the Bay of Bengal Need to take measures to maintain stable supply
5.Cash flow	All operating costs can be paid domestically.	Most of the purchase cost plus ocean transport cost are paid to overseas. Foreign currency is needed.
6.Employment security	Employment will increase in areas from production to transportation.	Employment in the domestic transportation industry will increase.
7.Environmental issues during mining	Measures to promote public understanding of environmental destruction are necessary.	None

Source: IEPMP Study Team

6.4.3 Key Policies for Coal Supply and Demand

1) Utilization of Domestic Coal

Coal quality and geological conditions in in Bangladesh are advantageous compared with other countries. It would be possible to meet coal demand in Bangladesh only with domestic coal in the future. In this regard, the following points are to be considered;

1) With utilization of indigenous coal, domestic energy prices will be stable and unaffected by the worldwide situation such as the Ukrainian crisis or energy price hike.
2) Utilization of domestic coal mines can reduce imported coal and prevent foreign currency outflow.
3) Utilization of domestic coal mines will generate employment and contribute to the development of regional economy.
4) Utilization of indigenous energy resources can provide people with affordable energy.

2) Key Policy Recommendations

Coal is expected to support development of electricity supply during the 2020s and 2030s. This would increase import of coal, even though Bangladesh is endowed with rich coal resources. Utilization of domestic coal mines will contribute to regional development as well as enhancement of energy supply security. However, many issues need to be solved by a comprehensive study in relation to coal mine development technology, project economics, environment, coal transportation, and, in particular, consent of local residents. As a prelude to tackle such approach, feasibility studies are required on candidate coal mines as proposed in Table 6.4-3. Main issues to be considered in said comprehensive study will be as follows:

1) Effective utilization of domestic resources is one of options to cope with possible increase in coal import. If domestic coal is utilized, new domestic coal development plan should be considered promptly, so that the preparation period for implementation could be shortened.

2) Early implementation of F/S on open-pit mining is an urgent issue.

3) If any newly developed domestic coal is to be supplied to a thermal power plant that is presently scheduled to use imported coal, F/S should also be conducted on the transportation route and the capacity of the relevant domestic infrastructure.

4) As a measure to ensure a stable supply of imported coal, it is beneficial to install coal transshipment facility at the port of Matarbari. This will enable lightering of ocean-class vessels as well as small-lot coal transport by river barges.

5) To enable prudent use of coal as above, it is necessary to explore every avenue to mitigate the environmental impact and, in particular, to carry out a full-fledged study on application of CCS.

6.5 Other Energy Sources

6.5.1 Requirement of Clean Energy Supply

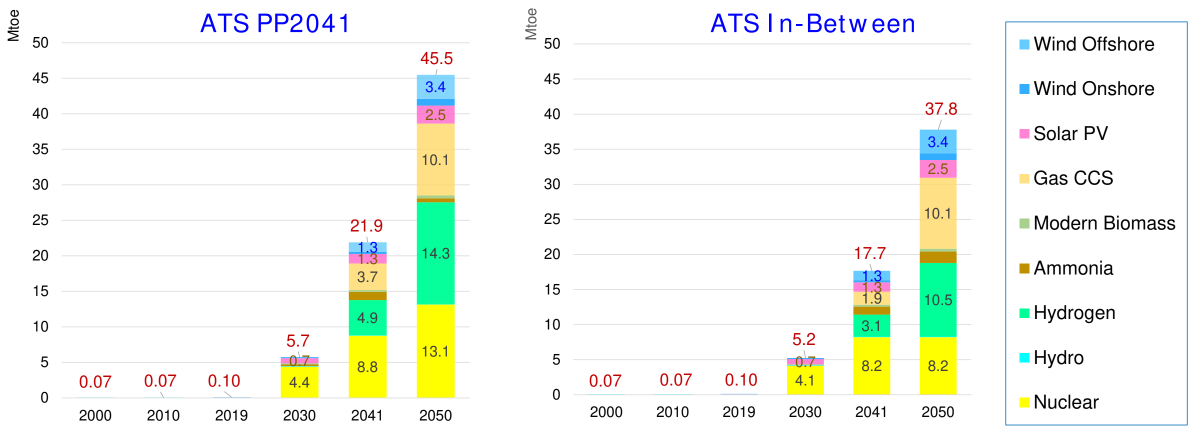
For building a low carbon economy with clean energy sources amounting up to 40% of the power generation mix in 2041, the introduction of clean energies must expand rapidly, including hydro, nuclear, solar PV, wind, modern biomass as well as CCS, ammonia and hydrogen. The total supply of clean energy 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 nil in 2019 to 27% in 2050 for the PP2041 case. In addition, power import includes that of hydro power cum green energies from the neighboring countries.

Table 6.5-1 Clean Energy Supply in the TPES Mix

	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
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 as discussed in Chapter 5. 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 due to high population density. Their introduction is scheduled at a maximum level reasonably conceivable, but the share of these variable new energies will remain below 20% even in 2050.



Source: IEPMP Study Team

Figure 6.5-1 Outlook of Clean Energy Supply

With limited potential of variable renewable resources as above, hydrogen and ammonia are expected to play important roles in the pursuit of a clean energy economy. They will in principle be imported from countries mainly in the Middle East where abundant solar resources are available for hydrogen and ammonia production via electrolysis.

Table 6.5-2 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

However, hydrogen and ammonia can be produced via various methods. Some of them would be available even within the country, such as surplus electricity during non-peak time brought by variable renewable generation, base-load type large power plants such as nuclear, and so on. New technologies may also emerge in the global efforts toward low carbonization. To start with, Bangladesh should join such global endeavors and tackle R&D of these technologies. It may start with study and investigation at first and may develop into pilot projects and eventually to commercial applications. Such activities will also bring up experts on these new technologies who are essential to make the country ready for clean energy economy.

6.5.2 Points to Note

For Bangladesh, the journey to a low carbon economy is not an easy one as the country is unfortunately not endowed with rich renewable energy resources, notably solar radiation, stable wind flow or geothermal heat. The country is characterized with its flat low land with extremely high population density. 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 are yet to be 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.

CCS, for instance, has gained increasing attentions in recent years as one of necessary solutions to realize net-zero emissions. A number of locations in the United States, Europe, and Australia are currently being developed as a “CCS hub” which accommodate multiple carbon capturing and storage operations in a single location.

On hydrogen, while the cost of producing “green hydrogen” is likely to decline in the future thanks to reduction of electrolyzer costs, “pink hydrogen” that is produced from nuclear energy may also become a major hydrogen supply source because of its stability (non-intermittency) of power supply. Supply cost of hydrogen, furthermore, will also decline as the technological development of hydrogen career such as ammonia, liquid organic hydrogen career (LOHC), and liquefied hydrogen (LH_2) will evolve. These technologies are expected to advance significantly in the future. Therefore, it is particularly important to closely monitor their progress and make decisions at an appropriate timing in line with the timeline and important milestones of the energy roadmap.

Hydrogen Application

Many concepts and technologies are being explored for hydrogen utilization which are classified as those mainly relating to source of hydrogen and those on handling of hydrogen in the process of transportation, storage, and utilization.

1. Source of hydrogen
    - Gray hydrogen: hydrogen produced from fossil fuels such as natural gas and coal
    - Blue hydrogen: gray hydrogen with CCS
    - Pink hydrogen: utilization of surplus electricity at nuclear plants
    - Green hydrogen: utilization of surplus electricity of renewable energy generation

2. Handling of hydrogen
    - Liquid hydrogen carrier: ammonia (pressurized), other hydrocarbons such as toluene
    - Liquefied hydrogen: pure hydrogen (extremely low temperature and/or high pressure)

Bangladesh is in a position yet to catch up with front-runners such as China and India among emerging countries. In the talk of energy policy, it should be kept it in mind that eradication of poverty and improvement of the living circumstance to secure citizen's health 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". The 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 poor. In particular, "clean" energy should be easily accessed. Thus, there is a need to switch from firewood to modern energies such as electricity and gas. that are considered to be clean, The question then is "how to supply them securely and at affordable prices, climate concerns aside?" It is aimed to rationally sort out priorities of goals and measures to achieve them under this Energy Master Plan.

6.6 Summary

6.6.1 Energy Roadmap and Milestones

For implementation of the Master Plan, a roadmap for the timing of start-up and investment decision of critical energy supply infrastructure is provided in Table 6.6-1. In the power system development, one of the critical decisions to be made in the short- to mid-term is on the third and fourth unit of additional nuclear plants. Since this Master Plan assumes these units will be on stream from 2033, its feasibility study must start at the latest by 2028. Besides the nuclear power plant, feasibility study of the first offshore wind farm may be undertaken at around 2028. Detailed study for natural gas with CCS and the hydrogen mono-firing power generation will be started at around 2030.

Natural gas will be the main energy to drive the economic growth in particular in the early period. 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.

With regard to the coal supply infrastructure, pending the coal production policy of the government of Bangladesh, investment decisions on Barapukuria underground extension – North and Digipara underground development projects need to be made by 2024. Because it takes relatively long time to prepare for starting production at coal mines, feasibility studies for other mines should also be started from 2024.

For the oil sector, in order to meet the increasing demand and imports, investment decisions must be made by 2025 on the expansion of the existing Eastern Refinery and the installation of a single point mooring system in Moheskhali. In addition, another LPG import facility also needs to be put on stream by 2030 to accommodate the medium-term demand increase; the feasibility study for this facility should be started around 2025.

Uncertainty is high on the long-term LPG demand trend pending clarification on the roles of city gas, LPG and electricity as cooking fuel. An in-depth review should be conducted on this issue before finalizing the long-term LPG plan to cope with the jump in the LPG demand anticipated for the 2030s and beyond.

In the natural gas and LNG sector, decisions are already made on introduction of the third and fourth FSRUs and construction of the onshore LNG terminal at Matarbari. The fourth FSRU is planned for installation in the western part of the country. Its feasibility study should be started well in advance of the expected on-stream year to consider the issues on the whole pipeline system as stated below, and to deal with various constraints including the shallow water depth in the western part of the country.

Besides the import facility, for a stable operation of the domestic gas pipeline system, construction of the new pipeline from Matarbari to Dhaka and the central and western loops as well as upgrading of the existing system are particularly important. The study for the network development should be kicked off as soon as possible. Satellite terminals are also considered to maintain the pressure level of the pipeline network and to ensure the stable gas supply operation. They should be made operational simultaneously with start-up of these import terminals. In line with completion of the Matarbari on-land LNG terminal, possibility of utilizing virtual pipeline system with LNG containers as well as developing cryogenic heat business may also be studied.

On introduction of cleaner energies such as renewable energies, hydrogen, ammonia and CCS, a preliminary Clean Energy Roadmap should be drawn covering the stages from R&D through commercial application: it should be periodically reviewed because of the high degree of uncertainties involved.

Table 6.6-1 Roadmap for critical energy supply infrastructure developments

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#7&#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.

Source: IEPMP Study Team

6.6.2 Key Issues to Note

To support high economic growth projected to achieve the goals for the PP2041, 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. Historically Bangladesh has been dependent on the indigenous natural gas production, but resources are depleting without remarkable discoveries in recent years. To reverse this trend, potential resources much talked about must be discovered and brought into production. In the world, many sophisticated technologies have been developed in the oil and gas exploration, development and production activities during the past two decades. These are expected to greatly change the stagnant status. To introduce technology and fund for the upstream activities from overseas, which are scarce in Bangladesh, it is necessary to prepare proper business circumstances.

b. 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 while improving the long-run economics, upgrading and expansion of land-based LNG import terminals should be given priority.

c. 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 new pipeline connecting Matarbari and Dhaka and 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 to the eastern system: one in the central part of the country around Dhaka and the other covering the western region with multiple input points. In addition, centralized operation system must be established with Gas Dispatch Center. The present gas system is partly obsolete with gas leakages and insufficient monitoring system. It is necessary to modernize and upgrade the system for safe and efficient management.

d. City gas supply for the residential and commercial sectors are presently being restrained, encouraging the introduction of LPG. It is necessary to examine pros and cons of city gas, LPG and electricity as the energy source for cooking and hot water supply and set out a balanced policy to achieve an efficient and low-carbon energy utilization.

2) Oil

a. Concurrently with increasing demand for mobility, oil consumption will expand significantly, keeping the second position in the energy supply mix. Small-scale expansion of the Chittagong refinery is scheduled, but most of the demand increase is going to be supplied by petroleum product imports. A balanced policy should be set out on the roles of domestic refining and product import by 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 bases, inland product pipelines and oil depots should be developed along the timeline.

c. LPG import is projected to expand substantially in the 2030s onwards. As mentioned for natural gas, it is necessary to set out a balanced policy 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 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 transshipping facility for river barges. It will make easier the lightering operation of ocean class vessels and small-lot transportation by river barges.

b. Bangladesh is endowed with coal resources, but with 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 use of domestic coal. Feasibility studies and policy discussions should be made at an earliest possible opportunity.

4) Other Energies

a. Bangladesh is not endowed with typical resources of renewable energies, notably solar, wind and geothermal. Spatial energy density of solar and wind power is low while the country's land area is limited. Application of new biomass technologies for biogas and biofuel faces the same issue in securing sufficient feedstock such as animal wastes and agricultural outputs. Ingenious attempts should be made to best utilize the limited resources and lands such as solar plants in collaboration with agriculture, floating solar, waste-based biogas, etc.

b. Under the circumstance, the country must depend upon industry based clean energy technologies such as nuclear, ammonia-hydrogen and CCS. It is important to develop the way to take in these fast-developing technologies, concerning not only production and import but also transportation, storage, and utilization of them, and to make timely investment decisions. To this end, Clean Energy Roadmap should be prepared, though many concepts and technologies are still unclear or ambiguous at present, to identify the pathway and steps toward a low-carbon economy.

Chapter 7 Priority Projects: Profile and Investment Amounts

More than $175 billion of investment will be necessary during the next three decades through 2050 to construct the energy infrastructure with a low-carbon structure. Most of the investment will occur in the electricity sector where new and innovative technologies must be proactively adopted to achieve the country's goal to increase the composition of clean energies up to 40%. Even in a global viewpoint, these new technologies are still in an early stage of socio-economic application. It is necessary to monitor their development, assess and evaluate most appropriate method to introduce them into Bangladesh, prepare appropriate market conditions and create high quality workforce to implement them. Sectoral assessment of energy investment is developed as below.

7.1 Power System Development

7.1.1 Power generation

Power system development in Bangladesh will require a significant amount of investment because of the sustained power demand growth in the coming decades. While the details of the power system development plans are elaborated in Chapter 5 and Appendix D, Table 7.1-1 summarizes the planned power generation capacity development in the ATS-PP2041 case of this Master Plan. By capacity, natural gas-fired power generation occupies the largest share of the required capacity development, followed by hydrogen and wind. Of the total incremental capacities, about 21% of the plan will be installed during the period from 2022 to 2030, 34% from 2031 to 2041, and the remaining 45% from 2042 to 2050.

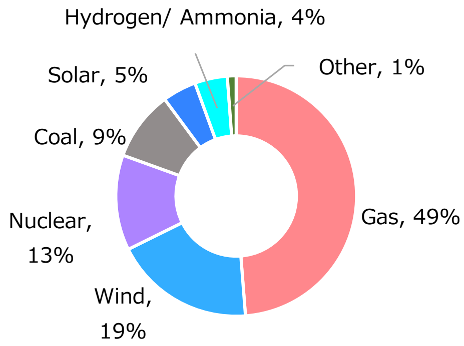
Table 7.1-1 Power Generation Capacity Additions and Required Investment (ATS-PP2041)

	Capacity Addition (GW)				Required Investmentt (US$ billion)			
	2023-2030	2031-2041	2042-2050	Total	2023-2030	2031-2041	2042-2050	Total
Gas	13.2	26.5	31.6	71.2	9.7	19.5	23.3	52.6
Gas+CCS	0.0	4.3	8.8	13.1	0.0	8.3	15.7	24.0
Coal	7.6	2.3	0.0	10.0	11.3	3.4	0.0	14.7
Oil	0.5	0.8	0.7	2.0	0.3	0.5	0.5	1.4
Fossil Fuel Total	21.3	33.9	41.1	96.3	21.3	31.8	39.5	92.6
Nuclear	2.4	2.2	2.2	6.8	7.0	6.6	6.6	20.1
Hydrogen	0.0	1.6	1.6	3.2	0.0	1.3	1.3	2.6
Ammonia	1.3	1.3	0.0	2.6	2.1	2.1	0.0	4.3
New Fuel Total	1.3	2.9	1.6	5.8	2.1	3.4	1.3	6.9
PV (Solar park)	3.1	0.4	2.5	6.0	1.2	0.2	0.7	2.1
PV (rooftop)	1.6	4.0	6.0	11.6	0.9	1.9	2.3	5.1
On-shore wind	0.8	0.8	3.4	5.0	0.8	0.9	3.6	5.3
Off-shore wind	0.0	6.0	9.0	15.0	0.0	10.8	13.7	24.4
Biomass	0.1	0.1	0.1	0.2	0.2	0.1	0.2	0.5
RE Total	5.5	11.3	21.0	37.8	3.1	13.8	20.5	37.4
Total	30.5	50.4	65.9	146.8	33.6	55.6	67.9	157.0

Remarks: Due to rounding, the total may not equal to the simple sum of each period.

Source: IEPMP Study Team

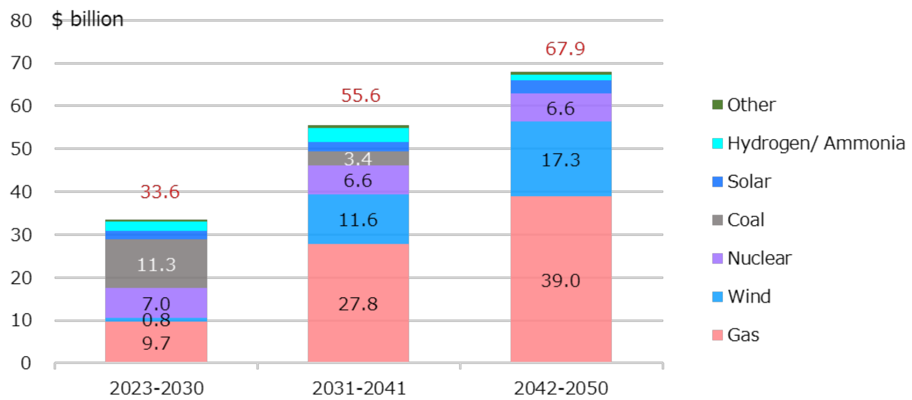
The required investment amount of these generation capacity installations is estimated at US$ 157 billion in total (Figure 7.1-1). The investment for natural gas-fired power generation (including those with CCS) is the largest (49%) followed by wind (19%), and nuclear (13%).



Source: IEPMP Study Team

Figure 7.1-1 Required Investment for Power Generation Capacity (ATS-PP2041)

Required investments for the generation capacity development will increase in later periods of this Master Plan. This is because of the accelerated demand growth in later periods and increased shares of higher cost power generation sources such as nuclear, hydrogen, and offshore wind (Figure 7.1-2). Currently, Bangladesh has a surplus generation capacity and thus additional investment will not be an urgent issue even though its power demand will keep growing. However, in the later stage, such surplus capacity will shrink, and investments will need to be accelerated in accordance with the demand growth. It should also be noted that the required investment will be subject to the actual demand development in the future.



Note: Gas includes both plants with and without CCS; Wind includes both onshore wind and offshore wind

Source: IEPMP Study Team

Figure 7.1-2 Required Investment for Power Development Plan (ATS-PP2041)

Annual required investment for the power generation sector is provided as in Table 7.1-2.

Table 7.1-2 Annual required investment for the power generation sector (ATS-PP2041)

$2021 million	Gas	Gas+CCS	Coal	Oil	Nuclear	Hydrogen	Ammonia	PV (Solar park)	PV (rooftop)	On-shore wind	Off-shore wind	Biomass
2023	2,935	0	2,765	487	0	0		383	200	94	0	12
2024	1,463	0	3,616	0	1,030	0		383	200	94	0	12
2025	1,966	0	0	0	1,030	0		383	200	94	0	12
2026	1,683	0	0	0	0	0		383	200	94	0	12
2027	660	0	635	0	0	0	660	383	200	94	0	12
2028	0	0	0	0	300	0		383	200	94	0	12
2029	1,600	0	0	0	0	0		383	200	94	0	12
2030	2,885	0	622	0	0	0	660	383	200	94	0	12
2031	3,679	598	2,328	0	0	0		40	364	75	545	5
2032	4,474	728	0	0	0	0		40	364	75	545	5
2033	688	112	0	100	1,116	0		40	364	75	545	5
2034	4,597	747	0	100	1,116	0		40	364	75	545	5
2035	1,135	185	0	100	0	0	660	40	364	75	545	5
2036	3,926	638	0	100	0	0		40	364	75	545	5
2037	1,935	315	0	100	0	0		40	364	75	545	5
2038	3,970	646	0	0	0	0		40	364	75	545	5
2039	1,204	196	0	100	0	0		40	364	75	545	5
2040	0	0	0	100	0	1,600	660	40	364	75	545	5
2041	860	140	0	100	0	0		40	364	75	545	5
2042	0	0	0	100	0	800		278	667	381	1,000	9
2043	2,818	782	0	100	0	0		278	667	381	1,000	9
2044	1,840	510	0	100	1,116	1,600		278	667	381	1,000	9
2045	626	174	0	100	1,116	800		278	667	381	1,000	9
2046	6,889	1,911	0	100	0	0		278	667	381	1,000	9
2047	3,757	1,043	0	0	0	0		278	667	381	1,000	9
2048	6,889	1,911	0	100	0	800		278	667	381	1,000	9
2049	3,757	1,043	0	0	0	800		278	667	381	1,000	9
2050	5,010	1,390	0	100	0	0		278	667	381	1,000	9

Source: IEPMP Study Team

In ATS In-Between case, the required power generation capacity development is estimated as in the Table 7.1-3, and the annual required investment amount is provided in Table 7.1-4. Compared to the estimate in ATS-PP2041 scenario, the entire size of capacity expansion and the required investment amount in ATS In-Between case are significantly curtailed reflecting the lower electricity demand in In-Between case.

Table 7.1-3 Power Generation Capacity Additions and Required Investment (ATS-In-Between)

	Capacity Addition (GW)				Required Investmentt (US$ billion)			
	2023-2030	2031-2041	2042-2050	Total	2023-2030	2031-2041	2042-2050	Total
Gas	8.2	19.5	11.1	38.8	6.0	14.4	8.2	28.6
Gas+CCS	0.0	3.2	3.1	6.3	0.0	6.1	5.5	11.6
Coal	7.0	3.8	0.0	10.8	10.4	5.5	0.0	15.9
Oil	1.0	1.8	4.7	7.4	0.7	1.2	3.2	5.1
Fossil Fuel Total	16.2	28.2	18.9	63.2	17.1	27.2	16.9	61.2
Nuclear	2.1	2.4	0.0	4.5	6.1	7.1	0.0	13.2
Hydrogen	0.0	1.6	1.6	3.2	0.0	1.3	1.3	2.6
Ammonia	1.3	1.3	0.0	2.6	2.1	2.1	0.0	4.3
New Fuel Total	1.3	2.9	1.6	5.8	2.1	3.4	1.3	6.9
PV (Solar park)	3.1	0.4	2.5	6.0	1.2	0.2	0.7	2.1
PV (rooftop)	1.6	4.0	6.0	11.6	0.9	1.9	2.3	5.1
On-shore wind	0.8	0.8	3.4	5.0	0.8	0.9	3.6	5.3
Off-shore wind	0.0	6.0	9.0	15.0	0.0	10.8	13.7	24.4
Biomass	0.1	0.1	0.1	0.2	0.2	0.1	0.2	0.5
RE Total	5.5	11.3	21.0	37.8	3.1	13.8	20.5	37.4
Total	25.1	44.8	41.5	111.4	28.4	51.5	38.7	118.6

Figures for ammonia show the capacity for co-firing at coal-fired power plants

Source: IEPMP Study Team

Table 7.1-4 Annual required investment for the power generation sector (ATS-In-Between)

$2021 million	Gas	Gas+CCS	Coal	Oil	Nuclear	Hydrogen	Ammonia	PV (Solar park)	PV (rooftop)	On-shore wind	Off-shore wind	Biomass
2023	1,286	0	1,541	654	0	0		383	200	94	0	12
2024	1,874	0	2,410	324	1,030	0		383	200	94	0	12
2025	1,636	0	1,808	0	1,030	0		383	200	94	0	12
2026	1,500	0	622	2	0	0		383	200	94	0	12
2027	1,735	0	635	0	0	0	660	383	200	94	0	12
2028	0	0	5	0	0	0		383	200	94	0	12
2029	150	0	0	0	0	0		383	200	94	0	12
2030	0	0	0	0	0	0	660	383	200	94	0	12
2031	0	0	1,200	0	0	0		40	364	75	545	5
2032	1,419	231	1,200	0	0	0		40	364	75	545	5
2033	1,032	168	0	153	1,200	0		40	364	75	545	5
2034	1,935	315	0	150	1,200	0		40	364	75	545	5
2035	2,451	399	150	0	0	0	660	40	364	75	545	5
2036	2,752	448	600	0	0	0		40	364	75	545	5
2037	2,537	413	0	500	0	0		40	364	75	545	5
2038	2,064	336	0	150	0	0		40	364	75	545	5
2039	2,451	399	0	250	0	0		40	364	75	545	5
2040	688	112	600	250	0	1,600	660	40	364	75	545	5
2041	2,150	350	0	350	0	0		40	364	75	545	5
2042	1,605	445	0	350	0	800		278	667	381	1,000	9
2043	1,605	445	0	350	0	0		278	667	381	1,000	9
2044	626	174	0	350	0	1,600		278	667	381	1,000	9
2045	705	195	0	500	0	1,400		278	667	381	1,000	9
2046	1,683	467	0	650	0	600		278	667	381	1,000	9
2047	2,583	717	0	350	0	0		278	667	381	1,000	9
2048	705	195	0	750	0	800		278	667	381	1,000	9
2049	1,252	348	0	750	0	800		278	667	381	1,000	9
2050	352	98	0	600	0	0		278	667	381	1,000	9

Source: IEPMP Study Team

7.1.2 Power transmission

The power transmission sector also requires a significant expansion during the period of IEPMP. Table 7.1-3 shows the amount of new major transmission infrastructure to be constructed by 2030. These facilities include both overhead transmission lines with conductors and underground transmission lines. The table shows that the total construction cost by 2030 is about US$ 2 billion, which indicates the annual required investment in the transmission sector of about US$ 0.4 billion.

Table 7.1-5 Power Transmission Capacity Additions and Required Investment

Sl. No.	Component	Unit	Unit price (in lac taka)		US $ /BDT		
Transmission line				**km**	**lac taka**	**0.0094**	**US $**
1	765 kV Double circuit Line	km	1,760	350	616,000.00		
2	400 kV Double circuit Line (Quad ACSR Finch)	km	980	141	138,180.00		
3	230 kV Double circuit Line (Twin ACSR Mallerd)	km	410	369.556	151,517.96		
4	132 kV Double circuit Line* (single Grosbeak)	km	150	527.5	79,125.00		
				Sub.total	984,822.96		925,733,582.40
Substation				**no.**			
1	400 kV Substation AIS	no.	55,000	17	935,000.00		
2	230 kV Substation AIS	no.	13,000	10	130,000.00		
3	132 kV Substation AIS	no.	6,500	7	45,500.00		
				Sub.total	1,110,500.00		1,043,870,000.00
						Total	1,969,603,582.40

Source: IEPMP Study Team based on the provided material from PGCB

The precise estimate of investment amount in the transmission sector from 2030 to 2050 requires detailed transmission system development plan and is beyond the scope of IEPMP. An approximate amount of required investment during the period is estimated at US$ 0.6 to 0.8 billion per year given the previous estimate made in the PSMP2016 and the above estimate by 2030.

While this Master Plan assumes that the electricity demand will grow from 2019 to 2050 by more than seven times in PP2041 case, the future demand outlook always contains high uncertainties and thus periodical review of demand analysis and above power generation and transmission investment plans is necessary.

7.2 Primary Energy Supply

7.2.1 Natural Gas and LNG

Natural gas will occupy the largest share of the total primary energy supply of Bangladesh, and its supply infrastructure will also require significant investments. Infrastructure projects in the natural gas and LNG sector are categorized into two segments: import facilities and the domestic supply networks. Projects that are planned for these two segments are summarized in Table 7.2-1 and Table 7.2-2, respectively. The largest number of projects is planned for installation of floating regasification and storage unit (FSRU), though they may be hired on lease, while one onshore receiving terminal (and its expansion) is also included. Most of these natural gas import facilities are planned in the Matarbari / Moheskhali area, but several FSRUs will also be installed in the western part of the country. Regarding the domestic natural gas supply network, the major component will be the construction of four major trunk pipelines. In addition to the trunk pipeline projects, development of virtual pipeline is included in the list.

The sum of the required investment in the natural gas / LNG sector is estimated at US$ 4.0 billion (Table 7.2-3) (US$ 3.2 billion for natural gas / LNG import and US$ 0.8 billion for domestic network development). Required amount of investment by item is largest for FSRU installation followed by onshore terminal construction. In general, FSRUs are hired on lease without incurring upfront expenditure, while land-based LNG terminals are constructed with material investment of fund which are generally procured through international institutional financing.

Table 7.2-1 Major Natural Gas Import Terminal Projects

Project	Location	Capacity (mmcfd)	Onstream	Remarks	Status
FSRU #3	Matarbari	750	2025-2030	Remodel	Base
FSRU #4	Payra	1,000	2028-2035	Remodel	Base
FSRU #5	TBN	1,000	2035-2041	Remodel	Contingent
FSRU #6	TBN	1,000	2041-2045	Remodel	Contingent
FSRU -Replacement #1	Matarbari	1,000	2041-2045	Remodel	Base
FSRU -Replacement #2	Matarbari	1,000	2041-2045	Remodel	Base
FSRU -Replacement #3	Matarbari	1,000	2045-2050	Remodel	Base
Onshore terminal #1	Matarbari	1,000	2035-2041	New build	Base
Total		7,750			

*FSRU may be utilized on leased basis

Source: IEPMP Study Team

Table 7.2-2 Major Domestic Natural Gas Supply Network Projects

Project	Type	Distance	Onstream	Remarks
Moheshkali~Ashugani	Pipeline	360 km	2025-2030	48 inch
Moheshkali~Feni	Pipeline	200 km	2025-2030	56 inch
Bheramara~Khulna	Pipeline	160 km	2025-2030	36 inch
Bakhrabad~Langajband	Pipeline	50 km	2025-2030	36 inch
Feni	Compressor		2025-2030	
Satelite terminals	Terminal		2025-2030	
Feni~Bakhrabad		100 km	2031-2041	56 inch
Ashugani	Compressor		2042-2050	

Source: IEPMP Study Team

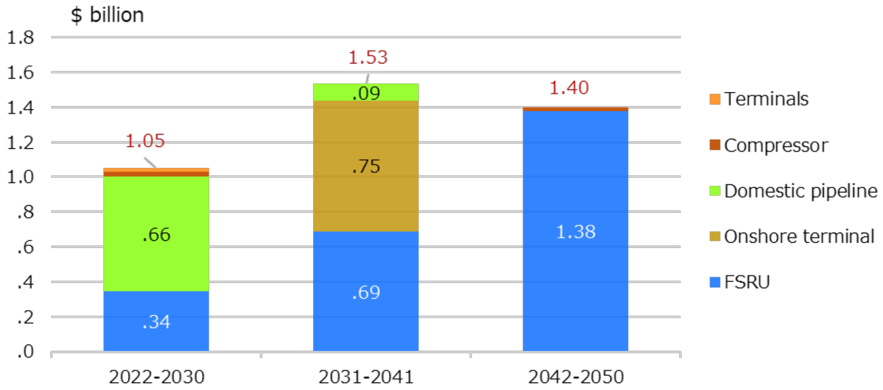
It should be noted that the above estimation of the necessary investment amount does not include the expenditure for exploration, development and production of domestic natural gas. However, natural gas cost analysis is provided in Section 7.4.

Table 7.2-3 Required Investment: Natural Gas and LNG Supply

	2022-2030	2031-2041	2042-2050	Total	
	$ million	$ million	$ million	$ million	
FSRU	344	688	1,376	2,408	60.4%
Onshore terminal		750		750	18.8%
Domestic pipeline	660	94		754	18.9%
Compressor	25		25	50	1.3%
Terminals	25			25	0.6%
Total	1,053	1,532	1,401	3,987	100.0%

Source: IEPMP Study Team

Required investments for natural gas and LNG sector will increase after 2030. This is also because of the same reason as the power system development: accelerated growth of the natural gas demand and more investment needs for natural gas import facilities (Figure 7.2-1). Although this chapter covers only the major infrastructure development, as the demand of natural gas expands in non-power generation sectors such as industry and building, distribution pipeline network for city gas and community gas will also need to be developed. The required investment will be subject to change depending on the actual demand development in the future; close monitoring of the demand and revision of the investment plan will be important.



Source: IEPMP Study Team

Figure 7.2-1 Required Investment: Gas Sector

7.2.2 Refinery and Oil Import Terminals

Petroleum products will enlarge its role in the total primary energy supply of Bangladesh. The expansion of its supply infrastructure will be limited to a certain area, nevertheless, it will also require huge investments. Infrastructure projects in the petroleum sector are categorized into four segments: refineries, import facilities, pipelines and oil depots. Projects that are planned in this Master Plan for these segments other than oil depots are summarized in the following tables, respectively. Expansion of refining capacity is planned for the existing ERL refinery. Regarding import facilities, construction of two SPMs is the major component.

Table 7.2-4 Refinery Expansion Projects

Refinery Project	Location	Capacity	Onstream	Investment	Remarks
		mil.tons/year		$ million	
ERL #2 Expansion	Chittagong	3.0	2028	2,200	New build
ERL #3 Expansion	Chittagong	10.0	2031-2041	6,667	New build

Source: IEPMP Study Team

Table 7.2-5 Oil Products Import Terminal Projects

Projects on Product Import	Location	Capacity	Onstream	Investment	Remarks
		mil.tons/year		$ million	
SPM & Import Terminal	Moheskhali	9.0	2023	700	Expansion
SPM #2 & Import Termial	TBN	10.0	2031-2041	700	New build
SPM #3 & Import Termial	TBN	10.0	2031-2041	700	New build
LPG Import Terminal	Moheskhali	1.0	2022-2030	305	New build
LPG #2 Import Terminal	TBN	2.0	2031-2041	610	New build
New LPG Import Terminals	TBN	5.0	2042-2050	1,525	New build
Total				4,540	

Source: IEPMP Study Team

Table 7.2-6 Oil Product Pipelines

Project	Location	Capacity	Onstream	Investment	Remarks
		mil.tons/year		$ million	
IBFPL (pipeline)		1.0	2023	33	New build
DCPL (pipeline)		2.7	2024	350	New build
JETA (pipeline)		0.9	2024	37	New build

Source: IEPMP Study Team

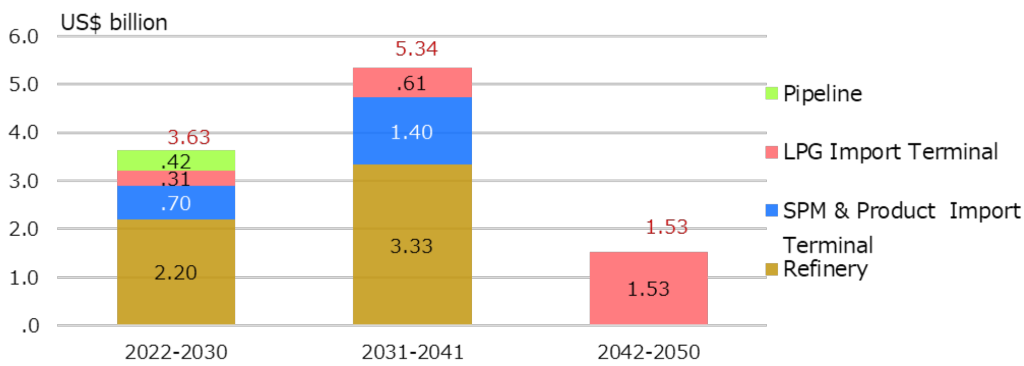
Required investments for the petroleum sector will be larger in the earlier period of this Master Plan. This is because oil demand will increase rapidly in this period. As described in Figure 6.3-1, the average growth rate of oil demand is much higher in the period of 2019-2030 compared with other periods.

Table 7.2-7 Required Investment: Oil Sector

	2022-2030	2031-2041	2042-2050	Total	
	$ million	$ million	$ million	$ million	
SPM & Product Import Terminal	700	1,400		2,100	15.2%
LPG Import Terminal	305	610	1,525	2,440	17.6%
Pipeline	420			420	3.0%
Refinery	2,200		6,667	8,867	64.1%
Total	3,625	2,010	8,192	13,827	100%

Source: IEPMP Study Team

In this Master Plan, expansion of the domestic refining capacity is assumed relatively low while a larger part of demand increase will depend on petroleum product import. However, in view of the long-run economics and supply security, priority would be given to much larger expansion of the refining capacity. If such scenario were adopted, investment of more than US$10 billion will become necessary.



Source: IEPMP Study Team

Figure 7.2-2 Required Investment: Oil Sector

7.2.3 Coal Development and Import

Coal is expected to be used in the industry and power sectors, and utilization of domestic resources will play an important role to satisfy the demand. Imported coal is used for power generation, however, this Master Plan expects that coal consumption for power generation will decrease during the 2040s and shift to ammonia-cofiring. Accordingly, no expansion of coal import facilities is assumed except for a coal transshipment terminal in Matarbari, and development of domestic coal mines is envisaged instead of coal imports. As indicated in Table 6.4-3, the six-project development, including planned and proposed projects by BCMCL, are considered in the period of this Master Plan. Required investments for the coal sector will increase in the earlier period in order to meet the demand increase during 2020s and 2030s. The estimated investments in the Barapukuria expansion and Digipara are based on the F/S results, however, the required investment will be subject to change depending on the results of the F/S for other projects.

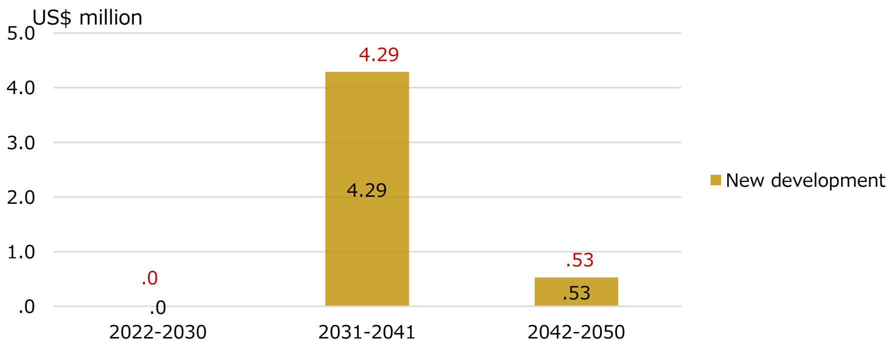
Table 7.2-8 Development of domestic coal mines

Project	Minig method	Capacity	Onstream*	Investment	Remarks
		mil.tons/year		$ million	
Barapukuria**	O/C	1.0-6.0	2031-2041	191	New development
Digipara	U/G	0.5-3.0	2031-2041	2,050	New development
Khalashpir**	U/G	0.5-2.0	2031-2041	2,050	New development
Phulbari**	O/C	1.0-7.0	2042-2050	530	New development

Note: * Those are possible timing of supply and production assumed by IEPMP Study Team.

** These coal mines may or may not be developed depending on the future domestic coal production plan (See Table 6.4-3 of Chapter 6).

Source: IEPMP Study Team



Source: IEPMP Study Team

Figure 7.2-3 Required Investment for Domestic Coal Development

7.3 Summary: Energy Investment

As summarized in Table 7.3-1, more than $180 billion of investment will be necessary during the next three decades through 2050 to construct the necessary energy infrastructure. This estimation does not include the investment on the following items.

a. Natural gas: upstream activities for exploration, development and production, and city gas distribution system. Though a hypothetical investment amount ($2.4 billion) is assumed for introduction of FSRUs, upfront investment would not occur in Bangladesh as FSRUs are generally hired on lease.

b. Oil: oil transport activities other than product pipeline, and oil depots.

c. Coal: domestic coal transport activities.

d. Electricity: transmission and distribution activities.

Table 7.3-1 Required Investment on Energy Infrastructure

	2022-2030	2031-2041	2042-2050	Total	
	$ billion	$ billion	$ billion	$ billion	
Coal	2.1	2.5	0.5	5.0	2.8%
Oil	3.6	2.0	8.2	13.8	7.7%
Natural Gas	1.1	1.5	1.4	4.0	2.2%
Fossil Fuel Total	6.7	6.0	10.1	22.9	12.7%
Fossil Fuel	21.3	23.5	23.8	68.6	38.2%
Nuclear	7.0	6.6	6.6	20.1	11.2%
RE:Solar, Wind, Biomass	3.1	13.8	20.5	37.4	20.8%
Ammonia/Hydrogen	2.1	3.4	1.3	6.9	3.8%
Gas + CCS	0.0	8.3	15.7	24.0	13.3%
Power Generation	33.6	55.6	67.9	157.0	87.3%
Total	40.3	61.6	78.0	179.9	100.0%

Source: IEPMP Study Team

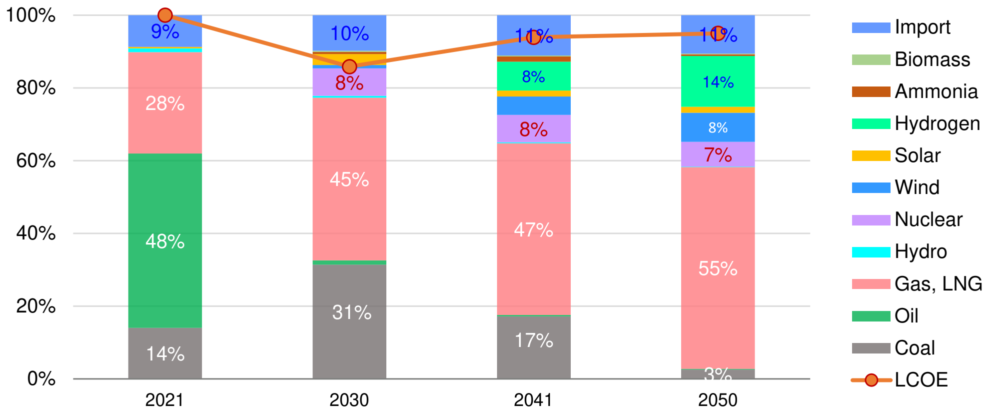
As shown in the table, the required amount will increase in the later periods as proactive investment will become necessary to promote low carbonization of the energy structure. Intensive investments on cleaner energies will occur mainly in the electricity sector.

An overwhelming amount of investment is required in the electricity sector; dominance of the sector will be even greater if the investment for transmission and distribution system is included. This means that the long-term electricity development plan should be scheduled with utmost care, and that the primary energy sector development should be well aligned to support optimization of the investment in the electricity sector. On the other hand, the electricity sector investment schedules adoption of innovative technologies such as co-firing with ammonia and hydrogen as well as CCS. Among them, a dedicated study is necessary to assess the potential of CCS utilization in Bangladesh. These technologies are still in the preliminary stage of socio-economic application in the world. For introduction of them, a business platform must be established considering the peculiar conditions in this country.

7.4 Cost of Energy Supply

7.4.1 Power supply cost

Supply cost and the composition of generated power is shown below. The supply cost is calculated as the weighted average of unit cost and power generation of each power generation source and is shown as an indexed value with the current (2021) figure set at 100.



Source: IEPMP Study Team

Figure 7.4-1 Supply Cost and Composition of Generated Power (ATS/PP2041 case)

The power supply cost will drop to around 80% in 2030 and then rise, but will remain below the current level. At present, the composition of oil-fired power plants with high fuel cost is high. But in 2030, the composition of oil-fired power plants will decrease sharply: instead, that of coal-fired power plants with lower fuel cost will increase. As a result, the supply cost in 2030 will drop by about 20 points from the current level. Towards 2050, composition of coal-fired power with lower fuel cost will decrease, while composition of hydrogen-fired power and gas-fired power with CCS, which have high generating costs, will increase. However, most of the gas-fired power plants that will be newly developed after 2030 will be of the latest combined-cycle designs with significantly higher thermal efficiency than those currently in operation. Therefore, even after 2040, supply costs will remain at a slightly lower level than at present.

7.4.2 Natural gas supply cost

Natural gas is the largest energy source both for power and non-power sectors in Bangladesh and thus its supply cost will affect the country's economy. Theoretical natural gas supply cost is also calculated as a weighted average of the unit cost of respective supply source and the expected supply volume. Unit cost of natural gas supply by source is provided in Table 7.4-1. Cost of domestic production and pipeline import are set in reference to the material published by IEA[32] and the cost for LNG import is estimated by the Study Team. For LNG price, global LNG market is assumed to be rebalanced and stabilized thanks to addition of new LNG export project which are being constructed and waiting for final investment decisions.

Table 7.4-1 Unit cost of natural gas supply

[32] International Energy Agency, "Domestic natural gas production costs, LNG import prices and industry gas prices in developing Asia import markets, 2018," 6 March 2020. (https://www.iea.org/data-and-statistics/charts/domestic-natural-gas-production-costs-lng-import-prices-and-industry-gas-prices-in-developing-asia-import-markets-2018-2) Accessed on August 16. 2022. This is an assessment on the present production and would not necessarily represent the cost of natural gas to be developed in the future.

Unit: US$/mmbtu	2020	2030	2040	2050
Domestic production	2.75	2.75	2.75	2.75
LNG import	8.31	6.95	7.03	7.10
Pipeline import	5.05	5.05	5.05	5.05

Note: LNG import include import from own equity.

Source: IEPMP Study Team

Based on the cost data in Table 7.4-1 and forecasted natural gas supply, theoretical cost of natural gas supply is calculated for 2030, 2041, and 2050 as shown in Table 7.4-2. Four different patterns are calculated applying the two demand scenarios (PP2041 case and In-between case) and the two domestic natural gas production scenarios (Base scenario and High-risk scenario). The highest cost increase will occur in the combination of PP2041 and Base production scenario; the indexed cost will increase by 95% from 2019 to 2050. This is because of the smaller domestic production, larger domestic demand, and thus the larger LNG import. The least cost increase case is the In-between - High risk case where the cost will increase by 75% during the same period because of its larger domestic production, smaller demand, and smaller LNG import.

Table 7.4-2 Estimated supply cost of natural gas in Bangladesh

2019=100	2019	2030	2041	2050
PP2041-Base	100	148	183	195
PP2041-High risk	100	137	162	180
In between - Base	100	145	180	193
In between - High risk	100	135	154	175

Source: IEPMP Study Team

7.4.3 Hydrogen and Ammonia supply cost

As Bangladesh is not endowed with sufficient natural gas and renewable energy resources, it will be a practical way to import hydrogen and ammonia from overseas. In the 2030s, import of blue-hydrogen and -ammonia generated from fossil fuels combined with CC(U)S is considered in accordance with the suggestion of the IEA[33] that they will be the most competitive source of clean energy around that time. On the other hand, there are reports that green-hydrogen and -ammonia, which are derived from renewable energy sources, will become as cheap as the blue-hydrogen in the 2040s and will become cheaper than the blue-hydrogen in the 2050s. Therefore, this Master Plan assumes to start introducing green hydrogen and ammonia in 2041 and gradually expand its use.

Table 7.4-3 shows the results of a preliminary estimation of the procurement costs of hydrogen and ammonia. The estimation is made based on the reliable literatures of the IEA, other government agencies, and private research firms, and are adjusted assuming procurement in

[33] The Future of Hydrogen (2019)

Bangladesh. See Appendix D for details of the calculations.

Table 7.4-3 Fuel cost of hydrogen and ammonia for power generation

Hydrogen	Weighted average of blue and green	Blue	Green
	US $ /kg-H2	US $ /kg-H2	US $ /kg-H2
2030	2.82	2.82	4.36
2041	2.60	2.50	3.43
2050	2.46	2.25	2.66

Ammonia	Weighted average of blue and green	Blue	Green
	US $ /ton-NH3	US $ /ton-NH3	US $ /ton-NH3
2030	355	355	632
2041	343	326	492
2050	340	302	378

Source: IEPMP Study Team

7.5 Policy Actions on Investment

To conclude this chapter, three policy actions are proposed in relation to the project development in Bangladesh. The first and foremost important policy action in this area will be to secure the required fund and technology. It will be ideal that power companies or oil and gas companies can secure necessary fund for their required investments by themselves, but given the current fiscal balances of these companies and the significant size of the required investments, some forms of the government's support will be inevitable. In addition, advanced technologies are generally expensive and owned mainly by international oil industry players. In this regard, inviting private and foreign investors will also be crucial to ensure the required investment in accordance with the demand growth. Multilateral development banks such as the World Bank and Asia Development Bank and export credit agencies may also be ready to support the infrastructure development of Bangladesh. Institutional arrangements required to incentivize private and foreign investors to the Bangladeshi energy sector as well as close and timely coordination with relevant development partners will be necessary to ensure seamless infrastructure development with sufficient investment fund.

Second, what should be considered in the context of infrastructure development is the reform of energy pricing system to enable the power companies and oil and gas companies to invest for the required supply system. As analyzed in the previous section, the supply cost of fossil fuels in Bangladesh will increase in the coming decades, and thus the existing domestic energy pricing system needs to be reformed to reflect such increasing cost of supply. Since the reform of energy pricing would cause grave impacts to the domestic economy, such pricing reform should be pursued with particular care. Drastic pricing reform may cause serious damage to the daily life of the Bangladesh citizen, and thus a long-term phased reform will be required. Nevertheless, a market-based pricing principle needs to be established in the long run to create a resilient energy system to cope with international energy price movements and at the same time to curb the burden on the national treasury. A long-term roadmap for the pricing reform may be drafted and discussions with major stakeholders may be initiated to pursue such reform in a timely manner. Given the anticipated rise in energy supply cost, maintaining the current pricing system would not be sustainable. Discussions toward the reform of energy pricing should be started as soon as possible.

Third, in order to introduce relatively costly clean energy sources to the energy mix, the government of Bangladesh may introduce a policy to support investments in projects to achieve the target. The government has set a numerical target for clean energy as of 2041 at 40%, and the power development plan assumed in this Master Plan is in line with this government's target. Costlier clean energy such as offshore wind or hydrogen, however, may not be adopted by simply applying market transactions; government's policy interventions will be required to install such clean energy supply systems as planned. Various policy initiatives will need to be considered, including the setting of numerical power generation mix targets, deregulation to promote investment, and streamlining of administrative procedures to facilitate the investments.

Chapter 8 Environment and Social Considerations

8.1 Methodology and Preliminary Findings

The Project falls under one of the generally sensitive sectors/characteristics or sensitive areas listed in accordance with the "JICA Guidelines for Environmental and Social Considerations" (promulgated in April 2010) [34], while the undesirable effects on the environment are considered as insignificant in light of the sector, project contents and regional characteristics. Therefore, the project falls under Category B. In developing this Integrated Electricity and Power Master Plan (IEPMP) , principles of the Strategic Environmental Assessment (SEA) are introduced.

8.1.1 Approach and Methodology

Experience of implementing SEA is yet limited in Bangladesh. For this SEA, the IEPMP Study Team has worked with Power Division and Energy and Mineral Resources Division of the Ministry of Power, Energy and Mineral Resources. During the SEA development, a series of stakeholder consultations as well as focus-group discussions were held to deliver the principles of SEA and its approach and methodology, and to collect opinions from the participants. The 1st Stakeholder Meeting (Inception Meeting) and the 2nd Stakeholder Meeting (Scoping Meeting) were held in November 2021 and in July 2022, respectively. Highlights of these meetings are summarized below; for details please refer to Appendix F. For the 3rd Stakeholder Meeting held in December 2022, please refer to Chapter 8.9.

8.1.2 Findings at the 1st Stakeholder Meeting (Inception) and 2nd Stakeholder Meeting (Scoping Stage)

Inception Meeting (1st Stakeholder Meeting) was held in November 2021 with 247 attendees including 31 female participants. The IEPMP Study Team presented a SEA development plan and schedule based on the progress status of the IEPMP compilation. Methodological approach as described below was presented along with work plan and schedule.

- 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 and social sustainability conditions in the context of the strategic action;
- Prediction and Evaluation of Impacts – Determines the potential impacts and the strategic

[34] According to JICA's Basic Policy on Environmental and Social Considerations, environmental and social impacts associated with development plans shall be addressed at the early stage or at the policy development stage. When a project carries out a study in the afore-mentioned project stage (such as master plan study), Strategic Environmental Assessment (SEA) shall be conducted to ensure the environmental sustainability with regard to implementation of the relevant program.

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.

At the SEA Scoping Meeting held in July 2022 with 148 participants, identification of environmental and social impacts associated with the project activities was presented as summarized below. Potential environmental and social impacts of developing energy and power infrastructure are illustrated in Table 8.1-1. As of December 2022, details of each scenario are drafted and comments from public remain open until its finalization by April 2023. This SEA will be finalized along with the final IEPMP.

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 are in operation since LNG import started in FY 2018.

In this SEA, with regard to natural gas, it is necessary to evaluate the supply side, such as gas field development and LNG procurement (e.g., receiving terminal and pipeline construction), as well as consumption side, 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 the environmental aspects such as air quality, water quality, and ecosystems, as well as resettlement and accidents that may occur when securing land for the plants.

2) Coal

In Bangladesh, coal is mainly supplied from the Barapukuria coal mine, the only domestic coal mine, and the rest is imported. In 2021 the Bangladeshi government has cancelled the plan to build 10 coal-fired power plants, and is now seeking to promote renewable energy. In addition, introduction of co-firing technology with ammonia and hydrogen is being considered for coal-fired power plants. In accepting ocean-class coal carriers from overseas, it is necessary to improve port facilities and fairways.

In the SEA, evaluation is made to address 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, whereas imported crude oil is processed at Eastern Refinery Limited (ERL), the only oil refinery in Bangladesh. To accommodate the increasing oil demand, a two-stage expansion of the ERL is planned together with expansion/construction of petroleum products import facilities. Construction of product pipelines and oil depots are also planned in line with these developments. Oil-fired power generation is relatively expensive from an economic standpoint and is on the decline.

This SEA pays 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 potential of onshore wind power is limited, higher potential is expected for offshore wind power. One of the challenges is the construction of a power transmission system from the coastal wind power generation sites to power consumption centers 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 should be considered. In Bangladesh, as one of the measures to protect and manage migratory Hilsa fishery, Hilsa sanctuaries are 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 should 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 by renewable energy, 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 the southeastern Bangladesh.

The SEA will be carried out with particular attention to land acquisition and associated resettlement for large-scale solar power generation. Bangladesh has high population density and restrictions on the conversion of agricultural land to solar parks have created barriers to land acquisition. Since Bangladesh is a riverine country located in the great alluvial fan of big rivers and the average elevation is less than 5 m above sea level, disaster risks such as flooding should be considered.

6) Nuclear

In Bangladesh, construction of the Rooppur nuclear power plant (2,400 MW to be operational in 2025), which is located inland, is underway by the Russian state-owned company, Rosatom.

Nuclear power generation emits least greenhouse gases compared with fossil fuel based power generation. In the SEA, instead of GHG emissions, evaluation will take into account the safety aspects, especially accidents during nuclear power plant operation, and management of radioactive materials such as waste materials, exhaust gas, wastewater, etc.

7) Hydrogen

Hydrogen power generation is a brand-new technology though it is assumed to be increasingly utilized.

The SEA will consider the 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 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 stage of electricity supply for electrolysis, such as wind and solar power generation, should also be examined. In addition, from a social perspective, hydrogen is an extremely flammable and explosive gas. With regard to the environmental and social risk related to hydrogen, strict attention must be paid to the safety management during production, storage, transportation and use.

8) Ammonia

In this Master Plan, introduction of power generation by co-firing and mono-firing of ammonia is considered.

For ammonia, it is necessary to consider the impact of production process at the same time, such as 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 should also 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). The SEA will examine information on protected areas and critical habitats to ensure that no significant negative impacts would occur.

b. Natural disasters

Bangladesh is a riverine country prone to flooding caused by inflows from the upstream catchments and localized heavy rainfalls; the country is located on the route through which cyclones pass through every year. SEA will consider the risk of disasters, in consideration of changes in the flood frequency and the magnitude due to climate change, as well as sea level rise and other effects.

c. Institutional arrangement related to environmental and social considerations

Toward 2050, the horizon of this Master Plan, existing systems relating 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 utilization in order to promote wind power generation and other sources as envisioned in the energy and power supply scenarios. In other words, it is necessary to establish zoning and environmental impact assessment provisions for wind power generation and a mechanism to manage the cumulative impacts.

Table 8.1-1 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 IEPMP Study Team

8.2 Project Description and Evaluation of Three Energy Outlook Scenarios (Alternative Analysis)

To consider the future energy and power supply scenario to cope with global climate change, as explained in Chapter 4, three energy scenarios are developed as below combined with different trajectories on relevant factors such as GDP growth and international energy prices.

1) Scenario Approach on Energy Outlook

In this study, three scenarios are considered: namely, Reference Scenario (REF), Advanced Technology Scenario (ATS), and Net-Zero Scenario (NZS) as shown in Table 8.2-1. Detailed scenario analysis is provided in Chapter 4.

Table 8.2-1 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: IEPMP Study Team

2) 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 the remaining 7.5% comes from imports.

REF continues to depend on natural gas, while new technological advancement goes on only moderately following the past trend. On the other hand, ATS assumes accelerated progress in technology, institution and energy conservation as much as practically possible, and adoption of a variety of power and energy sources such as solar, onshore and offshore wind, and other emerging technologies notably hydrogen, ammonia and CCS. Ratio of renewable energy under ATS is similar to that of the countries like Thailand and China.

In contrast, NZS takes up strict decarbonization measures to achieve net zero by 2050, revealing that this development path is too ambitious as it requires substantial technology transformation within the limited timeframe, which would impact the economic activities in the country too severely.

Among three energy scenarios, ATS PP2041/ATS in-between case is selected as the well balanced scenario for the Master Plan as its comparison is shown in Table 8.2-2 in the light of economic affordability, environmental sustainability, and energy security. ATS will achieve the NDC conditional target by 2030.

Table 8.2-2 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 CO_2 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 by 2036	
	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 1: EEI: Energy efficiency index, DCI: Decarbonization Index, PES: Primary Energy Supply, PP2041: Perspective Plan of Bangladesh 2021-41

Note 2: Licences for keeping under possession of Hydrogen cylinder and Ammonia cylinder must be taken from Department of Explosives according to Gas Cylinder Rules, 1991.

Source: IEPMP Study Team

8.3 Current States of the Environment

The IEPMP proposes a comprehensive plan for energy and power infrastructure development that includes construction of power and energy facilities, LNG import terminals, and transmission and distribution systems. Selection of the physical locations of subprojects needs to be determined based on the characteristics of location specific environmental and social impacts. It should be taken into account that Bangladesh is located in the low elevation area prone to natural hazards such as flooding, cyclones, and climate risks.

The SEA study has examined the baseline of the environment at national level because the IEPMP develops trajectory of energy and power supply. This plan proposes tentative subproject locations for clean energy application, but the selection of the potential sites requires feasibility studies as well as specific environmental and social impact assessment to be carried out in the future, thus the SEA will not conduct an individual evaluation of the sites. The environmental and social baseline information is summarized in Annex C of Appendix F, while the relevant laws and regulations, and international treaties and conventions applicable for the infrastructure development are described in Annex D of Appendix F.

1) Gap Analysis Between National Laws and JICA Guidelines

In the SEA process, gap analysis was conducted on the difference between National Laws and JICA Guidelines. It found that the existing legal framework needs improvement in the areas of transparency of public disclosure, consideration on vulnerable groups, occupational health and safety conditions and compliance with the national environmental quality standards; more details are described in Chapter 3 of Appendix F.

8.4 Strategic Environmental Objectives

Bangladesh is recognized worldwide as one of the most vulnerable countries to the impacts of global warming and climate change because of its unique geographic feature; dominance of floodplains, low elevation from the sea, high population density, and high levels of poverty.

Bangladesh must consider a wide range of environmental and social impacts associated with development of the projected energy and power systems. For sustainability of the infrastructure development, Strategic Environmental Objectives (SEO) are introduced as shown in Table 8.4-1 and referenced as an indicative instrument/tool, against which provisions of the IEPMP, e.g., type of energy application, geographic location, climatic and habitat conditions, and human health, etc., require assessment of the environmental and social impacts.

Table 8.4-1 Strategic Environnemental Objective (SEO)

Environmental Parameter	No.	Bangladesh's Laws, Acts, and Regulations	SEO	Indicator	Targets
Biodiversity, Fauna and Flora	B1	Environmental Conservation Act	To ensure compliance with Ecologically Critical Areas (ECAs)	Subproject impacts on the 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 etc.	Subproject impacts on the 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	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 subprojects of IEPMP.
	B4	The Protection and Conservation of Fish Rules	To ensure compliance with the Rules, no fishing by explosives in inland waters and within coastal waters.	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 damages to the hydrogeological and ecological function of the soil resource	Subproject requires substantial alternation of topology and geologic condition in the area.	Develop guideline and procedure on prevention of soil contamination to minimize deterioration of soil and implement mitigation measures not to contaminate soil.
Water	W1	Water Act	To comply with water quality standards, water rights, and clearance certificates of the Act	Subproject activity requires wastewater discharge into rivers, estuaries, and coastal waters.	Protect utilization of water resources in the water stressed areas and control pollution.
	W2	Environmental Conservation Rules	To comply with Environmental Quality Standards (EQS) for surface water, groundwater and industrial effluents	Subproject is subject to categorization of four classes required for environmental clearance.	Undertake impact assessment and formulate an environmental management plan to monitor the status of the environment.

Environmental Parameter	No.	Bangladesh's Laws, Acts, and Regulations	SEO	Indicator	Targets
Air and Climatic Factors	AC1	Environmental Conservation Rules	To comply with Environmental Quality Standards (EQS) for ambient air, emissions, and noise	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 population and human health from exposure to 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 in line with JICA Guidelines.
Natural Hazards (e.g., response to flood, 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.

Source: IEPMP Study Team

8.5 Alternative Considerations and Evaluation for Subproject

Considering the nature of the Project, the IEPMP outlines the next three decades of the power and energy plan; a variety of energy and power development is proposed to meet the projected demand of the sectors such as industry, energy, commercial and agriculture. This section introduces a comparative evaluation approach for alternative considerations at subproject level, which may improve overall environmental components of subproject and abate conflict of negative impacts or trade off with appropriate mitigation measures.

The alternatives are evaluated by using the multi-criteria to determine how they would likely be affected by the subproject interventions. The multi-criteria are based on the indicators of the SEOs and the alternatives are referenced if they are against the criteria and identify which interactions may cause negative or positive effects on specific environmental and social components of the environment.

Criteria for determining the environmental and social effects are referenced by SEOs. The indicative guidance is classified as; (1) Likely to improve the status of SEOs[35], (2) Potential conflict with the status of SEOs likely to be mitigated[36], (3) Probable conflict with the status of SEOs not to be mitigated[37], and (4) No significant interaction with the status of SEOs. When a subproject is proposed, these criteria will be used to evaluate alternatives that meet the SEOs in a more sustainable manner.

8.6 Cumulative Effects

Under the IEPMP, there are potential site-specific locations proposed for clean energy applications as recommendations but assessment of in-combination effects with other plans or projects will be done when any 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; the in-combination assessment is a matter of applying a practical and realistic approach, which requires coordination among the government authorities and industries. While it is conceivable at subproject level, Table 8.6-1 illustrates cumulative effects by type of energy and power development.

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[35] Interactions would be likely to improve the status of a particular SEO and likely to result in a positive effect on the environmental component.

[36] Interactions would potentially conflict with the status of an SEO and would be likely to be mitigated.

[37] Interactions that would probably conflict with the status of an SEO and would be unlikely to be mitigated.

Table 8.6-1 Cumulative Effects by Type of Energy and Power Development

Type of Energy and Power Generation	Environnemental Interaction on Cumulative Effects
Gas Fired Plant	• Operational storm and water discharges, air emission, habitat loss, impact on local water resources in combination with other projects having similar activities affecting the natural environment.
Coal Fired Plant	• Operational storm and process water discharges, air emission, construction habitat loss, impacts on water resources/wetlands in combination with other projects having similar activities affecting the natural environment.
Oil	• Operational air emissions of GHG, storm and process water discharges, construction habitat loss in combination with other projects having similar activities affecting the natural environment.
Nuclear	• Aside from the source of heat, nuclear power plants are like coal-fired power plants but require different safety measures. • 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, air emission, construction habitat loss in combination with other projects having similar activities affecting the natural environment.
Solar PV	• Reflections from Solar PV could potentially affect the interests of aviation personnel at airport, 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, air emission, construction habitat loss in combination with other projects with similar activities affecting the natural environment.

Source: IEPMP Study Team

8.7 Strategic Environmental and Social Management Plan/Mitigation Measures

A Strategic Environmental and Social Management Plan (SESMP) is prepared to guide how site-specific mitigation measures are implemented during construction and operation phases of a subproject. It aims to create a linkage between the impacts of project activities and the mitigation measures to minimize negative impacts and enhance positive impacts. Table 8.7-1 only provides summary of the highlighted impacts and measures; for more details, please refer to Chapter 7 of Appendix F.

The environmental management plan (EMP) at subproject level will be formulated when project and site specific environmental and social impact assessments are undertaken on any specific project. This SESMP prescribes and directs the management of environmental aspects of the proposed infrastructure development activities. The specific objectives of the SESMP are to:

- Provide appropriate management of environmental issues resulting from all activities associated with implementation of all subprojects 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 SESMP include among others:

- All investors/developers will adhere to the recommendations of this SESMP;
- 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 and social aspects and it will be implemented accordingly and supplemented by international good practices if not specified in the existing laws and regulations.

Table 8.7-1 Highlighted Impacts, Sources and Mitigation Measures by Type of Energy and Power System Development[38]

Type of Energy and Power Generation	Environmental Impact	Impact source/activity	Mitigation Measures
Coal, Gas, and Oil Fired Plant	Air emission	Exhaust, Venting, Flaring and Fugitive Emission	• Specify air emission specifications and implement source gas reduction measure.
	Wastewater/effluent	Cooling and heating system	• Discharge water to surface waters within 3 degrees Celsius of ambient temperature at the mixing zone.
	Occupational health and safety	Confined space	• Requiring work permits for all confined space entries, provided with appropriate access controls.
Liquefied Natural Gas	Hazardous materials	Storage, transfer and transport of LNG	• LNG storage tanks and components should meet international standards for structural design.
	Noise generation	Regasification process	• No personnel should be exposed to a noise level greater than 85dB(A).
	Community health and safety	Natural gas leaks during operation and transport	• Prepare an emergency preparedness and response plan that considers the role of communities.
Nuclear	Waste	Disposal of spent nuclear fuel	• Design regulations on the handling, transportation, storage, and disposal of nuclear materials.
	Occupational health and safety	Operation or system failure	• Monitor reactor’s environmental radiation, and set out emergency response plan and evacuation plan.
Hydroelectric	Habitat loss	Reservoir filing terrestrial wildlife	• Rescue species in threatened with extinction and create the new habitat ecologically suitable and protect.
	Involuntary Displacement	Loss of land due to construction of reservoir	• Support resettlement and provide new housing, land and other material assistances in accordance with laws.
Geothermal	Effluents	Drilling fluids and cuttings	• Recovery and storage of oil-based drilling fluids and cuttings in dedicated storage tanks or sumps.
	Well blowouts and pipeline failure	Well drilling, injectivity testing, cooling system	• Regular maintenance of wellheads and geothermal fluid pipelines, including corrosion control and inspection.
Solar PV	Habitat loss	Land clearance	• Rescue species threatened with extinction and create new habitats ecologically suitable and protected.
	Involuntary Displacement	Land clearance	• Support resettlement and provide new housing, land and other material assistances in accordance with laws.
	Waste management	Used storage battery and solar panels	• Develop a management protocol/procedure to handle hazardous wastes materials derived from battery and solar panels
Wind (Onshore and Offshore)	Biodiversity	Collision related fatality, displacement of wildlife	• Onshore/Offshore: Plan the construction activities to avoid sensitive times of the year (e.g., migration and breeding seasons).

[38] This table only represents some examples of impacts which may be significant but does not cover all aspects of impacts. Please refer to Chapter 8 of Appendix F for more details.

	Shadow flicker	Wind turbine	• Onshore: Avoid shadow flicker being experienced or to meet limits placed on the duration.
	Occupational health and safety	Working at height, over water, and lifting operation	• Develop a safe system of work to mitigate the hazards, including Personal Protective Equipment (PPE).
Biomass	Water quality	Cooling water and auxiliary equipment	• Adjust the discharge temperature, flow, use of a closed-cycle, recirculating cooling water system.
	Air emission	Combustion of biomass	• Installation of particulate controls capable of over 99 percent removal efficiency, such as ESPs or Fabric Filters (baghouses) for solid fuel-fired power plants
Ammonia	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.
CCS	Air emission	Leakage of CO_2 from storage and transport	• Monitor gas leaks, regulate the well construction specifications and transport modality.

Note: Licence for storage and transfer of Liquefied Natural Gas (LNG) must be taken from Department of Explosives according to the provisions of Liquefied Petroleum Gas (LPG) Rules, 2004 and permission for transport of Liquefied Natural Gas (LNG) must be taken from Department of Explosives according to Natural Gas Safety Rules, 1991.

Source: IEPMP Study Team

8.8 Monitoring Measures

Monitoring can identify unforeseen adverse effects in case the proposed measures are not properly implemented to prepare appropriate remedial actions to minimize or avoid the risks. 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. Proposed monitoring parameters are biodiversity, water and soil quality, air quality, human health and safety, natural hazards, and waste management (see Chapter 8 of Appendix F). Central to monitoring the implementation of subprojects is to ensure that robust system is in place, and all key mitigation measures are constantly updated, corrected and reported to the relevant authorities. Table 8.8-1below illustrates the recommended monitoring measures, frequency, and responsible institution.

Table 8.8-1 Environmental and Social Monitoring Measures, Source of Information, Frequency and Responsible Institutions

SEO Code	Monitoring Measures	Source of Information	Frequency of Monitoring		Responsible Institution
			Construction Phase	Operation Phase	
B1	Fauna and flora species	Local studies MOEF	Annually	-	Project developer MOEF
B2	Fauna and flora species	Local studies MOEF	Annually	-	Project developer MOEF
B3	Fauna and flora species	Local studies MOEF	Annually	-	Project developer MOEF
B4	Fishery species	Local studies MOEF	Annually	-	Project developer MOEF
S1	Soil erosion	Local studies MOEF	Quarterly	Quarterly	Project developer MOEF
W1	Water quality under environmental quality standards (EQS)	Local studies MOEF	Quarterly	Quarterly	Project developer MOEF
W2	Water quality under environmental quality standards (EQS)	Local studies MOEF	Quarterly	Quarterly	Project developer MOEF
AC1	Air, and noise quality levels	Local studies MOEF	Quarterly	Quarterly	Project developer MOEF
PH1	Illness, incident measures, labor working condition	Record of employee health, incident, and safety protocol	Quarterly	Quarterly	Project developer MOEF
PH2	Individual compensation, the	Record of compensation, the	Annually	Annually	Project developer

	property information, and market price	property, and market price			MOEF
NH1	Weather condition, early warning system	Annual committee meeting report on emergency response plan and its exercise record	Annually	Annually	Project developer MOEF
WM1	Quantities, types of waste (hazardous, chemical, nuclear wastes)	Record of waste management	Quarterly	Quarterly	Project developer MOEF

MOEF = Ministry of Environment, Forestry and Climate Change

Note: The details of monitoring measures including frequency shall be adjusted and elaborated in consideration of each subproject' characteristics.

Source: IEPMP Study Team

8.9 3rd Stakeholder Meeting (Final Consultation Meeting)

The Ministry of Power, Energy and Mineral Resources and IEPMP 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). A total of over 290 individuals (40 participants via online platform) took part in the final consultation meeting, representing the government officials, academic professionals, civil society, and development partners.

The meeting concluded that the Government of Bangladesh and IEPMP Study Team 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, 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, a Q&A session was provided to receive comments from the floor, where most of the comments were made in relation to the implementation of the IEPMP in the future. Some of the comments are summarized below:

Table 8.9-1 Comments Received and Responses During the Final Stakeholder Meeting

#	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 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 future potential development can be incorporated and adopted accordingly.
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.	
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 IEPMP 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 be reviewed and revised as new technologies are constantly evolving over time.

8.10 Conclusions and Recommendations

8.10.1 Conclusions

The broad objectives of the SEA have been introduced to various stakeholders in the course of the SEA 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 the SEA for this Master Plan are 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 should be considered for implementation of the energy and power development at subproject level, considering impact identification, cumulative effects and the environmental management plans specific to nature of sub-projects, and (iii) provide monitoring of environmental quality.

To ensure implementation of the proposed SEA, it is recommended that MOPEMP will create Environmental Unit covering both the Power Division and Energy and Mineral Resources Division. It should also work closely with the Department of Environment of the Ministry of Environment, Forest and Climate Change (MOEF). Their work will include ensuring that all investors in the energy sector comply with the SEA's objectives, indicators and targets for their individual subprojects and ensure implementation of all the recommended measures in collaboration with all the relevant line agencies/sectors.

8.10.2 Recommendations

For implementation of the IEPMP, it is recommended for the government to develop and adopt the following policy, governance and EHS management measures to ensure that project developers and investors prepare and implement necessary measures:

a. The proposed SESMP should be implemented effectively at subproject level ensuring that all the recommended mitigation measures are implemented.
b. The MPEMR should establish an Environmental Unit to oversee, monitor and coordinate all the environmental and social aspects of the IEPMP.
c. Policy on Renewable Energy should be developed to formulate economic instruments and tools to incentivize and facilitate investment in renewable applications by 2024.
d. Legal framework on clean energy (construction and operational procedures for nuclear) should be developed by 2024.
    - Rules and regulations on occupational health and safety (e.g., construction safety, labor conditions, and management system) should be developed by 2024.
    - Rules and regulations on safety of nuclear plant operation, radioactive waste and wastewater management, operational safety and health guideline should be developed and adopted.
e. EHS guidelines should be developed and adopted on (i) offshore and (ii) onshore wind farms, (iii) solar park, (iv) CCS, (v) hydrogen mono firing power generation, and (vi) electric power transmission and distribution.
f. The redress grievance mechanism guidelines should be developed and exercised by all investors for construction and operation of infrastructure.

Part 3 Building Prosperous Affluent Society

In line with the world efforts to curb global warming, Bangladesh has declared its target to increase the ratio of clean energy in the power supply mix to 40% in 2041. This is a very hard task for a country who expects robust increase in energy consumption in the process of economic growth to catch up with high-income countries. Part 3 discusses proposals on how Bangladesh should make its wish toward creation of a low-carbon society materialize.

Chapter 9 Institutional Design on Energy Management

In pursuit of high economic growth Bangladesh must achieve double targets to significantly expand its energy platform as well as low carbonization simultaneously. This chapter discusses the present issues and desired actions, and the basic institution for energy management. In this regard, upgrading of the energy data management system and legal framework of LNG import are discussed specifically in 9.2 and 9.3 below.

9.1 Challenges toward Clean Energy Society

Many options are being developed worldwide to pursue low carbonization of a society, and they are still evolving. In addition to construction of the energy infrastructure in a grand scale, technologies, industry system and markets must be developed. In this action, Bangladesh must consider appropriate selection of the options in view of the country's background such as geography and climate, natural endowment, economic development stage, and environmental vulnerability, as well as economics, business scale and environmental/social impacts of options.

9.1.1 Mechanisms and measures to realize Clean Energy Society

In pursuit of low carbonization, various mechanisms have been explored and applied to modify the energy market since the early stage of introducing innovative technologies such as emission trade scheme (ETS), carbon tax (CT) and feed in tariff (FIT). Including direct regulations and subsidies, proper policies must be adopted in consideration of the natural and economic conditions of a country. Features of these options are as follows:

- ETS: theoretically ideal but not easy to maneuver the market purposely. If the ceiling is set loose, market would not respond. If the ceiling is strict, carbon intensive industry will be killed. In addition, emission trade itself would become an objective of market speculation leading to market failures.

- FIT: effective to assure stable income over the project period lowering the threshold for participation, but creates later years burden. It might encourage excess investment in premature technologies and would cause massive dumping of them when the granted conditions expire.

- CT: able to control the load on the energy market and avoid market failures by speculation. But it does not necessarily promote proactive actions toward low carbonization, for example, incurring capital escape. On the other hand, CT will support the national treasury to create special purpose budget plans.
- Regulations and Subsidies: a general approach that directly promotes national policies. Providing grants, subsidies and tax break, upfront expenditure may be lowered and/or economics will be improved. However, capability of the private sector is an issue. Regulations and subsidizing programs should be reviewed and fine-tuned in accordance with changes in national and global circumstances.
- National Project: directly creates necessary infrastructure, but would produce rigid and inefficient businesses. It also requires budget out of the national treasury.

Fund is necessary to push forward low carbon options. There are various mechanisms available in the world, in addition to general tax, special-purpose tax and carbon tax, such as international grant, loans from international development institutions such as World Bank, Asian Development Bank and cooperative agencies of developed countries, project finance, cloud funding, regular investment by foreign players and sale of emission allowance. Appropriate methods should be explored among them.

In an effort to tackle carbon neutrality, innovative technologies and mechanisms are being explored in front-running countries. To take them in, education of the society is essential. Particularly in the building and transport sectors, human capacity development on procurement of proper goods and services is necessary to promote low-carbon initiatives. Public acceptance of low carbon projects is also indispensable to make them a reality. Public awareness, understanding and support are the important drivers for social change. It is essential for Bangladesh to create a society where the public will voluntarily move toward a low-carbon society.

The voyage to a low carbon society should be navigated adopting appropriate methods and options as described above. To introduce technologies and investments relating to fossil fuels, proper business circumstances and market design should be prepared to pave the way to invite national and international energy companies having sophisticated technologies, experiences and/or funds. They may also have advanced capabilities on industry specific technologies such as CCS, ammonia and hydrogen. To promote businesses on viable renewable energies such as PV and wind, various market mechanisms have been developed to date. There would be no single magic answer, but all kinds of methods should be examined to find the fairway to the goal.

9.1.2 Issues and policy actions

In Bangladesh's pursuit of an affluent and prosperous clean energy society, there are many issues and challenges to be solved. To deal with such challenges, this Master Plan proposes following policy actions:

1) Re-confirming the clean energy target as of 2041

The government of Bangladesh has announced to raise the share of clean energies in its electricity generation mix up to 40% by 2041. With this Master Plan, the government should reaffirm this crucial goal. By setting and declaring an explicit numerical target, the government can send a clear signal of its commitment to develop a clean energy society to various stakeholders both in the country and abroad. This will facilitate mobilization of various financial and human resources within the government. Furthermore, making this goal known to the global audiences can also contribute to the fund raising and influx of technology needed to attain the goal.

2) Revitalizing energy efficiency and conservation actions

Besides adoption of clean energy, energy efficiency and conservation (EE&C, also EEC) actions should be another pillar of Bangladesh's endeavor toward clean energy society. Saving energy consumption simply brings economic benefits by reducing expenses for energy. It is equivalent to creation of domestic energy supply. It also contributes to reduction of the country's dependence on imported fossil fuels. Needless to say, it obviously benefits the climate by cutting carbon emissions. In this context, EE&C must be given a top priority in consideration of energy policy. Recommendations on detail action plans and policies will be discussed in Section 9.2.

3) Maximizing benefits of domestic renewable resources

Bangladesh unfortunately is not blessed with abundant renewable energy resources such as solar and wind. Its land is relatively limited restricting development of domestic renewable resources. However, in order to realize a clean energy society, it is essential to cultivate and utilize these resources to the maximum extent. There are many policy arrangements available for the government to undertake.

On the solar power, the donation scheme of the government-owned land should be expanded to invite more active bidding for development of solar parks. Innovative solar power generation options such as solar sharing with agricultural sector to address the land constraints should be promoted by the government leadership. Incentive systems targeting individual houses and buildings for development of roof-top solar installation will also be considered as prioritized policy actions. On the wind power, a detailed wind condition survey should be conducted for more accurate understanding of the wind power resources and identification of the preferable locations for large-scale wind farms. Surveys on the potential impacts on environment and fishery resources should also be implemented to facilitate installation of offshore wind power units. In addition, development of innovative biomass utilization such as biogas and biofuels should be considered in good collaboration with the agricultural sector.

4) Policy supports to clean energy development

Most of clean energies require additional cost for adoption, and thus are difficult to introduce without policy supports. Options for such policy have a wide variety such as a renewable portfolio standard (RPS) that obliges power generators to adopt a certain share of clean energy, a carbon pricing system that economically assists replacement of the existing fossil fuels with clean energy, subsidizing investments in clean energy supply infrastructure, and a feed-in-tariff (FIT) system that guarantees investors a fixed price for their clean energy sales. Among them, the most-oft adopted policy option is FIT system. It has been introduced not only in developed countries in Europe and Japan, but also in developing Asia such as China, Vietnam, and Thailand.

Thorough discussion is necessary to find out which option is most appropriate in the political, economic, and social contexts in Bangladesh, while it is clear that clean energy goal will not be achieved without policy supports. Examinations for policy options need to be initiated as early as possible.

5) Safe and reliable nuclear power generation

In Bangladesh, nuclear energy will be introduced soon while its share is set at a moderate level in this Master Plan. Nuclear will be an indispensable power source for Bangladesh toward realization of a clean energy society as it can stably supply large amounts of electricity with zero carbon emissions. It is therefore essential to establish a system to ensure the safe and reliable operation. It is urgent to train a sufficient number of qualified engineers and skilled operators to sustain the safe and reliable operation of nuclear power plants and nuclear fuel cycle. Enough operational training need to be done to prepare for any unexpected troubles. In this regard, international cooperation will be important for Bangladesh to take up experiences and best practices of countries with long experience of nuclear power plant operation.

In the long run, development of the high temperature gas-cooled reactor (HTGR) technology should be monitored carefully. The HTGR aims at significant improvement of the generation efficiency to 50% from 33% for LWR/BWR plants.

6) Adopting novel energy technologies

As discussed above, highest priority must be given to maximize the introduction of renewable energy sources such as solar and wind. However, it is not possible to achieve the clean energy goal only with them as such resources are limited. There are novel energy technologies such as hydrogen power generation, co-firing of ammonia at thermal power plant, and carbon capture and storage (CCS). All of them are yet to be developed extensively, but commercialization efforts are accelerating around the world. These novel technologies are proactively considered in this Master Plan to make up for the limited renewable energy resources.

Since dedicated infrastructure will be needed to expand the use of hydrogen and ammonia, it is recommended to draft a dedicated master plan that further examines the details of hydrogen utilization such as future demand, preferred consumption locations, supply routes from the import location to the demand location, and development of import facilities. Since introduction of ammonia is planned for co-firing at coal-fired power plants in a relatively short period (~2030), it is necessary to start demonstration test at domestic plants at an earliest timing. Potential of domestic hydrogen production will also be explored on sources such as green hydrogen based on surplus renewable electricity or pink hydrogen based on nuclear energy. When hydrogen will be utilized as co-firing fuel at gas fired power plant, hydrogen carrier other than ammonia, such as liquid organic hydrogen carrier (LOHC) or liquid hydrogen, may worth considering as an option. With regard to CCS, suitable sites for storage such as depleted gas fields should be identified, and their storage potentials and economics should be investigated to facilitate the feasibility study.

7) Promoting R&D of low-carbon technologies

Various new technologies must be introduced to realize a low-carbon society. In particular, technologies on electricity supply and utilization are important as the electricity demand will grow fastest among energy sources as the main energy to drive the economic growth. Once those technologies are digested and further developed domestically, Bangladesh will be able to enjoy the full fruits; profits from the sale and even export of domestically developed technologies in addition to creation of new employment. As Bangladesh is currently dependent on imports for many low-carbon technologies, the country should promote research and development of home-grown technologies on top of the import to acquire means to realize a low-carbon society on its own. In this regard, an international cooperation with development partners to develop a pilot project may become a good starting point to foster R&D capacities in Bangladesh.

8) Other concerns

Besides the above issues, various policy challenges may come up as Bangladesh adopts more renewable energy resources. One of such challenges will be the voltage control in the power distribution. To manage the issue, technical conditions and standards must be prepared under the government's initiative. Distribution management system (DMS) should also be installed to ensure optimal control of the power supply voltage.

For the development of offshore wind power, a supply base with fabrication facilities and work ships for installation are essential. These logistic facilities should be prepared along the Bay of Bengal in accordance with the wind power development program.

For the solar power, disposal or recycling systems for obsolete solar panels must be developed. In general, solar panels become obsolete and are replaced after 25 years or so of operation. As installation of solar power expand in the future, proper policy measures should be prepared to deal with the used solar panels.

For construction and operation of these facilities, a substantial workforce is necessary. Human capacity development is an important pillar of the integral energy system.

9.2 Energy Efficiency and Conservation

Promotion of energy efficiency and conservation (EE&C, also EEC) resembles exploration for shadow energy sources that would not accompany carbon emissions. It is beneficial in both ways for promoting energy security as well as environmental sustainability. In this context, EE&C must be given the top priority in formulation of the national energy plan.

9.2.1 Actions and policies for EE&C

In view of the observed status of EE&C activities and policies in Bangladesh, actions given below would be the key to accelerating the EEC.

It is necessary to set ambitious EEC targets and policies through 2050. In EECMP2016, a target is set to improve the primary energy consumption per GDP by 20% by 2030. It is important to further accelerate EEC and, for example, the following reduction potentials are estimated in ATS.

a) By 2040: to improve by 38% compared to 2030
b) By 2050: to improve by 59% compared to 2030

where, GDP is estimated to grow from 471B$ in 2030 to 1727B$ in 2041 and 2575B$ while the primary energy consumption is estimated to increase from 74.3Mtoe in 2030 to 118.2Mtoe in 2041 and 168.5Mtoe in 2050.

Likewise, EEC potentials (ATS versus REF) are estimated for the PP2041 case on the final energy consumption basis as shown in the Table 9.2-1.

Table 9.2-1 EEC Sector Reduction Potential by Scenario

PP2041 Case	Final Energy Consumption				EEC Target		EEC Ratio	
	2041		2050		2041	2050	2041	2050
Scenario	REF	ATS	REF	ATS	REF to ATS			
	Mtoe	Mtoe	Mtoe	Mtoe	Mtoe	Mtoe	%	%
Industry	37.9	30.6	61.4	47.8	-7.4	-13.6	-19.4	-22.2
Commercial and Residential	33.8	29.5	47.1	38.9	-4.3	-8.2	-12.8	-17.3
Transport	21.0	19.9	31.8	29.0	-1.1	-2.8	-5.3	-8.8
Other	6.7	6.7	9.0	9.0	-	-	-	-
Total	99.4	86.6	149.3	124.7	-12.8	-24.6	-12.9	-16.5

Source: IEPMP Study Team

Table 9.2-2 Energy Efficiency Updated Implementation Roadmap

		2020	2025	2030	2035	2040
Macro	Bangladesh			▼Target: Intensity 20% reduction		
1. Labeling program	Review of existing program	Priority decision: LED, Ceiling fan, Refrigerator, AC				
			Voluntary operation			
	(Testing procedure, registlation system, data base)		Preparation			
			Mandatory operation			
	Heat pump (for buildings and industry)		Preparation			
			Voluntary operation			
	Irrigation pump		Preparation			
			Voluntary operation			
	For next target		Preparation			
2. EE building program	Building Energy Efficiency & Environment Rating (BEEER)▼		Voluntary operation			
	Technical guide book for ZEB	Release ▼		▼Set Target of New government building to nZEB		
	Development of promotion tools :BEEER & ZEB					
	Integration og BEEER & ZEB					
3. Benchmark program (audit guideliens)	Building	▼Release				
	Iron & steel	▼Release				
	Chemical	▼Release				
	Operation			▼Revision		
	Others					
4. Energy management guidelines	Guidelines					
	Existing (Fire-tube boiler, public building, Compressed air system, AC, steam distribution system)		Operation			
	Others			Depends		
5. DC program	Review& expand	▼150				
	CEA program	▼18	Target total 100 ▼			
	Co-opartion of DC & CEA programs					
	CEM program	Preparation				
		▼Start				
6. Finance program	EECPFP	▼End				
	IDCOL, BIFFL					
	Other financing schemes					
7. Transport program	Oil driven cars					
	Analysis					
	Energy efficiency standard			Release and operation		
	EV etc.	Conectivity analisis		▼Target 10times larger		
	Analysis					
	Guideline for charging (done)					
	Guideline for EV			Release and operation		
8. Agriculture program	Energy improvement program for agri-machineries					
	Data collecting & analysis					
	Energy efficiency standard			Release and operation		
9. Awareness raising & award program	School					
	Industry, building					
10. Monitoring program	Energy balance report (on-going)					

Actions required for each sector to implement under the updated EECMP will be as follows:

1) Industry Sector:

a) Expanding the coverage of Designated Large Energy Consumers (DCs), and improving their capability;

b) Increasing the number of Certified Energy Auditors;

c) Technical survey for Certified Energy Auditors in order to collect supplementary information for energy management, alternatively called a "benchmarking program" in steel and chemical subsectors;

d) Disseminating Best Available Technologies (BAT)[39] continuously. It is significant for

[39] Japanese Business Alliance for Smart Energy Worldwide published "Smart Energy Products & Technologies 2023" https://www.jase-w.eccj.or.jp/technologies/index.html
The Japan Iron and Steel Federation published "Technologies Customized List for India and ASEAN" https://www.jisf.or.jp/en/activity/climate/Technologies/index.html

improving energy efficiency, for example, to introduce boilers together with cogeneration systems, high efficiency generators, furnaces, as mentioned in the BAT and other decarbonizing technologies;

e) Mobilizing concessional finances to invest in the high-efficiency equipment mentioned above.

2) Residential & Commercial Sector:

a) Expanding DCs to commercial sector such as shopping malls, hotels, restaurants, schools and other large facilities;
b) Mandatory S&L program (all equipment); Develop an implementation plan for each equipment (clearly indicating the transition plan from voluntary to mandatory so that manufacturers can be prepared);
c) Expansion of S&L program coverage and strengthening of standard levels through the establishment of a periodic energy efficiency standard review system; Refer to neighboring countries and international standards when selecting equipment subject to energy efficiency standards and establishing standard values.
d) Establishing energy performance testing laboratory and strengthening monitoring system
a) Periodic update of Bangladesh National Building Code (BNBC) and the mandatory Building Energy Efficiency & Environment Rating (BEEER)
b) Accelerate implementation of BEEER and ZEB with developing a multifaceted approach to encourage participation.

3) Transportation Sector:

a) To establish the S&L program in order to promote EEVs (fuel-efficient internal combustion engine (ICE) vehicles, hybrid vehicles (HV), electric vehicles, and alternative fuel vehicles (CNG, LPG, biodiesel, ethanol, hydrogen, fuel cells, etc.)
b) To put "Electric Vehicle Charging Guideline" into practice in order to support energy-efficient electric vehicle penetration.
c) Tax incentives and subsidies will enable energy efficient vehicles to compete in the market.

4) Agriculture Sector:

a) Introduction of an EE standard & labeling program for irrigation pumps.
b) Expanding the use of irrigation pumps with the independent PV system for cutting grid peak demand.

In addition to the EE&C among the energy users as discussed above, EE&C at energy suppliers is also important to save the national energy consumption. Main issues and rationalization plans are discussed by sector in Chapter 5 and 6. Likewise for energy users, the general check and review system should also be applied to the energy suppliers in electricity, oil, gas, coal and other sectors as follows:

a) Expanding the coverage of DCs to energy supply sector such as power generation, oil refinery, mining, LNG import and other large energy suppliers
b) Monitoring and ensuring the EE progress with periodical reporting
c) Mandatory energy audits
d) Mandatory maintenance training

It should also be noted that energy suppliers should be the primary actors to promote awareness on EE&C among their customers and support them to enhance EE&C providing beneficial options. To start with, energy suppliers should play the primary role in establishing the energy data management system as discussed in 9.3.

9.2.2 Platform for implementation of EE&C

Introducing the above programs and measures requires many actions. It is necessary to fine tune the priority of programs with considerations on the magnitude of energy reduction potential, easing of required efforts, economic efficiency, necessity and the time for coordination with related institutions, etc. At the same time, adequate IT system and experienced staff must be provided to operate the energy management system properly. To implement the above mentioned programs, the staff and budgets provided for EE&C are apparently in short. Bangladesh is yet to design and introduce numerous programs. During this build-up stage, a large number of human resources and sufficient budgets need to be put into the operation.

To start with, the prioritized policy action will be the system development for energy data collection and analysis by sector and sub-sector through regular reporting system. This makes it possible to identify prioritized sectors and sub-sectors for energy conservation as well as magnitude of energy requirement. These are also essential for developing focused energy conservation systems. Gaining a clear picture of the reality of energy use in each sector through reliable data collection system will support the government and industrial officials to examine and find an optimal solution to enhance the energy efficiency in the prioritized sectors.

9.3 Energy Data Management System

9.3.1 Current Status of Energy Statistics

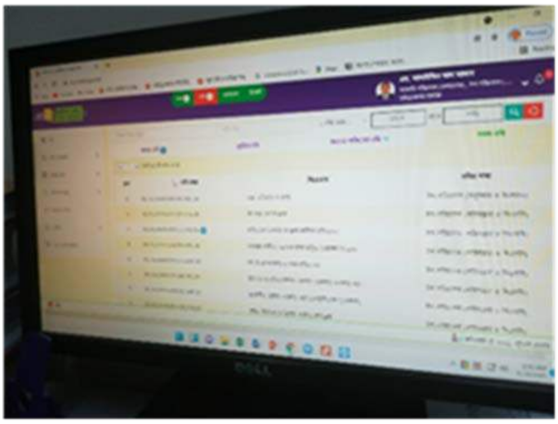
Energy data for Bangladesh is available on the websites of oil, gas, coal, and electricity companies, including sales volumes. Data is updated relatively quickly. In Bangladesh, energy statistics are handled by the Hydrocarbon Unit (HCU) under EMRD, the Sustainable and Renewable Energy Development Authority (SREDA) under the Power Division (PD), and the Bangladesh Bureau of Statistics (BBS) under the Ministry of Planning. The fiscal year of Bangladesh is from July 1 to June 30. If it is labeled “2020-2021” for example, it indicates the fiscal year 2021.

The energy data for Bangladesh published by the above three agencies are consistent and well managed by the energy companies that provide the data. In other countries, there are large discrepancies among the agencies that publish energy data, and it is sometimes difficult to know which data is reliable.

1) Hydrocarbon Unit (HCU)

The HCU provides energy information and other information on their website. Among the energy information published by the HCU, there are four periodical reports: Annual Report on Gas Production, Distribution and Consumption, Report on Energy Scenario of Bangladesh, Monthly Report on Gas and Coal Reserve & Production, and Annual Report of Hydrocarbon Unit. These reports can be downloaded from their respective websites. Petroleum products data is obtained from the Bangladesh Petroleum Corporation (BPC) and the National Board of Revenue (NBR). Gas production data is obtained monthly from the state-owned Bangladesh Petroleum Exploration and Production Company Limited (BAPEX), BGPEX, Sylhet Gas Fields Limited (SGFL) and international oil companies such as Chevron and Tullow. Gas consumption data is obtained from gas distribution companies. LNG data is obtained from Rupantarita Prakritik Gas Company Limited (RPGCL). Coal production data is obtained from Barapukuria Coal Mine Company Limited (BCMCL).

The data from the energy companies is forwarded through a web system (Electronic Documentation) called e-Nothi (see Figure 9.3-1). These data can be used by respective government officials who have IDs and passwords. The interface is entirely in Bengali.



Source: HCU

Figure 9.3-1 Web Page of Electronic Documentation

The HCU has access to the web system (Electronic Documentation) and collects data from the energy supply companies. Private companies such as Chevron and Tullow cannot access the web system, so the HCU gets their data via email. The data is provided in PDF format with signature. Using these data, the HCU publishes Report on Energy Scenario of Bangladesh, Annual Report on Gas Production, Distribution and Consumption, Monthly Report on Gas and Coal Reserve & Production, etc. on their website.

Since the data from each company is in PDF format, the HCU is re-entering the data into an Excel file. It may take several days to re-enter the data from each company. It is necessary to improve the work efficiency by eliminating the re-entry work.

2) SREDA

SREDA does not have a department dedicated to energy statistics, but the Energy Efficiency and Conservation Department publishes the National Energy Balance. The National Energy Balance began to be published in FY 2016-17 and has been published every year until now (FY 2019-2020) except for FY 2018-19. The National Energy Balance was created for the purpose of monitoring the improvement of energy efficiency and conservation and consists of the following four parts.

1. Energy Supply and Demand Trend
2. Energy Balance and Intensity
3. Energy Balance Statistics
4. National Energy Security and Emission Reduction

Data are obtained from BBS, HCU, BPC, Petrobangla, Eastern Refinery Limited (ERL), Rupantarita Prakritik Gas Company Limited (RPGCL), and BPDB.

The energy balance table for FY 2019-20 is similar to the IEA energy balance table as shown in Table 9.3-1. However, the energy balance table for FY 2019-20 does not include bunker oil and biomass. For future work, the industry needs to be classified into subsectors, in particular, to recognize movements of energy intensive sub-sectors such as cement, steel, fertilizer, petrochemicals and paper and pulp.

Table 9.3-1 National Energy Balance Table in FY2019-20

FY2019-20 (unit: ktoe)	Coal	Oil	Petroleum products	Natural gas	Biofuels and waste	PV and wind power	Hydro power	Imported electricity	Grid power	Total
Production	496	587		20,919	14,990	5	71			37,068
Imports	4,165	1,275	7,138	5,354				574		18,506
Exports			0							0
Maritime & aviation bunkers										
Stock change		-5	-32							-37
Others			-50							-50
Total energy supply	4,661	1,857	7,056	26,273	14,990	5	71	574		55,487
Statistical differences		-181	-861							-1,042
Electric power plants	-761		-1,040	-12,046		-5	-71	-574	6,142	-8,355
Autoproducers (captive)			-352	-4,004					1,525	-2,831
Oil refineries		-1,089	961							-128
Condensate & NGL fractionation		-587	202							-385
Industrial own use			-11							-11
Losses			-36						-693	-729
Total final consumption	3,900		5,919	10,223	14,990				6,974	42,005
Industry	3,900		400	5,556					3,028	12,884
Iron & steel										
Chemical and petrochemical				1,441						1,441
Non-ferrous metals										
Non-metallic minerals	3,900									3,900
Transport equipment										
Machinery										
Mining & quarrying										
Food and tobacco										
Paper, pulp and print										
Wood and wood products										
Textile and leather										
Construction										
Industries n.e.s.										
Transport			3,360	954						4,314
Residential			1,090	3,506	14,990				3,107	22,693
Commercial & public services			72	176					707	955
Agriculture, forestry			941	30					132	1,103
Non-energy use			56							56

Source: Compiled from HCU, BPC, BCMCL, Petrobangla, ERL and BPDB data

Unit: ktoe

Source: National Energy balance 2019-20, SREDA

3) BBS

The Bangladesh Bureau of Statistics (BBS) under the Ministry of Planning maintains economic statistics for Bangladesh. BBS covers energy data as well as economic statistics. The Statistical Yearbook Bangladesh consists of 15 chapters, of which Chapter 6 is the energy sector. The data sources for energy are BPDB and Rural Electrification Board (REB) for power sector, BPC for oil sector, NBR for coal sector, and Petrobangla for gas sector. BBS does not have any energy experts, but two staffs in charge of mining and quarrying and power are compiling energy data. BBS submits energy data to the International Energy Agency (IEA). Only the production and import/export of coal, natural gas, and crude oil are submitted as energy data. Presently LPG import is totally missing in the IEA statistics even though it is growing fast. The problem is that if they are doing incorrect statistical processing, they are not aware of it because they are not experts well experienced in energy. In particular, BBS recognizes the need for training on energy units and other matters.

9.3.2 Energy Data Collection

To grasp the energy consumption in Bangladesh by sectors such as households, commercial, industrial, transport, and agriculture, sales data of electricity, gas, and oil companies were collected. The objective of this exercise was to assist the preparation of GHG inventory and Nationally Determined Contributions (NDCs).

Table 9.3-2 15 Energy Supply Companies

Power Company	
1	Dhaka Electricity Supply Company (DESCO)
2	Dhaka Power Distribution Company (DPDC)
3	Northern Electricity Supply Company (NESCO)
4	West Zone Power Distribution Company Ltd (WZPDCL)
5	Bangladesh Rural Electrification Board (BREB)
6	Bangladesh Power Development Board (BPDB)
Gas Company	
1	Titas Gas Transmission and Distribution Company Ltd (TGTDCL)
2	Pashchimanchal Gas Company Ltd (PGCL)
3	Karnaphuli Gas Distribution Company Ltd (KGDCL)
4	Bakhrabad Gas Distribution Company Ltd (BGDCL)
5	Jalalabad Gas Transmission and Distribution System Ltd (JGTDSL)
6	Sundarban Gas Company Ltd (SGCL)
Oil Company	
1	Padma Oil Company Limited (POCL)
2	Jamuna Oil Company Limited (JOCL)
3	Meghna Petroleum Limited (MPL)

Source: prepared by IEPMP Study Team

Total 15 companies (6 power distribution companies, 6 gas distribution companies, and 3 oil distribution companies) as listed in Table 9.3-2 were requested to submit data. To request the data, the IEPMP Study Team prepared a data template based on the tariff classification of power and gas distribution companies. The industrial sector was categorized into subsectors according to the IEA's energy balance table. Initially, the Study Team planned to collect the latest data (FY 2020-21), but due to the drop in energy demand caused by COVID-19 pandemic, the team decided to collect data for the FY 2018-19, which is not affected by COVID-19. Each energy company was requested to submit data for each sector and raw data for verification.

1) Electricity

Table 9.3-3 shows a summary of the collected data. Among them, Bangladesh Rural Electrification Board (BREB) is the largest electricity distribution company in charge of rural electrification, providing 50% of the total electricity demand, followed by Bangladesh Power Development Board (BPDB) with 17%, Dhaka Power Distribution Company (DPDC) with 13 %, Dhaka Electricity Supply Company (DESCO) with 8 %, Northern Electricity Supply Company (NESCO) with 6 %, and West Zone Power Distribution Company Ltd. (NESCO) with 5%. Table 9.3-4 shows electricity consumption by industrial sub-sectors. Textile and leather accounted for 26% of the total consumption, followed by iron and steel at 23%.

Table 9.3-3 Summary of Collected Data: 2018-19 (Power Sector)

Company	BPDB	DPDC	DESCO	BREB	WZPDCL	NESCO	Total		
Unit	GWh	GWh	GWh	GWh	GWh	GWh	GWh	ktoe	%
Residential	4,536	3,676	2,736	17,945	1,614	1,968	32,476	2,793	52.8
Commercial	1,398	1,589	1,353	2,273	437	329	7,380	635	12.0
Industrial	4,186	2,889	686	8,558	784	958	18,062	1,553	29.3
Irrigation/Agri Pumps	168	0	0	1,466	24	63	1,722	148	2.8
Street Lights	144	30	13	7	172	47	414	36	0.7
Construction	24	33	61	29	8	12	167	14	0.3
Battery Charging Stations			-	61	13	56	130	11	0.2
Education/Religious/Hospital	114	87	74	489	70	72	906	78	1.5
Others	2		281		-		283	24	0.5
Total	10,573	8,304	5,205	30,829	3,124	3,505	61,540	5,292	100.0
%	17	13	8	50	5	6	100		

Source: Power Distribution Companies

Table 9.3-4 Electricity Consumption by Industrial Sub-sectors

Company	BPDB	DPDC	DESCO	BREB	WZPDCL	NESCO	Total		
Unit	GWh	GWh	GWh	GWh	GWh	GWh	GWh	ktoe	%
Industry	4,211	2,921	747	8,587	792	970	18,229	1,568	100.0
Mining and quarrying	32	-	-	15	-	103	150	13	0.8
Construction	24	33	63	30	14	12	177	15	1.0
Manufacturing	3,195	1,703	427	7,738	564	361	13,987	1,203	76.7
Iron and steel	2,653	875	11	682	-	4	4,225	363	23.2
Chemical and petrochemical	36	92	26	96	73	0	325	28	1.8
Non-ferrous metals	-	4	4	35	47	1	90	8	0.5
Non-metallic minerals	102	322	2	611	253	17	1,307	112	7.2
Transport equipment	-	-	6	63	10	-	80	7	0.4
Machinery	13	3	0	116	-	-	131	11	0.7
Food and tobacco	246	54	50	1,800	135	321	2,606	224	14.3
Paper, pulp and printing	34	22	18	262	5	13	355	30	1.9
Wood and wood products	55	1	2	56	26	4	143	12	0.8
Textile and leather	56	330	307	4,016	15	1	4,726	406	25.9
Industry not elsewhere specified	959	1,186	257	805	214	495	3,915	337	21.5

Note: Total industry is the summation of Industrial and Construction in Table 9.3-2.

Source: Power Distribution Companies

2) Gas

Table 9.3-5 shows a summary of the collected data. Titas Gas Transmission and Distribution Company Ltd (TGTDCL) is the largest gas distribution company, supplying 59% of the total gas demand, followed by Bakhrabad Gas Distribution Company Ltd (BGDCL) with 13%, Jalalabad Gas Transmission and Distribution System Ltd (JGTDSL) with 11%, Karnaphuli Gas Distribution Company Ltd (KGDCL) with 9%, Pashchimanchal Gas Company Ltd (PGCL) with 5%, and Sundarban Gas Company Ltd (SGCL) with 3%. Table 9.3-6 shows gas consumption by industrial sub-sectors. Textile and leather accounted for 51% of the total consumption, followed by non-metallic minerals at 11%.

Table 9.3-5 Summary of Collected Data: 2018-19 (Gas Sector)

Company	TGTDCL	PGCL	KGDCL	BGDCL	JGTDSL	SGCL	Total		
Unit	MMCM	MMCM	MMCM	MMCM	MMCM	MMCM	MMCM	ktoe	%
Metered Domestic	89	4	617	14	15	0	739	708	2.6
Non-metered Domestic	2,895	135	-	511	-	-	3,540	3,396	12.5
Commercial	109	7	37	40	32	0	224	215	0.8
Industrial	3,907	43	461	66	285	7	4,769	4,574	16.8
C.N.G	692	68	149	185	135	-	1,228	1,178	4.3
Captive	4,285	49	453	105	203	4	5,099	4,890	18.0
Grid Connected Power Plant	4,197	973	868	2,473	2,575	965	12,051	11,558	42.6
Fertilizer	394	-	-	268	-	-	662	635	2.3
Condensate	1	-	-	-	-	-	1	1	0.0
Total	16,569	1,279	2,584	3,661	3,244	976	28,313	27,155	100.0
%	59	5	9	13	11	3	100		

Source: Gas Distribution Companies

Table 9.3-6 Gas Consumption by Industrial Sub-sectors

Company	TGTDCL	PGCL	KGDCL	BGDCL	JGTDSL	SGCL	Total		
Unit	MMCM	MMCM	MMCM	MMCM	MMCM	MMCM	MMCM	ktoe	%
Industry	3,907	43	461	66	285	7	4,769	4,574	100.0
Mining and quarrying	-	-	-	-	-	-	-	-	0.0
Construction	-	-	-	-	-	-	-	-	0.0
Manufacturing	3,201	39	393	59	277	7	3,976	3,814	83.4
Iron and steel	204	1	188	5	-	-	398	382	8.3
Chemical and petrochemical	58	4	20	14	8	-	104	99	2.2
Non-ferrous metals	12	5	1	3	0	-	22	21	0.5
Non-metallic minerals	341	2	8	-	189	4	543	520	11.4
Transport equipment	3	-	-	-	-	-	3	3	0.1
Machinery	-	-	0	0	-	3	3	3	0.1
Food and tobacco	94	13	31	17	63	1	219	210	4.6
Paper, pulp and printing	187	5	27	0	-	-	219	210	4.6
Wood and wood products	16	-	-	-	-	-	16	15	0.3
Textile and leather	2,286	9	119	19	18	-	2,451	2,350	51.4
Industry not elsewhere specified	706	4	68	7	8	-	793	761	16.6

Source: Gas Distribution Companies

3) Oil

Table 9.3-7 shows the summary of the collected data and Table 9.3-8 shows oil consumption by petroleum products in Bangladesh. However, the industry is not classified into sub-sectors. It is difficult to identify end-users beyond retail stores. Padma Oil Company Limited (POCL), Jamuna Oil Company Limited (JOCL), and Meghna Petroleum Limited (MPL) are subsidiaries of Bangladesh Petroleum Corporation (BPC) and they are responsible for oil sales.

In Bangladesh, High Speed Diesel (HSD) demand accounts for 71.5% of the total oil demand. Transport sector has the highest demand, followed by agricultural sector. Gasoline demand is lower than diesel demand due to the widespread use of CNG vehicles.

Table 9.3-7 Summary of Collected Data: 2018-19 (Oil Sector)

Sector Spec. Supplies	Products	POCL	JOCL	MPL	Total (ton)	Total (ktoe)
Residential	SKO	27,814	46,158	45,732	119,704	132
	LPG	4,187	4,608	4,475	13,270	16
Transport	HOBC	92,257	71,178	100,209	263,644	282
	MS	114,251	98,550	103,111	315,912	338
	SKO	0	0	18	18	0
	HSD	804,015	710,618	1,089,680	2,604,313	2,886
	FO	0	0	13,414	13,414	15
	JET A-1	427,300	0	0	427,300	476
Industrial	HOBC	0	0	1,029	1,029	1
	MS	0	0	76	76	0
	SKO	1,430	919	432	2,781	3
	HSD	87,327	101,219	160,863	349,409	387
	FO	6,071	6,989	3,946	17,006	19
Agriculture	HSD	302,887	392,586	377,895	1,073,368	1,190
Power Generation	HSD	153,480	127,270	130,050	410,800	455
	FO	196,955	167,550	244,747	609,252	679
Others	HOBC	0	0	1,592	1,592	2
	MS	0	0	2,374	2,374	3
	SKO	0	0	1,205	1,205	1
	HSD	0	0	45,442	45,442	50
	LPG	0	0	814	814	1

Note: SKO: Superior Kerosene Oil, LPG: Liquid Petroleum Gas, HOBC: High Octane Blending Component, MS: Motor Spirit, HSD: High Speed Diesel, FO: Furnace Oil, JET A-1: Jet Fuel

Source: Oil Marketing Companies

Table 9.3-8 Oil Consumption by Petroleum Products

Company / Products	POCL	JOCL	MPL	Total		
	ton	ton	ton	ton	ktoe	%
SKO	29,244	47,077	47,387	123,708	130	2.0
LPG	4,187	4,608	5,289	14,084	16	0.2
HOBC	92,257	71,178	102,830	266,265	335	5.2
MS	114,251	98,550	105,561	318,362	337	5.2
HSD	1,347,709	1,331,693	1,803,930	4,483,332	4,618	71.5
FO	203,026	174,539	262,107	639,672	614	9.5
JET A-1	427,300	0	0	427,300	410	6.3
Total	2,217,974	1,727,645	2,327,104	6,272,723	6,461	100.0

Source: Oil Marketing Companies

4) Issues and Solutions

Table 9.3-9 shows the observed issues and proposed solutions based on this energy consumption survey.

Table 9.3-9 Issues to be identified and Proposed Solutions

Issues	Solutions
It is difficult to identify the industry sector from the company name.	Set the IEA industry subsector classification code for each customer as well as tariff code
Data submission was refused due to no obligation to submit data.	Government sets data submission obligation and deadline under the statistical law.
IEA industry classification is not known.	Distribute the IEA industry classifications.
When data were submitted in a signed PDF, it should be retyped into Excel for checking.	Ask to submit both PDF and Excel files.
Need to obtain imported LPG supply data.	Request importers to provide data as well.
Need supply data for non-energy uses such as lubricants, asphalt, etc.	Requests oil distribution companies to provide data for non-energy use.

9.3.3 Preparation of Energy Balance Table

Energy supply data in Bangladesh is already published on the websites of energy companies and government agencies. Based on the published data, SREDA prepares an energy balance table every year. An Excel macro program to prepare the energy balance table has already been built. Annual reports and other information are published on the websites of respective energy companies and government agencies from October to December. The energy balance sheet is prepared within about one month after the data is compiled. However, data for each industry subsector is not published and the amount of energy supply in the industry sector is shown as a total. The energy balance table prepared by SREDA could be further improved by obtaining the following data.

- Obtain data for each industry subsector from energy supply companies.
- Obtain bunker oil data for calculation of primary energy supply.
- Add data on captive use in power sector (currently estimated based on public sector data (BPDB Annual Report 2019-20, page 59)).
- Add LPG data imported by private companies (Energy Scenario of Bangladesh 2019-20 published by HCU, page 22).

In this study, electricity, gas, and oil distribution companies were asked to provide supply data on the industrial subsectors in order to identify the demand in industrial subsectors.

The classification method was to categorize customers into 12 subsectors according to the IEA's industrial classification. Companies of which business type is unknown are classified as “other”. For energy suppliers which have a large number of customers, only customers with large supply volumes were classified into subsectors, while customers with small supply volumes were classified as “others”. The subsector classification process took about two months. Classification would be easier and more accurate if industry subsector codes are added to the client lists in advance.

Unfortunately, in this study, the Study Team was not able to obtain data by each industrial subsector from the oil distributors. Although supply data by customer was obtained from one of the three distributors, it was not possible to classify overall demand into 12 industrial subsectors due to a lack of data, that amounts to 20% of the total consumption.

1) Data request for companies

a. Energy supply data by each industry subsector

Requested energy supply data by each industry subsector; to oil, gas, and electricity distributors.

b. LPG

Requested supply volumes by residential, commercial, and transport sectors; to LP Gas Ltd. under BPC and major private LPG companies[40].

c. Bunker oil

Requested supply volumes of fuel for ocean-going vessels and international aviation; to BPC.

d. Own use in power plants

Requested gross and net generation data; to IPPs.

2) Preparation of data request

Before requesting data, the following preparations were required.

a. Preparation of data template

It is important that a common data template be prepared in advance in Excel and received as an Excel file. Generally, Bangladeshi data is submitted as a signed PDF. Therefore, the recipient has to re-enter the data into the Excel format. This is inefficient. If evidence of an approved document is required, submission in both PDF and Excel format could be asked for.

b. Preparation of instruction manual on IEA Industrial Classification

Distribute the IEA Industry Classification Table to energy suppliers such as oil, gas, and power distribution companies. The existing classification table prepared by the IEA is quite detailed. It would be easier to understand if unnecessary items are removed step by step and a simplified version is prepared suitable for Bangladesh.

[40] Bashundhara LP Gas Ltd, INDEX LP GAS Limited, Jamuna Spacetech Joint Venture Limited. Orion Gas Ltd, LAUGFS Gas Ltd, Omera LPG, Totalgaz Bangladesh, JMI LPG, Navana LPG Limited, Petromax LPG Ltd, BM Energy Bangladesh Ltd, Beximco LPG Unit-1 Ltd, etc.

c. LPG sector classification method

If it is difficult to classify LPG demand by sectors (residential, commercial) due to too many distributors, sector demand should be classified by cylinder capacity. For example, it is assumed here that 10-kg cylinders are for residential use and 30- and/or 40-kg cylinders are for commercial use. The final decision is made by LPG suppliers. The national LPG demand is already published by HCU, so LPG demand by sector is estimated using the data from major private companies.

D. Rules for supplying fuel to plants with own generators

Some large plants have own generator(s). If the fuel supplier supplies fuel separately to the own generator and others, the fuel for the own generator is classified as Captive.

3) Industrial subsector data verification

The energy demand survey conducted in this study sometimes found that the summation of industrial subsectors did not match the published data. It is necessary to check if these two match consistently. In the process of preparing statistics, data collection is repeated every year. It is also necessary to check whether there are any big changes compared to the previous year. If there is any big change, it is also necessary to ask the energy supply company on the reason.

4) Procedures for preparing Energy Balance Table

Data handling will be divided into energy sector and power sector. Institution in EMRD is responsible for the energy sector and institution in PD is responsible for the power sector. The energy balance table is compiled as per following procedure:

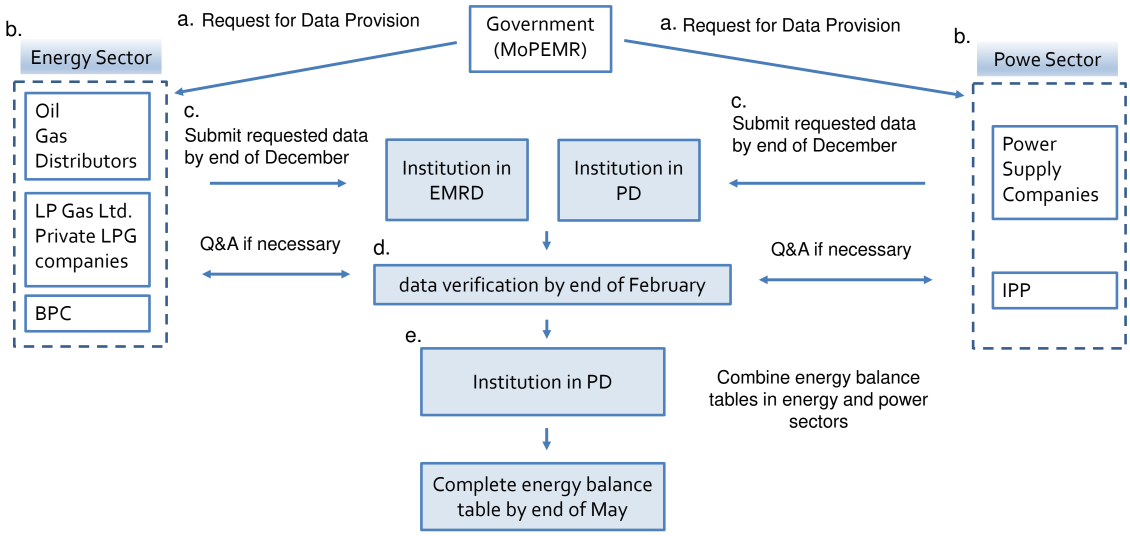
a. The government requests energy suppliers to submit energy supply data.

b. Energy suppliers add industry codes on their customer lists. Category of the industries will follow the IEA industry classification rules. Industries that cannot be classified are classified as “other” at present. If the number of customers is large, only those customers with large supply volume shall be classified at present and the rest shall be classified as “others”.

c. The deadline for data submission shall be the end of December. The data shall be submitted to both institutions in EMRD and PD.

d. Both institutions will verify the data by the end of February.

e. Institution in PD completes the energy balance table by the end of May.



Source: IEPMP Study Team

Figure 9.3-2 Procedures for Preparing Energy Balance Table

9.3.4 Support for GHG Inventory Reporting

Under the UNFCCC provisions, Parties, with exception of LDCs and SIDs, are expected to submit a National Communication every two years, which should contain a recent inventory of national GHG emissions and removals.

Under the enhanced transparency framework of the Paris Agreement, each Party shall regularly provide the information including a national inventory report of anthropogenic emissions by sources and removals by sinks of greenhouse gases (Paris Agreement, Article 13). All Parties, except for the least developed country Parties and small island developing States, shall submit the information above no less frequently than on a biennial basis, and that the least developed country Parties and small island developing States may submit this information at their discretion (Decision 1/CP.21 Adoption of the Paris Agreement). Parties shall submit their first biennial transparency report and national inventory report at the latest by 31 December 2024 (Decision 18/CMA.1 Modalities, procedures and guidelines for the transparency framework for action and support referred to in Article 13 of the Paris Agreement).

The information provided in the Initial National Communication, which was submitted in 2002, was for the year 1994 for the gases CO_2, CH_4 and N_2O. The estimates of emissions were made in the Second National Communication, submitted in 2012, and the Third National Communication, submitted in 2018, for the years 2005 and 2006-2012 respectively. The Fourth National Communication is planned to be submitted in 2023.

The latest national inventory for the year 2012 in the Third National Communication was prepared by a consultant NACOM, which won the tender. The preparation of a national inventory of GHG emissions and removals in Bangladesh had been made on an ad hoc basis, however, the third national communication established a GHG data base management system and archive that contains information for future reference.

For collection of reliable data, a generic template was communicated to the respective agencies through a letter of data request by the Department of Environment of the Ministry of Environment, Forest and Climate Change (MOEF). Fuel consumption by each sector was collected from relevant sources (Table 9.3-10). These were then reorganized into the sub-sectors under the energy sector.

As there was, however, no industry specific data available at the utility level, nor the data on natural gas consumption breakdown on the transport sector, expert judgement was taken to segregate total energy consumed by the industrial sector into different industry subsectors, and to estimate the distribution among road, railways and agricultural off-road vehicles, and different categories of motor vehicles.

Table 9.3-10 is the comparison of methodologies and data sources between the national inventory and the energy data collection in IEPMP. They are almost similar but the energy data collection in IEPMP is improved on the data of standby generators in industry.

Table 9.3-10 Preparation process of a national inventory and the energy collection in IEPMP

Fuel		Sector	Inventory (Third National Communication)	Energy Data Collection in IEPMP
Natural Gas		Data Sources	Petrobangla (distribution companies)	TGTDCL, BGDCL, JGTDSL, KGDCL, PGCL and SGCL
		Power	○	○
		Captive Power	○	○
		Fertilizer	○	○
		Industry	○ Data is not available by different industry mix. Expert judgement.	○ Categorized into subsectors
		Tea	○	-
		Commercial	○	○
		Domestic	○	○
		CNG for Transportation	○ Data is not available by different vehicle mix. Expert judgement.	○
		Raw material for producing urea	Subtracted by estimating the total quantity of urea produced and calculating the amount of carbon in urea	-
Liquid Fuels		Data Sources	BPC and its subsidiaries	POCL, JOCL and MPL
	Diesel	Transportation	○	○
		Agriculture	○	○
		Standby generators	- (Not possible to estimate)	○
		Industrial	-	○
		Others	-	○

	Kerosene	Residential	○	○
		Agriculture	○	-
		Industrial	-	○
		Transport	-	○
		Others	-	○
	Gasoline	Transportation	○	○
		Small electricity generators	- (Not allocated)	○
		Others	-	○
	Jet Fuel	Aviation	○ Data on domestic aviation and international bunkers was not available. Expert comments.	○
	Furnace Oil	Electricity generation	○ Available in the BPDB system planning and the BPC yearly sales reporting.	○
		Furnaces in various industries	○	○
		Navigation	○ Data on fuel usages by international and national marine vessels.	○
	LPG	Residential	○ Total sales was allocated.	○
		Commercial	- (Not allocated)	-
		Others	-	○
			Since imported also by the private sector, collection of data proved to be difficult.	Collecting
Solid Fuel		Data Sources	Petrobangla	-
		Power generation	○ Only government owned power generating station	-
		Brick making	○ Total coal consumption are come from standard coal consumption and the number of bricks produced, estimated on the number of kilns on technologies.	-

Source: Third national communication and the IEPMP Study.

In view of the above discussion, following actions should be considered:

a. A 'durable', rather than an ad hoc, energy data management system should be established based on the GHG database management system of national inventory and the energy data collection system proposed in this IEPMP.

b. The Department of Environment of MOEF should continue to be a focal point for the energy data collection in preparing an inventory, supported by the respective governmental agencies.

c. A standing expert committee and methodologies should be established on the allocation of energy and emissions between subsectors, but not based on an ad hoc expert judgement or comments.

9.3.5 Updated NDC

Energy-related CO_2 emissions will increase from 57.4 $MtCO_2e$ in 2012 to 169.7 $MtCO_2e$ in 2030 in the ATS PP2041 case. For methane, which has received particular attention in recent years, only natural gas leakage is considered. Natural gas leakage occurs along the supply chain, especially in the distribution system. As it is assumed that 0.1% of the natural gas sales volume leaks out from the system as per default IPCC values, methane emission slightly increases from 0.5 $MtCO_2e$ in 2012 to 0.7 $MtCO_2e$ in 2030 in the ATS PP2041 case. The total GHG emissions in 2030 would be 299.0 $MtCO_2e$ as estimated in Table 9.3-11.

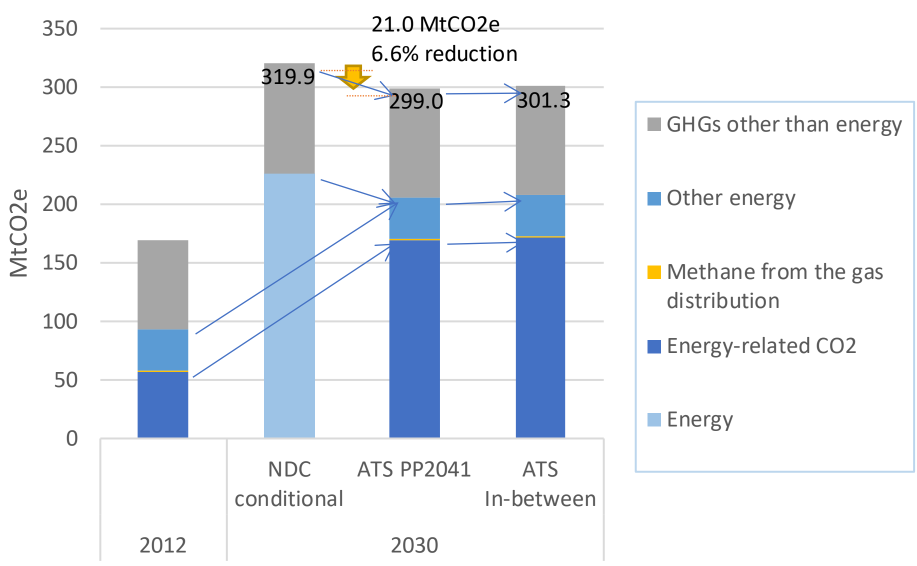
Table 9.3-11 GHG emissions by sector/gas ($MtCO_2e$)

		2012	2030			Remarks
			NDC conditional	ATS PP2041	ATS In-between	
Energy		93.09	226.56	205.59	207.89	The figures in 2012 and NDC conditional are from Updated NDC.
	Energy-related CO_2	57.4		169.7	172.1	IEPMP study.
	Methane from the gas distribution	0.5		0.7	0.6	IEPMP study.
	Other	35.19		35.19	35.19	The figure in 2012 is calculated as: (Energy) - (Energy-related CO_2) - (Methane from the gas distribution). The figures in ATS PP2041 and ATS In-between are assumed the same as that in 2012.
GHGs other than energy		75.96	93.38	93.38	93.38	The figures in 2012 and NDC conditional are from Updated NDC, and those in ATS PP2041 and ATS In-between are assumed as the same as that in NDC conditional.
Total		169.05	319.94	298.97	301.27	

Source: Nationally determined contribution and the IEPMP Study.

Review of NDC

In view of the above discussion, next review of the 2030 emission levels of NDC should consider the amount discussed above, namely, 299.0 $MtCO_2e$, 21.0 $MtCO_2e$ or 6.6% below the levels of conditional case in the existing NDC, 319.9 $MtCO_2e$ (Figure 9.3-3).



Source: National determined contribution and the IEPMP Study.

Figure 9.3-3 Proposed updated NDC

9.4 Legal and Regulatory Framework on LNG Import

Natural gas will continue to be the mainstay of Bangladesh's energy supply, as it is today. Among other things, as investment in LNG imports and natural gas supply infrastructure becomes increasingly important, it is imperative that an appropriate LNG legal and regulatory framework be in place to foster healthy industry and investment. This section derives recommendations through a comparative analysis of laws and regulations of Bangladesh, with reference to those of the U.S., who has a long history of natural gas production and LNG terminals.

- Task 1: Analysis of existing laws and regulations in Bangladesh with regard to LNG import and subsequent distribution 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 distribution 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.

For detail analysis and recommendations, kindly refer to Appendix H.

9.4.1 Task 1

It was recommended in the previous report for JICA that Bangladesh should modify energy laws and regulations modeling after the US laws and regulations, which are formulated and enacted through the long history and experience of natural gas production and distribution in the US as well as import and export of LNG to and from the US. To encourage investors from foreign countries into Bangladesh's energy, gas and LNG sector, it is critical that Bangladesh be equipped with laws and regulations applicable to LNG import and subsequent re-gasified gas distribution that match or even exceed international standards in all aspects including safety, environmental and operational perspectives. Bangladesh Energy Regulatory Commission (BERC) is established by the Bangladesh Energy Regulatory Commission Act of 2003 while Federal Energy Regulatory Commission (FERC) in the US is established by the Department of Energy Organization Act of 1977. Although both organizations have similar names and appear to play similar roles in administering energy regulatory framework of each of the countries, FERC obviously has profound experiences over its 45-year history under ever changing environment of energy and gas industry in the US and global market. BERC certainly would have benefit by studying these FERC's experiences and how FERC took administrative initiatives in resolving complicated issues at critical moments of energy, gas and power industry in the US.

9.4.2 Task 2

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 based on preliminary findings of existing power, gas and LNG laws and regulations in Bangladesh. At this time, analysis has not yet been fully completed on these laws and regulations in comparison with US laws and FERC regulations. Accordingly, the concrete action plan will be proposed toward recommended modifications to these laws and regulations. However, at the very high level, it is recommend that following issues be considered in enhancing power, gas and LNG regulatory framework in Bangladesh. Some of these issues may have been already addressed under the current regulatory framework in Bangladesh, however, due to 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 energy industry by private sector, in particular by foreign investors, visibility and predictability of legal framework of energy laws and regulations is critically important. As energy industry sees participation by private investors, it is anticipated that an 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 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

9.4.3 Task 3

Geopolitical tensions has created a significant impact to global natural gas and LNG market. Many European buyers suspended pipeline gas purchase from Russia and instead moved to import LNG from other counties. Under the circumstances, LNG market is experiencing shortage of supply and inflated prices, which is expected to continue in the foreseeable future. As a relatively new buyer of LNG, Bangladesh needs to enhance its ability to negotiate and execute LNG purchase and sales agreements to secure constant supply of LNG at competitive prices. Japan has been the largest importer of LNG for many decades and at times experienced similar situations in the past. Following recommendations by Japanese LNG buyers to Bangladesh would be beneficial.

- Standardization of contract framework, auction process
- Diversification of supply source
- Expanded operational flexibilities
- Collaboration with international LNG buyers to achieve operational flexibilities
- Safety issues:
    - Reliability of Facilities
    - Stability of Supply
    - Flexibility of Operations
- Training by skilled LNG buyers on commercial and contractual issues
- Certain form of collaboration with skilled LNG buyers

Chapter 10 Way Forward

10.1 Energy：Key Elements to Support Development

Bangladesh is pushing forward its economic growth proactively under the Vision 2041 aiming to achieve a high-income country status by the 70th anniversary of its independence. Economy of Bangladesh is expected to expand more than 5-fold from now. To achieve this mission, energy demand will inevitably increase even after utmost efforts on energy efficiency and conservation. The final energy consumption will expand 3.75-fold between 2019 and 2050; even in slower economic growth case, it will expand more than 3-fold. Among sectors, energy consumption in the industrial sector will expand fast as the main driver of the economic growth. In line with modernization of life and increasing demand for mobility, energy consumption in the residential sector and transport sector will also expand greatly. Among energy sources, electric consumption will expand vigorously, followed by petroleum products. Energy intensive industries are relatively scarce in Bangladesh, and sophisticated high-tech industries will lead the economic growth. Thus, electricity dominates in the energy consumption of the industrial sector while demand for natural gas may remain relatively slow.

There are two key issues to be considered on the future energy consumption. One is the energy to drive motor vehicles. This Master Plan aims to achieve the EV ratio of 40% in 2050. However, this is a bold assumption and will be greatly affected by the progress of the global vehicle electrification. And, in turn, it will impact the energy demand selection between petroleum products and electricity. In view of the great uncertainties on the matter, the global trend must be monitored closely, and the plan should be fine-tuned accordingly.

Another issue is the fuel for cooking and hot water supply. With obsolete city gas system accompanied by declining gas production in the country, natural gas sale as city gas is being curbed under the government policy and replaced by LPG. However, traditional biomass notably firewood still dominates in the residential and commercial sector supplying two-thirds of the fuel consumption. In the modernization process of cooking fuel under the present policy, demand for LPG may increase robustly, though electricity may play some role. LPG must be imported and mostly distributed using cylinders transported by trucks. This would worsen the traffic congestion in the metropolitan areas. On the other hand, the global LPG market is historically volatile, and prices fluctuate greatly. In this regard, it is important to establish a prudent allocation of roles of city gas and LPG together with city development plans.

With rising concerns on climate change, the world is coming into the age of energy transition, where Bangladesh is not an exception. In accordance with the global trend toward low carbonization, the Prime Minister Hasina announced at COP26 in 2021[41] that Bangladesh will aim to raise the clean energy ratio in the power generation mix up to 40% by 2041; this includes

[41] https://unfccc.int/sites/default/files/resource/BANGLADESH_cop26cmp16cma3_HLS_EN.pdf

every type of clean energies such as PV, wind, nuclear, new biomass fuel, fossil-fuel burning with CCS, ammonia, hydrogen and green power import.

In line with this ambitious target, this Master Plan aims to lower the traditional fossil fuel ratio in the power generation mix to below 60% in 2041; it will be further reduced to 45% in 2050. In the primary energy supply, non-electricity demand typically for motor fuel is growing, and thus clean energy ratio becomes lower. Nevertheless, the overall clean energy ratio must go up to above 20% in 2041 and further increase to 30% by 2050.

Unfortunately, Bangladesh is not rich in popular renewable energies notably solar, wind and geothermal. Therefore, the main part of the clean energy supply must be sought from the industry-based technologies such as nuclear, CCS, modern biomass and non-carbon fuels like ammonia and hydrogen as well as import of hydropower-based green electricity from the neighboring countries. To realize this, it is necessary to establish practicable methods on how to supply them covering the whole value chain from production or import, transportation, storage, distribution, and utilization. At any rate, a robust expansion of energy infrastructure is necessary in the coming decades.

To this end, Bangladesh must introduce new types of energies and technologies. Many of them are still in the very early stage of development and some are even yet to emerge. Nevertheless, Bangladesh must begin preparation to introduce them well before actual application. It is now necessary to start investigation on the global movements and draft a trial action plan such as Clean Energy Roadmap leading the country to the status ready for adoption of clean energies and technologies.

While aiming at building a low carbon energy structure, Bangladesh must establish a firm and resilient energy platform on the part where traditional fossil fuels, such as coal, oil and natural gas, need to be used. In pursuit of this, domestic resources such as coal and natural gas must be explored and developed to a maximum extent, as the fundamental energy sources to sustain the time of energy transition, so as to enhance energy security, stimulate domestic economy and harness foreign currency outflow. It is needless to say that utmost care must be paid on environmental and social impacts of these activities, as well as due consideration on eradication of poverty and improvement of human health conditions. On these attempts, key issues to note are as follows while the roadmap for action plan is discussed in Section 6.6:

> Natural gas: it is of foremost importance to introduce latest technologies to enhance exploration, development, and production of indigenous natural gas resources. To this end, favorable business conditions should be prepared to invite most advanced high-technologies to revitalize the declining production and to challenge exploration of unconventional resources and deepwater potentials. At the same time, LNG import facilities and the national gas pipeline network, in particular the new pipeline between Matarbari and Dhaka, should be developed in time to import and distribute natural gas

efficiently.

Coal: Feasibility studies should be implemented on candidate coal mine projects and appropriate decision should be made taking account of the impacts on regional economy, society, and environment. At the same time, possibility of CCS must be sought to make coal as a practicable option.

Oil: oil import and processing facilities must be expanded to accommodate the increasing demand. It is important to consider an appropriate balance between refinery construction and product import in the light of economics and energy security. Likewise with natural gas, an efficient distribution system of petroleum products must be established further developing the ongoing rationalization plan.

Nuclear: nuclear is an energy source to be developed with utmost care on safety and security. It is supposed to supply a part of the base load with its massive generation capacity. The reactor-type for the future stage development should be carefully investigated while various technologies are being developed in the world. In the long run, attention should also be paid to development of the high temperature gas-cooled reactor (HTGR) technology in view of the significant improvement in generation efficiency; HTGR aims to achieve a 50% generation efficiency compared with 33% for light-water reactor plants.

Renewables: technology and economic viability are in principle established on solar PV and wind turbine. With limited land and resource base, Bangladesh needs to invent an effective method on how to roll out practicable projects. In addition, development of biomass-based projects to utilize wastes, agricultural products, algae, etc. for production of biogas and biofuel should be promoted with due consideration on land use.

CCS, Ammonia and Hydrogen: experimental projects are starting worldwide but studies on their technology and economic viability are still in a preliminary stage. These options are considered to play important roles in the challenge of Bangladesh to strive for low carbonization. A task force team may be organized to closely investigate the world progress in these technologies and their applications. Such studies may also include exploring for possibilities of ammonia and/or hydrogen production in Bangladesh combined with utilization of renewable energy sources as well as surplus power from nuclear and other clean power plants. CCS is another important option to mitigate CO_2 emissions from fossil fuel use.

Fuel Cell, Battery, other new fuels: possibilities of introducing innovative technologies on new fuels and energy storage system should be promoted in order to support low carbonization.

Among others, development of the power supply system is of foremost importance, as electricity will be the most desired and required energy to empower the high economic development. Upgrading, modernization and new construction of power stations, transmission network and distribution system should be implemented steadily according to the roadmap as explained in Chapter 6.

10.2 Aiming at Net-Zero Carbon Emissions

While establishing the energy infrastructure as the platform to become a high-income country by 2041, Bangladesh aims to become a "Decarbonization-ready" country by 2050 preparing for eventual achievement of carbon neutrality. After 2050 will be the time for accelerated energy transition toward decarbonization with enhanced efforts on transformation of energy consumption structure, promotion of clean energies, and advancement of institutions and instruments. By that time, the world will have reached more matured stage to utilize clean energy technologies and systems.

a. Transformation of energy consumption structure:

Toward carbon neutrality beyond 2050, energy and resource use efficiency must be maximized. Besides promoting energy efficient technologies as explained in Chapter 9, rationalization of energy prices and changing social behavior through education are essential. Incentives for energy conservation would not work if energy prices were kept low artificially. Appropriate purchase behavior would not be achieved if citizens were indifferent to the need of energy conservation.

In addition, since electricity is an easier energy carrier to utilize clean energies, it is essential to electrify the energy use as much as practicable. Buildings and vehicles are the areas where electrification is relatively easy; then, electrification should be promoted in step with low carbonization of the electricity supplied. On the other hand, some industrial sectors are difficult to convert its energy use to electricity; in these areas, low carbonization should be addressed through sector-specific technology development.

Particular attention shall be paid on buildings, transport, and industrial infrastructure that have long lifespan and hence are apt to generate a lock-in effect that fixes the future carbon emissions in energy use. Replacement of these stocks will require several decades. Therefore, long-term sub-sector roadmaps should be established keeping this in mind, in which future investments should be shifted toward carbon-neutralization stepwise and as much as practicable.

b. Promotion and popularization of clean energies:

To enhance low carbonization toward neutrality, every possibility should be pursued for lower cost, better efficiency and conservation, and stable operation in feedstock, production, transport, distribution, and utilization of clean energies. This should include all possible measures such as solar and wind power, hydrogen and ammonia, biogas and biofuel by new biomass, algae and wastes, CCS, nuclear, hydro, and any other new energies and measures to emerge. Currently, Bangladesh is dependent on imports for the supply of clean energy technologies. However, from the perspective of strengthening industrial competitiveness, Bangladesh should take on the challenge of their domestic production through technology transfer, human resource development, and independent research and development.

Solar photo voltaic	Increased conversion efficiency is being studied. New types of solar power, such as Perovskite, are also being studied for their potential to be produced at lower cost. In terms of installation location, a floating type is being considered, but an evaluation of the impact on water bodies is needed.
Wind power	The cost of wind turbines is being reduced by increasing their unit size. In offshore wind power, development of floating wind turbines is progressing. Construction requires unique technology and facilities.
Hydrogen and its derivatives	Various production methods are available, not only “Blue” derived from fossil fuels and “Green” derived from renewable energy sources, but also using waste heat from nuclear power generation, etc., and their commercialization is being pursued. Starting from hydrogen, possibilities are being explored on ammonia combined with nitrogen, synthetic methane, and synthetic fuel combined with carbon. They have higher energy density per space [J/m2] compared to solar and wind power.
CCS	The technology is already established and there are several examples of commercial use in enhanced oil recovery (EOR). There are also examples of applications in power plants and chemical plants. Bangladesh is reportedly endowed with significant potential for CCS, which should be confirmed through proper technical study.
Biomass	While widely distributed and available, most of them are not readily suitable as feedstock for large-scale use because of the high collection cost. Therefore, small-scale local use is common except for bagasse. It also requires large land for production. First generation biomass that competes with food is not desirable.

c. Advanced institutions and instruments:

Appropriate institutions may change as the energy supply-demand structure changes. Today, developed countries leading the way in decarbonization are experimenting a variety of new institutions and instruments. Bangladesh may refer to them, and should develop and implement institutions and instruments suitable for their own context. Such institutions and instruments include market design with effective promotion measures including efficient tax system, subsidy, and funding as well as co-use of land and water spaces in harmonious collaboration with agriculture, fishery, and other sectors.

Technologies and institutions will change greatly through the quest for clean energy including those yet to emerge. Therefore, Clean Energy Roadmap should be drafted and updated from time to time to reflect the latest development in the world. Such efforts will hopefully accelerate the decarbonization.

10.3 Toward Prosperous Developed Country

This Master Plan attempts to illustrate the pathway for development of the energy sector in the coming three decades through 2050. It assumes proactive adoption of high technologies toward low carbonization of the energy structure and utmost efforts on the energy efficiency and conservation. Nevertheless, energy demand will expand greatly during the project period. In addition to the volume-wise expansion, construction of the energy infrastructure must consider optimum configuration of the energy transmission system in view of the distribution of demands and energy input points such as import ports, power stations, refineries, and indigenous production fields. Of course, these constructions must be coherent with national development plans for land, community, transport, and other infrastructure while assuring sound environment conditions.

For implementation of the plan, it is necessary to mobilize the fund in a grand scale as well as most advanced technologies, and even the technologies yet to emerge, to achieve low carbonization of the energy structure. And, most importantly, human capacity development should be programmed to bring up wide range of experts and professionals who will implement the plan at the front of actual fields. For implementation of this plan, appropriate institutions and systems should be established with necessary structure reform as follows:

1) Clearly define the roles of the public and private sectors to implement the Master Plan including nomination of organizations in charge of individual assignments by sector. Their mandates and budgets should also be prepared in due course.

2) Prepare proper market design with clear rules and regulations, considering the principal players to be engaged in businesses of energy production, import, processing, transmission and distribution.
   - Venders of energy equipment and appliances are also important for effective

implementation of energy efficiency and conservation measures such as standard and labeling.

- Laws and regulations should be aligned in accordance with international practices so as to invite national and international players as active participants.
- It is also important to create a "one-stop office" on project implementation to simplify legal procedures and assure coherent policy application.

3) Clearly define the roles of the public and the private sectors on procurement of land, right of way and, most importantly, fund for energy projects. Prepare appropriate supporting systems such as tax break, subsidy, fund raising, connection to international cooperation and any other means. These are particularly important to make it possible to introduce sub-commercial, cumbersome and/or huge clean energy projects as well as to enhance R&D on new and innovative technologies.

4) Prepare training programs and education opportunities to bring up experts and professionals not only in the technical field but also on the administration and management of energy plans, projects and business operations.

5) Prepare a comprehensive energy statistics management system to cover all the relevant sector coherently. Accurate and reliable record is the fundamental platform to consider proper energy planning and budget.

6) Draft Clean Energy Roadmap, though many elements are still vague and uncertain, to pave the way how to introduce clean energies including R&D, pilot projects and commercial application. This will be the first step to make Bangladesh ready for low carbonization.

Future is always uncertain and unpredictable. However, there are also some unalterable factors to be observed as below which are persistent even after changes in global circumstances that may occur in the future.

1) Ensure diverse energy mix to enhance resilience of the energy system. In Europe, energy prices have soared after mid-2021 partly due to weather-driven slump in increasing wind power generation. Then, since 2022, Europe is struggling to secure stable electricity and gas supply due to overdependence on certain energy sources and import partners. Our energy system is always exposed to a variety of shocks occurring elsewhere in the world. Diversifying the energy mix can make the system resilient against them.

2) Prepare appropriate business playground and cost reflective energy tariff to secure fund for investment. Significant investment will be required to meet the growing energy demand with a mission to achieve a low-carbon society. Theoretically, the beneficiaries, i.e., consumers, should bear the cost of necessary investments made by energy and utility companies, while, without proper investment, consumers simply cannot obtain the supply. Reform of business circumstance and energy tariff system should be considered in a timely

manner to keep a proper balance between investors and the final beneficiaries.

At present, the world is experiencing a serious upheaval in the energy market first caused by the COVID-19 pandemic and then geopolitical tensions. This Master Plan assumes that impact of these events will be fugitive and be mitigated in the long run. On the other hand, the global movement toward carbon neutrality has put significant pressure on the upstream investment. Fossil fuels are still the backbone of the world energy supply but would become insufficient once the world economy comes out of the stagnancy caused by the COVID-19 pandemic and geopolitical tensions. New energy sources widely talked and expected are yet to become the reliable main player.

This Master Plan presents an energy scenario based on the conditions considered as plausible at present. But anything may change directions and magnitudes at any time triggered by various future events. It is always a hard task to foresee the future movement of political and economic environment, energy prices, and trends in new technologies. It is necessary to carefully monitor their movement in the world and fine-tune the Master Plan from time to time.

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