People's Republic of Bangladesh
Power Division, Ministry of Power, Energy and Mineral Resources
Coral Power Generation Company Bangladesh Limited

Preparatory Survey on Matarbari Ultra Super Critical Coal-Fired Power Plant Development Project Phase 2 in Bangladesh

Final Report

January, 2022

Japan International Cooperation Agency (JICA)
Tokyo Electric Power Services Co., Ltd. (TEPSCO)

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Executive Summary

Objective

The purpose of preparatory survey on Matarbari Ultra Super Critical Coal-Fired Power Plant Development Project Phase 2 in Bangladesh (hereinafter referred to as "the Project") is to conduct a survey on the purpose, summary, project cost, project implementation schedule, implementation (procurement/construction) method, project implementation organization, operation and maintenance system, environmental and social considerations, etc. in order to examine the implementation of the Japanese ODA loan Project in accordance with the instruction of the Government of Japan.

Project Location

The Project location is inside of Matarbari coal-fired power plant located in the Matarbari union, Cox's Bazar district, Chattogram division which is located approx. 280km southeast of Dhaka, the capital of Bangladesh.

Necessity of the Project

This Project is in line with the policy of the Bangladesh's power sector to meet the Bangladesh's rapidly growing electricity demand and to diversify energy sources by using coal which is highly economical.

The necessity and priority of this Project is confirmed from following points of view:

- Necessity to supply stable power
- Necessity to diversify the energy source
- Consistency with development plan of the coal-fired thermal power plants on June 27, 2021 and Nationally Determined Contributions (NDCs) dated August 26, 2021

Technical Study

In consideration of countermeasure against accelerating global warming in recent years, it has shifted in the direction of increasing renewable energy and reducing coal-fired power plant. In order to respond to this circumstance, this Project is decided to adopt flexible load technology, which can realize the load-changing rate as high as possible and can realize the minimum stable load as low as possible. The technology will help introduction of variable renewable energy in the future with more smooth adjustment of the load.

Conceptual Design

The ultra super critical coal-fired power plants with flexible load technology (Units 3/4) are planned to be constructed adjacent to Units 1/2. The design concept of Units 3/4 are planned to be high-efficiency coal-fired power plant same as Units 1/2 since latest updated USC technology is following for the implementation of Unit 1/2. However, in comparison with Units 1/2, further improvements will be considered in terms of environmental performance and that contribute to power system stabilization in view of the future renewable energy adoption.

In addition, this Project is an expansion project of the Matarbari coal-fired power plant. Some equipment's and infrastructure of Units 1/2 Project will be used as common facility for this Project. As a result, power generation cost of overall project (Unit 1-4) will be lower.

The plant type, size and capacity will be an ultra super critical coal-fired power plant with a single unit capacity of 600MW at generator end (generator terminal after deduction excitation loss) and two units same as Units 1/2. Therefore, the scale of the project is assumed to be 600MW x 2 = 1,200MW.

Main Equipment

The main equipment of this Project is followings which are almost the same as Units 1/2.

- Boiler and Auxiliaries
- Coal Supply Facilities (Unloader is common facilities with Units 1/2)
- Coal and Ash Handling Equipment
- Steam Turbine and Auxiliaries
- BOP (Balance of Plant) (Desalination plant, Demineralization plant, Wastewater treatment plant, Circulating water supply system, Compressed air system, Fire-fighting system etc.)

- Electrical Equipment
- Instrumentation and Control Equipment
- Civil, Architectural Building (Ash pond and Coal / light oil unloading berth is common facilities with Units 1/2)

Environmental Facilities (NOx, SOx, PM reduction system)

To contribute to the reduction of environmental impact and comply with emission standards of Bangladesh and considering IFC/WB EHS Guideline, the "limestone gypsum method" is applied to the SOx reduction system, "SCR (selective catalytic reduction) method" is applied to the NOx reduction system and "electrostatic precipitators" is applied to the PM reduction system.

The stack outlet emission concentration of Units 3/4 is planned as follows.

SOx: 200 mg/Nm^3
NOx: 62 mg/Nm^3 (as NO_2)
Particulate matter: 25 mg/Nm^3
Both (ref. O_2 = 6% dry base)

Coal Handling Facility and Ash Handling Equipment

The design concept of the coal handling facility is considered with the expansion of Units 1/2 Project. Coal unloading berth and coal unloader are common facilities with Units 1/2. The capacity and equipment configuration including coal storage area is same as Units 1/2.

The annual imported coal considering rated power factor of Units 3/4 is 3,972,952 ton/year as performance coal basis and 4,351,384 ton/year as design coal basis (lowest calorie)

The design concept of the ash handling equipment is same as Units 1/2. The ash handling system consists of clinker ash handling system, fly ash handling system and ash recycling system. In addition, in consideration of reuse / selling of fly ash, transportation equipment, storage facilities and ship loading equipment are also considered.

The annual generated ash volume is 243,343 ton/year (170,170 m^3/year)

Ash Pond

Ash pond of Units 3/4 will be constructed under the Units 1/2 project. Ash will be disposed at 1st ash pond area the first after the commencement of operation of Units 1/2. This 1st ash pond is designed / planned to be satisfied with the required capacity at least 5 years operation for Units 1/2 (volume of 1st ash pond is 4,504,500 m^3). After full of ash in 1st ash pond, ash will be disposed in the remaining ash pond area continuously. In this regard, the partition wall will be constructed between the 1st ash pond and remaining ash pond. The total capacity of ash pond is 26,569,000 m^3.

The result of calculation in consideration of annual generated ash and rainfall, the 1st ash pond can be used 12.5 years for the operation of Units 1/2, and the total capacity of ash pond is designed to receive all of the generated ash from power plants for 36.9 years in case Units 3/4 is operating concurrently with Units 1/2.

Cooling Water System

The design concept, capacity and equipment configuration of cooling water system is same as Units 1/2.

The total required quantity of water from the sea is approx. 179,455ton/h for Units 3/4, required quantity of steam turbine condenser cooling water is approx. 170,400ton/h for Units 3/4 and required quantity of boiler make-up water (demineralized water) is approx. 20ton/h for Units 3/4. Underground water for steam turbine condenser cooling is not considered due to environmental concerns.

Water Treatment System and Wastewater Treatment System

The design concept and equipment configuration of water treatment system is same as Units 1/2. However due to change of desulfurization system of Units 3/4 from seawater desulfurization method to limestone gypsum method in consideration of desulfurization efficiency, the capacity of desalination plant will be increased.

The design concept and equipment configuration of wastewater treatment system is same as Units 1/2. However, due to change of desulfurization system, the wastewater from this system should be considered.

Electrical System

The design concept, capacity and equipment configuration of electrical system is same as Units 1/2. The generated power output from generator will be stepped up to 400kV by generator step-up transformer and transmitted to the grid network via 400kV switchyard.

In consideration of cost impact and usage frequency, the switchgear bus tie between Units 1/2 and Units 3/4 will not be planned.

I&C System

The design concept and equipment configuration of instrumentation and control system is same as Units 1/2. However, in order to monitor the operation conditions between Units 1/2 and Units 3/4, the interconnection of the DCS (Distributed Control System) between Units 1/2 and Units 3/4 and modification work for DCS of Units 1/2 is considered.

Plant Layout and Land Development

The construction area of Units 3/4 will utilize the designated space of Matarbari coal-fired power plant which is the north side of Units 1/2. The plant layout of coal yard and the main equipment will be arranged same as Units 1/2 as much as possible. Even though the construction area is less than Units 1/2, denitration system is required additionally and desulfurization system is changed to limestone gypsum system, all necessary facilities can be installed at the limited space.

The design concept of land development is same as Units 1/2. That is, the land development is planned as Power block area = MSL + 10.0m and Coal yard area = MSL + 5.0m.

Power Evacuation System

Total capacity of the Units 1/2 Project and the Units 3/4 will be 2,400MW at generator end. Power evacuation from the power plant switchyard will be through the 400kV transmission system from the existing Matarbari coal-fired power plant. The transmission lines connected to the Project site will have the enough capacity to convey all the power to the consumers in normal condition (N-0). In case of a power system accident in the 400kV transmission lines between Madunaghat substation and Bashkhali substation (N-1), two units at S.Alam has to be stopped to prevent overload at the 400kV transmission lines between Madunaghat substation and Bashkhali substation. PGCB will construct a new 400/230/132 kV substation to the north of Matarbari PP, and there will be no overloading problem with the 400kV transmission lines in the case of the accident in the said 400kV transmission lines after the construction of the new substation.

Construction Method

The design concept and construction method of land development and soil improvement is same as Units 1/2. Basically, the procedure of equipment installation work also will be same as Units 1/2.

The transportation of materials and equipment including main equipment will be procured from overseas and domestic. However, in case development plan including Matarbari Port Access Road around the Matarbari area is delay, almost of all the material and equipment will be delivered by marine transportation. The permanent equipment unloading jetty and several temporary jetties are constructed under the Units 1/2 project. The materials and equipment of Units 3/4 will be unloaded from these jetties.

The laydown area for Units 3/4 Project is considered not only a part of power block area of Units 3/4 but also ash pond area.

Implementation Schedule

The expected project implementation schedule for Unit 3 is July 2030 and Unit 4 is January 2031. The project implementation schedule will be finalized during JICA appraisal mission or later.

Consulting Services

The content of the consulting service (TOR) includes the provision of all technical support to CPGCBL for implementation of the Units 3/4 Project, which is covering the following equipment and period;

- Equipment: Power generation equipment, Related auxiliary equipment and ancillary equipment that compose the plant together with the power generation equipment
- Period: Bid preparation (including basic design), Bidding, Bid evaluation, Equipment procurement, Construction / Installation works, Defect notification

The TORs prepared in accordance with the "Consultant TOR Preparation Guide for ODA Loan Projects" provided by JICA.

Project Implementation and Management System

The executive agency of Units 3/4 Project will be CPGCBL (Coal Power Generation Company Bangladesh Limited) which is conducting Units 1/2 project now. CPGCBL has a plan to establish PIU (Project Implementation Unit) for construction period. PIU set-up will be shifted in O&M set-up after construction period. Capacity development of PIU and O&M set-up can be achieved by proper implementation of employment plan and training plan.

Environmental and Social Consideration

Since Units 3/4 Project site locates in the part of the Units 1/2 project site, there is no land acquisition. In order to comply with the more stringent international standard (IFC/WB EHS Guidelines 2007), JICA strongly requested CPGCBL to adopt Selective Catalytic Reduction (SCR) method for NOx reduction.

As the environmental measures, CPGCBL has decided the installation of SCR, EP, and FGD to reduce the emission of air pollutants. In addition, the introduction of ultra super critical power plant technology is expected to contribute to reducing CO_2 emissions as much as possible.

During construction phase and operation phase, CPGCBL plans to monitor the surrounding environment in accordance with environmental management plan and environmental monitoring plan.

Project Cost

[Confidential Information]

Project Evaluation

[Confidential Information]

Implementation Method

In this Project, the Contractor will carry out the detailed design of the project and the construction work on site, but it is assumed that the consultant will prepare the basic design and determine the specifications for the Project. Therefore, it is concluded to adopt the JICA SBD Design Build or FIDIC Yellow method as the most effective contractual agreement in which states these obligations that covers the construction of the Project.

The short list for selecting a consultant will be prepared in accordance with Section 3.04 of the "Guidelines for the Employment of Consultants under Japanese ODA Loans".

The selection policy of Contractor is that 1) setting of PQ (Pre-qualification) conditions and 2) ICB (International Competitive Bidding) following PQ method.

Conclusion

The result of studying the various perspectives such as necessity, technical, financial and environmental, it is confirmed that the Project is feasible and recommended to proceed as soon as possible.

Table of Contents

List of Tables

List of Figures

Abbreviations

Abbreviation	Full Name
ADB	Asian Development Bank
AERMOD	AMS/EPA Regulatory Model
AFOLU	Agriculture, Forestry and Other Land Use
AIS	Air Insulated Switchgear
AMS	Advanced Monitoring System
APSCL	Ashuganji Power Station Company Limited
ASME	American Society of Mechanical Engineers
AVT	All Volatile Treatment
BAPEX	Bangladesh Petroleum Exploration and Production Company Limited
BAU	Business as usual
BCCSAP	Bangladesh Climate Change Strategy Action Plan
BCMCL	Barapukuria Coal Mine Company Limited
BCPCL	Bangladesh-China Power Company Limited
BCU	Building Control Unit
BERC	Bangladesh Energy Regulatory Commission
BFP	Boiler Feed Pump
BGFCL	Bangladesh Gas Fields Company Limited
BIFPC	Bangladesh-India Friendship Power Company Pvt Ltd
BMD	Bureau of Mineral Development
BNRS	Bangladesh National REDD + Strategy
BOD	Biochemical Oxygen Demand
BP	British Petroleum
BPDB	Bangladesh Power Development Board
BPI	Bangladesh Petroleum Institute
BPMI	Bangladesh Power Management Institute
BREB	Bangladesh Rural Electrification Board
BRT	Bus Rapid Transit
BWDB	Bangladesh Water Development Board
CC	Cross Compound
CCAC	Climate and Clean Air Coalition
CCPP	Combined Cycle Power Plant
CCR	Central Control Room
CCS	Carbon Capture and Storage
CCU	Carbon Capture and Utilization
CDM	Clean Development Mechanism
CEI	Chief Electric Inspector
CFL/LED	Compact Fluorescent / Light Emitting Diode
CIF	Cost Insurance and Freight
CMC	China National Machinery Import & Export (Group) Corporation
CNG	Compressed Natural Gas

CO2	Carbon Dioxide
COD	Chemical Oxygen Demand
COD	Commercial Operation Date
Covid-19	Coronavirus disease 2019
CP	Condensate Pump
CPGCBL	Coal Power Generation Company of Bangladesh Limited
CPM	Condensable Particular Matter
CTT	Coal Transshipment Terminal
CVF	Climate Vulnerable Forum
CWP	Circulating Water Pump
CWT	Combined Water Treatment
DC	Duputy Commissioner
DCS	Distributed Control System
DE	Department of Explosive
D-EHC	Digital Electro Hydraulic Controller
DESCO	Dhaka Electric Supply Company Limited
DFR	Draft final report
DG	Director General
DO	Dissolved Oxygen
DoE	Department of Environment
DoF	Department of Forest
DPDC	Dhaka Power Distribution Company Limited
DPP	Development Project Proposal
ECA	Ecologically Critical Area
ECA	The Bangladesh Environmental Conservation Act
ECC	Environmental Clearance Certificate
ECF	Extended Fund Facility
ECR	Environmental Conservation Rules
EDCF	Economic Development Cooperation Fund
EEBL	Excelerate Energy Bangladesh Limited
EGCB	Electricity Generation Company of Bangladesh
EHS	Environment, Health and Safety
EIA	Environmental Impact Assessment: EIA
EMP	Environmental Management Plan
EMU	Environmental Management Unit
EPRC	Energy and Power Research Council
ERD	European Report on Development
ERL	Effects Range-Low
ERM	Effects Range-Median
ESC	Environmental and Social Considerations
ESP	Electrostatic Precipitator
ETP	Effluent Treatment Plant
EU	European Union
FAC	Final Acceptance Certificate

FAO	Fishery and aquaculture country profile
FCB	Fast Cut Back
FDF	Forced Draft Fan
FGD	Flue Gas Desulfurization
FI	Fouling Index
FIDIC	International Federation of Consulting Engineers
FIT	Feed-in Tariff
FOB	Free on Board
FPM	Filterable Particular Matter
FRL	Forest Reference Level
FS	Feasibility Study
FSRU	Floating Storage and Regasification Unit
GAH	Gas Air Heater
GAR	Gross as received
GCB	Gas Circuit Breaker
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GR	Game Reserve
GRC	Grievance Redness Committee
GSB	Geological Survey of Bangladesh
GSMP	Gas Sector Master Plan
GSUT	Generator Step-up Transformer
HCFC	Hydro chloro fluoro carbon
HDPE	High Density Polyethylene
HEI	Heat Exchange Institute
HFC	Hydro fluoro carbon
HFO	Heavy Fuel Oil
HHV	Higher Heating Value
HP	High Pressure
HSD	High Speed Diesel
ICS	Improved Cooking Stoves
ICT	Information and Communication Technology
IDA	International Development Association
IDCOL	Infrastructure Development Company Limited
IEA	International Energy Agency
IEE	Initial Environmental Examination
IFC	International Finance Corporation
IGCC	Integrated Coal Gasification Combined Cycle
IMF	International Monetary Fund
INDC	Intended Nationally Determined Contributions
IOC	International Major Oil Company
IP	Intermediate Pressure
IPB	Isolated Phase Bus
IPP	Independent Power Producer

ISO	International Organization for Standardization
JICA	Japan International Cooperation Agency
JIS	Japanese Industrial Standards
JVT	Joint Valuation Team
KOICA	Korea International Cooperation Agency
KPI	Key Performance Indicator
LA	Loan Agreement
LARAP	Land Acquisition and Resettlement Action Plan
LCD	Liquid Crystal Display
LEED	Leadership in Energy and Environmental Design
LGED	Local Government Engineering Department
LHV	Lower Heating Value
LNG	Liquefied Natural Gas
LP	Low Pressure
LPG	Liquefied Petroleum Gas
MIS	Management Information System
MM	Man-Month
MM5	The Fifth-Generation NCAR/Penn State Mesoscale Model
MoEF	Ministry of Environment and Forest
MoEFCC	Ministry of Environment, Forest and Climate Change
MoL	Ministry of Land
MoPEMR	Ministry of Power, Energy & Mineral Resources
MoU	Memorandum of Understanding
MRT	Mass Rapid Transit
MSF	Multi Stage Flash
MSPA	Maste Sales and Purchase Agreement
MVC	Mechanical Vapor Compression
NAP	National Action Plan
NAR	Net as received
NCAR	National Center for Atmospheric Research
NDC	Nationally Determined Contributions
NEDO	New Energy and Industrial Technology Development Organization
NEP	National Energy Policy
NFI	National Forest Inventory
NFMS	National Forest Monitoring System
NFPA	National Fire Protection Association
NLDC	National Load Dispatch Center
NOAA	National Oceanic and Atmospheric Administration
NOC	No Objection Certificate
NOx	Nitrogen Oxide
NP	National Park
NPSH	Net Positive Suction Head
NTPC	National Thermal Power Corporation
NTU	Nephelometric Turbidity Unit

NWPGCL	North West Power Generation Company Limited
NWT	Neutral Water Treatment
O2	Oxygen
ODA	Official Development Assistance
OECD	Organisation for Economic Co-operation and Development
OEM	Original Equipment Manufacturer
OLTC	On-Load Tap Changer
ONAF	Oil Natural Air Forced
ONAN	Oil Natural Air Natural
ONGC	Oil and Natural Gas Corp
OTI	Oman Trading International Ltd.
p.a.	per annum
PAF	Primary Air Fan
PBS	Palli Bidyut Samity
PGCB	Power Grid Company of Bangladesh
PIU	Project Implementation Unit
PM	Particulate Matter
PMO	Prime Minister’s Office
PO	Partner Organization
PP2041	Perspective Plan of Bangladesh
PPA	Power Purchase Agreement
PQ	Pre-qualification
PSC	Product Sharing Contract
PSC	Public Service Commission
PSMP2016	Power Sector Master Plan 2016
PV	Photovoltaics
PVAT	Property Valuation Advisory Team
REB	Rural Electrification Board
RF	Reserved Forest
RHD	Roads and Highways Deprtment
RO	Reverse Osmosis
RPCL	Rural Power Company Limited
RPO	Renewable Purchase Obligation
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
SAT	Station Auxiliary Transformer
SC	Site Clearance
SC	Super Critical
SCADA	Supervisory Control And Data Acquisition
SCF	Standard Conversion Factor
SCR	Selective Catalytic Reduction
SCS	Station Control System
SDI	Silt Density Index
SGFL	Sylhet Gas Fields Limited

SHS	Solar Home System
SIPPs	Small Independent Power Producers
SLCPs	Short Lived Climate Pollutants
SMEs	Small and Medium Enterprises
SOFC	Solid Oxide Fuel Cell
SOx	Sulfur Oxide
SPA	Sales and Purchase Agreement
SPM	Suspended Particulate Matter
SREDA	Sustainable and Renewable Energy Development Authority
SS	Suspended Solid
TC	Tandem Compound
TDS	Total Dissolved Solids
TOR	Terms of Reference
TSO	Transmission System Operator
TSP	Total Suspended Particles
TSS	Total Suspended Solids
UAT	Unit Auxiliary Transformer
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNO	Upazila Nirbahi Officer: Upazila Executive Officer
USC	Ultra Super Critical
UV	Ultraviolet
V20	Vulnerable Twenty
WB	World Bank
WS	Wildlife Sanctuary
WZPDCL	West Zone Power Distribution Company Limited

Units

Abbreviation	Full Name
%	percent
μg/kg	microgram per kilogram
Abbreviation	Full Name
bar	bar
BCF	billion cubic feet
cm^3/L	cubic centimeter per liter
dB	decibel
GWh	gigawatt hours
ha	hectare
Hz	hertz
kcal/h	kilocalorie per hour
kcal/kg	kilocalorie per kilogram
kcal/kg ºC	kilocalorie per kilogram degree celsius
kg/h	kilogram per hour
kg/m^3	kilogram per cubic meter
km	kilometer
km/h	kilometer per hour
km^2	square kilometer
kPa (abs)	kilopascal (absolute)
kV	kilovolt
kVA	kilovolt ampere
kW	kilowatt
kWh	kilowatt hour
kWh/m^2	kilowatt hour per square meter
kWh/m^3	kilowatt hour per cubic meter
L/h	liter per hour
L/kWh	liter per kilowatt hour
m	meter
m/s	meter per second
m^3	cubic meter
m^3/min	cubic meter per minute
m^3/s	cubic meter per second
m^3/year	cubic meter per year
mcf/ton	million cubic feet per ton
mg/L	milligram per liter
mg/Nm^3	milligram per normal cubic meter
ml	milliliter
mm	millimeter
mmscfd	million standard cubic feet per day
MPa (g)	megapascal (gauge)

mS/m	millisiemens per meter
MW	megawatt
MWh/m^2	megawatt hour per square meter
MWh/y	megawatt hour per year
Nm^3/h	normal cubic meter per hour
ºC	degree celsius
ppb	parts per billion
ppm	parts per million
ppt	parts per thousands
rpm	revolutions per minute
t	ton
t/h	ton per hour
t/y	ton per year
TCF	trillion cubic feet
TJ/t	terajoule per ton
Tk/kWh	taka per kilowatt hour
toe	tonne of oil equivalent
ton/day	ton per day
ton/year	ton per year
µg/l	microgram per liter
µm	micrometer

Chapter 1 Preface

1.1 Background

In the People's Republic of Bangladesh, the demand for electricity is rapidly increasing due to stable economic growth and industrialization in recent years. According to the Revisiting PSMP 2016, the electricity demand at low case (without EE&C measures) will be increased approx. 10.2%[1] at an annual rate over the 10-year period from 2021. On the other hand, since the production of domestic natural gas, on which 72%[2] of power generation, is declining, LNG imports was started from 2018. Excessive dependence on a single energy source could lead to energy security problems in the event of fuel supply disruptions and related equipment problems, which could lead to power supply shortages and soaring fuel supply costs. Therefore, it is necessary to proceed diversification of energy sources for energy security.

In the Bangladesh's "8th 5-Year Plan" continues to build on the successes of the 6th 5-Year Plan and the 7th 5-Year Plan in terms of power and energy policy, and strengthens the strategy in the following four new areas.

- Update of the Power System Master Plan 2016
- Strengthen renewable energy deployment
- Improve the financial strength of the power and energy sector
- Energy conservation and improvement of thermal efficiency of generators

Under these circumstances, through the "Matarbari Ultra Super Critical Coal-Fired Power Plant Project" (FY2014 LA signing), the Government of Japan is supporting the construction of a highly efficient ultra-super critical Power Plant (Units 1/2) with a rated output of 1,200MW and related facilities, transmission line, etc. (hereinafter referred as "Units 1/2 Project")

The "Matarbari Ultra Super Critical Coal-Fired Power Plant Development Project Phase 2" (hereinafter referred as to "Project") is an expansion phase of the Units 1/2 Project to construct a highly efficient ultra-super critical coal-fired power plant (Units 3/4) with a rated output of 1,200MW and related facilities.

This Project is in line with the policy of the Bangladesh's power sector (Latest Power Development Plan as of June 2021 and Coal Power Plant Development Plan as of 27/June/2021) to meet the Bangladesh's rapidly growing electricity demand and to diversify energy sources by using coal which is highly economical.

[1] In case low case (with EE&C measures), annual rate is approx. 8.0%
[2] BPDB Annual Report 2019-2020

1.2 Objective and Target Areas of this Study

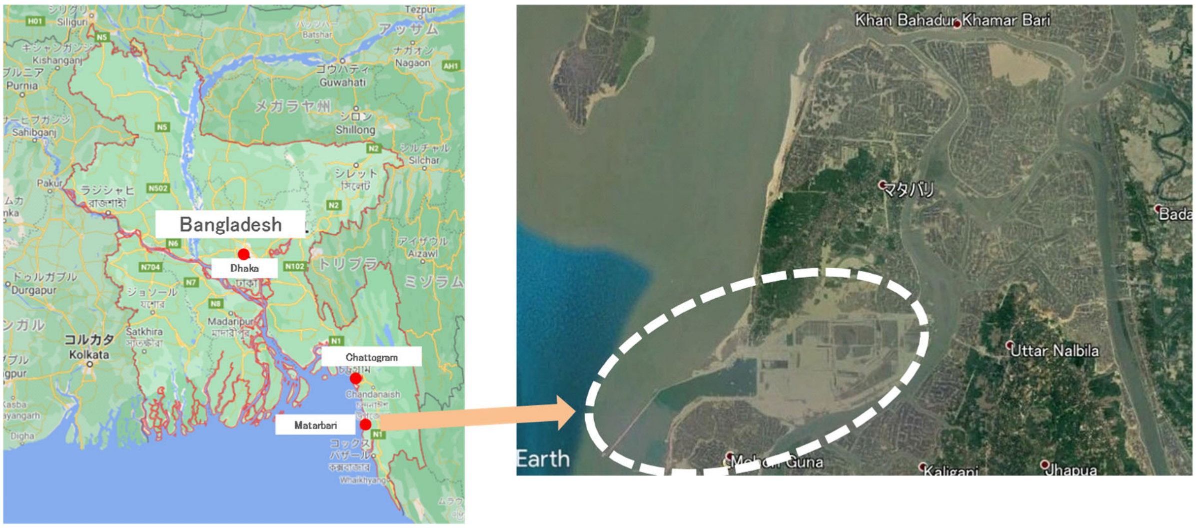
1.2.1 Objective of this Study

The purpose of this Study is to conduct a survey on the purpose, summary, project cost, project implementation schedule, implementation (procurement/construction) method, project implementation organization, operation and maintenance system, environmental and social considerations, etc. in order to examine the implementation of the Japanese ODA loan Project in accordance with the instruction of the Government of Japan.

1.2.2 Target Areas of this Study

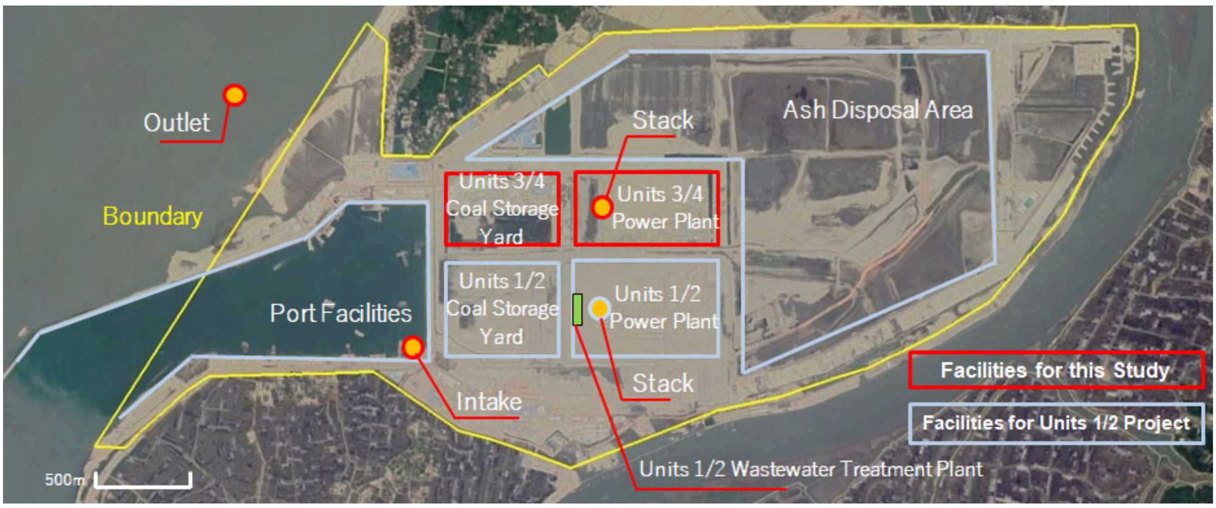
The target areas of this Study is shown in Figure 1.2-1. The main study area is the Matarbari union, Cox's Bazar district, Chattogram division which is located approx. 280km southeast of Dhaka, the capital of Bangladesh.

The expected layout of this Study and Units 1/2 Project at this time is shown in Figure 1.2-2.



Source: Study Team from Google Map and Google Earth

Figure 1.2-1 Targets Areas of this Study



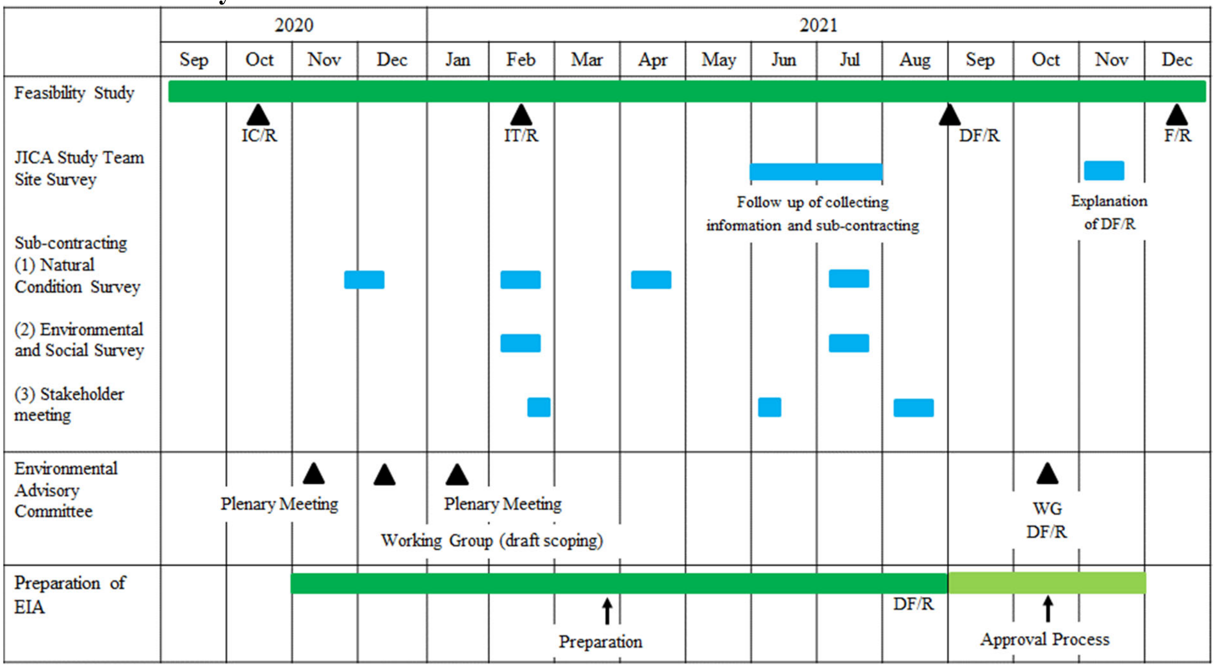
Source: Study Team from Google Earth

Figure 1.2-2 Expected layout for this Study and Units 1/2 Project

1.3 Study Schedule

This Study is started on September 25, 2020 and ended in middle of December 2021. The study schedule is shown in Table 1.3-1.

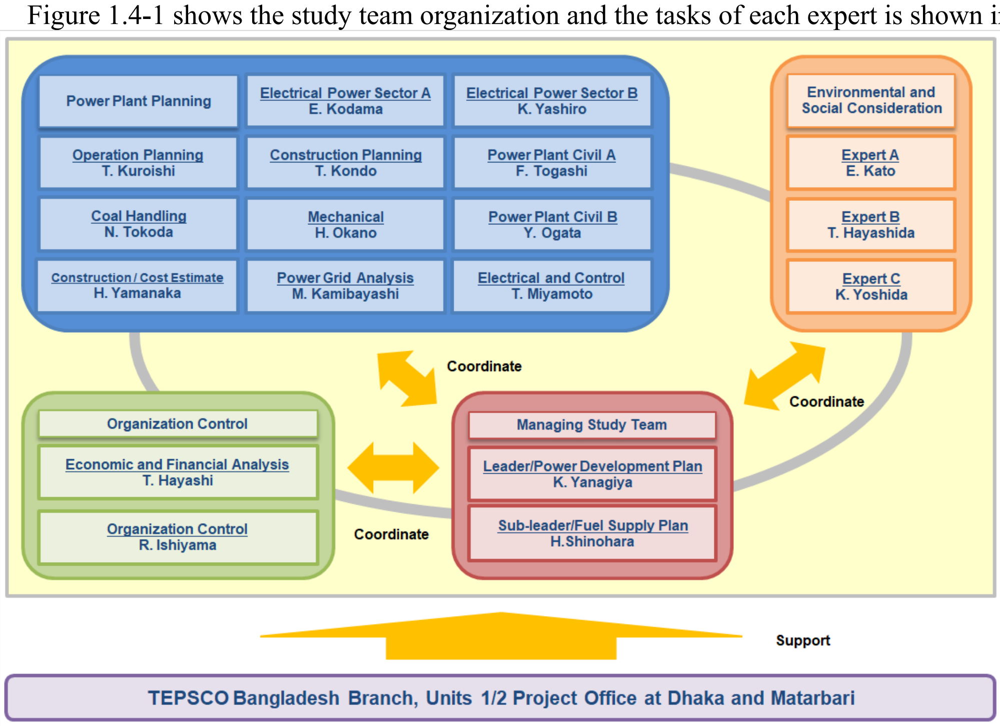
Table 1.3-1 Study Schedule



Source: Study Team

1.4 Study Team Organization

Source: Study Team
Figure 1.4-1 shows the study team organization and the tasks of each expert is shown in Table 1.4-1.



Source: Study Team
Figure 1.4-1 Study Team Organization

Table 1.4-1 Tasks of each Experts

Name	Task
Keitaro YANAGIYA	As team leader, it is responsible for following tasks. (1) Overall supervision of the study, guidance of team members and management work progress (2) Liaison and consultation with JICA, counterpart international organization, etc. (3) Management and guidance of all study work and safety management of team members (4) Overall review of study of project implementation schedule (5) Preparation of an implementation plan for consulting services (6) Overall review of study for environmental and social considerations (7) Assistance for applying DPP (8) Accompanying and responding to JICA mission
Hiroshi SHINOHARA	As sub-team leader, it is responsible for following tasks. (1) Assistant for overall supervision of the study, guidance of team members and management work progress (2) Assistant for liaison and consultation with JICA, counterpart, international organizations, etc. (3) Assistant for management and guidance of all study work and safety management of team members (4) Assistant for preparation of an implementation plan for consulting services (5) Study of fuel supply plan (6) Accompanying and responding to JICA mission
Etsuji KODAMA	As expert of electric power sector analysis, it is responsible for following tasks. (1) Study for description and implementation of high-level plans and strategies for the energy and power sector and climate change (2) Study for current status of the energy sector as it relates to this project (3) Study for current status of climate change measures related to this project (4) Study for status of support from other donors
Kazushige YASHIRO	As expert of electric power sector analysis, it is responsible for following tasks. (1) Study for current status of the power sector as it relates to this project (2) Study for latest trends in coal-fired power plant
Takashi KUROISHI	As expert of thermal power operation planning, it is responsible for following tasks. (1) Collection and analysis of related materials and information (2) Study on reduction of environmental issue (3) Preparation of the summary for this project outline (4) Project implementation and maintenance system (5) Preliminary estimation of the project cost
Tomoyuki KONDO	As expert of thermal power construction planning, it is responsible for following tasks. (1) Collection and analysis of related materials and information

Name	Task
	(2) Study on reduction of environmental issue (3) Preparation of the summary for this project outline (4) Basic Design of Power Plant (5) Study of construction method (6) Preliminary estimation of the project cost (7) Comparison of the project cost and other expenditures by other donors (8) Formulating of project implementation method
Fumiya TOGASHI	As expert of thermal power civil engineer, it is responsible for following tasks. (1) Collection and analysis of related materials and information (2) Survey on natural conditions (3) Preparation of the summary for this project outline (4) Basic Design of Power Plant (5) Study of construction method (6) Preliminary estimation of the project cost (7) Comparison of the project cost and other expenditures by other donors (8) Formulating of project implementation method
Yuri OGATA	As expert of thermal power civil engineer, it is responsible for following tasks. (1) Collection and analysis of related materials and information (2) Survey on natural conditions (3) Preparation of the summary for this project outline (4) Basic Design of Power Plant (5) Study of construction method (6) Study for environmental and social considerations
Naoto TOKODA	As expert of thermal power mechanical engineer, it is responsible for following tasks of coal handling facility. (1) Collection and analysis of related materials and information (2) Preparation of the summary for this project outline (3) Basic Design of Power Plant (4) Study of construction method (5) Preliminary estimation of the project cost (6) Comparison of the project cost and other expenditures by other donors (7) Formulating of project implementation method
Hideyuki OKANO	As expert of thermal power mechanical engineer, it is responsible for following tasks of mechanical facility. (1) Collection and analysis of related materials and information (2) Preparation of the summary for this project outline (3) Basic Design of Power Plant (4) Study of construction method (5) Preliminary estimation of the project cost (6) Comparison of the project cost and other expenditures by other donors (7) Formulating of project implementation method
Tatsuya MIYAMOTO	As expert of thermal power electrical engineer, it is responsible for following tasks of electrical/control equipment. (1) Collection and analysis of related materials and

Name	Task
	information (2) Power system concerning the project and survey of the current situation of the existing equipment (3) Preparation of the summary for this project outline (4) Basic Design of Power Plant (5) Study of construction method (6) Preliminary estimation of the project cost (7) Comparison of the project cost and other expenditures by other donors (8) Formulating of project implementation method
Toru KOBUKATA →Hirotaka YAMANAKA	As expert of construction planning/project cost estimate, it is responsible for following tasks. (1) Collection and analysis of related materials and information (2) Preparation of the summary for this project outline (3) Study of construction method (4) Study of project implementation schedule (5) Preliminary estimation of the project cost (6) Comparison of the project cost and other expenditures by other donors (7) Formulating of project implementation method
Toshiyuki HAYASHI	As expert of economic and financial analysis, it is responsible for following tasks. (1) Collection and analysis of related materials and information (2) Project implementation and maintenance system (3) Preliminary estimation of the project cost (4) Comparison of the project cost and other expenditures by other donors (5) Formulating of project implementation method (6) Study on project evaluation
Makoto KAMIBAYASHI	As expert of power grid analysis, it is responsible for following tasks. (1) Collection and analysis of related materials and information (2) Power system concerning the project and survey of the current situation of the existing equipment (3) Preparation of the summary for this project outline
Ryuji ISHIYAMA	As expert of organization control, it is responsible for following tasks. (1) Power system concerning the project and survey of the current situation of the existing equipment (2) Study of project implementation schedule (3) Project implementation and maintenance system (4) Preliminary estimation of the project cost (5) Study on measures to mainstream gender
Eiichi KATO	As expert of environmental consideration, it is responsible for following tasks. (1) Collection and analysis of related materials and information (2) Survey on natural conditions (pollution abatement) (3) Preparation of the summary for this project outline (4) Study of construction method (5) Study of project implementation schedule (6) Study for environmental and social considerations

Name	Task
	(pollution abatement) (7) Accompanying and responding to JICA mission
Takanori HAYASHIDA	As expert of environmental consideration, it is responsible for following tasks. (1) Collection and analysis of related materials and information (2) Survey on natural conditions (natural environment) (3) Preparation of the summary for this project outline (4) Study of construction method (5) Study of project implementation schedule (6) Study for environmental and social considerations (natural environment)
Kazuhiro YOSHIDA	As expert of social consideration, it is responsible for following tasks. (1) Collection and analysis of related materials and information (2) Survey on natural conditions (3) Preparation of the summary for this project outline (4) Study of construction method (5) Study of project implementation schedule (6) Study for environmental and social considerations (social consideration)

Source: Study Team

1.5 Study Manning Schedule

Figure 1.5-1 shows the study manning schedule.

	Task	Name	Firm	2020				2021												Man-Month	
				Sep	Oct	Noc	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	
																				Site	Japan
Site Survey	Team Leader	K. Yanagiya	TEPSCO															30		1.00	
	Sub-team Leader	H. Shinohara	TEPSCO										30	30				30		3.00	
	Electric Power Sector	E. Kodama	TEPSCO																	0.00	
	Electric Power Sector	K. Yashiro	TEPSCO										27							0.90	
	Thermal Power Operation Planning	T. Kuroishi	TEPSCO										27							0.90	
	Thermal Power Construction Planning	T. Kondo	TEPSCO																	0.00	
	Thermal Power Civil	F. Togashi	TEPSCO																	0.00	
	Thermal Power Civil	Y. Ogata	TEPSCO																	0.00	
	Thermal Power Mechanical	N. Tokoda	TEPSCO																	0.00	
	Thermal Power Mechanical	H. Okano	TEPSCO																	0.00	
	Thermal Power Electrical	T. Miyamoto	TEPSCO																	0.00	
	Construction Planning/Project Cost Estimate	H. Yamanaka	TEPSCO																	0.00	
	Economic and Financial Analysis	T. Hayashi	TEPSCO																	0.00	
	Power Grid Analysis	T. Kamibayashi	TEPSCO										27							0.90	
	Organization Control	R. Ishiyama	TEPSCO																	0.00	
	Environmental Consideration	E. Kato	TEPSCO															30		1.00	
	Environmental Consideration	T. Hayashida	TEPSCO																	0.00	
	Social Consideration	K. Yoshida	TEPSCO																	0.00	
	Sub-total for Site Survey																			7.70	
	Task	Name	Firm	2020				2021												Man-Month	
				9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	Total	
																				Site	Japan
Work in Japan	Team Leader	K. Yanagiya	TEPSCO	15							40										2.75
	Sub-team Leader	H. Shinohara	TEPSCO	20							10										1.50
	Electric Power Sector	E. Kodama	TEPSCO	8							28										1.80
	Electric Power Sector	K. Yashiro	TEPSCO	20							22										2.10
	Thermal Power Operation Planning	T. Kuroishi	TEPSCO	15							12										1.35
	Thermal Power Construction Planning	T. Kondo	TEPSCO	15							30										2.25
	Thermal Power Civil	F. Togashi	TEPSCO	10							30										2.00
	Thermal Power Civil	Y. Ogata	TEPSCO	15							30										2.25
	Thermal Power Mechanical	N. Tokoda	TEPSCO	15							30										2.25
	Thermal Power Mechanical	H. Okano	TEPSCO	10							30										2.00
	Thermal Power Electrical	T. Miyamoto	TEPSCO	10							20										1.50
	Construction Planning/Project Cost Estimate	H. Yamanaka	TEPSCO	10							20										1.50
	Economic and Financial Analysis	T. Hayashi	TEPSCO	15							35										2.50
	Power Grid Analysis	T. Kamibayashi	TEPSCO	10							12										1.10
	Organization Control	R. Ishiyama	TEPSCO								20										1.00
	Environmental Consideration	E. Kato	TEPSCO	10							50										3.00
	Environmental Consideration	T. Hayashida	TEPSCO	15							25										2.00
	Social Consideration	K. Yoshida	TEPSCO	25							40										3.25
	Sub-total for Work in Japan																				36.10

△IC/R
△P/R
★ EAC (Plenary Meeting)
★ EAC (working group, drafting scoping)
★ EAC (Plenary Meeting)
△DF/R
△F/R
★ EAC (Plenary Meeting (DF/R))

	Site	Japan
Total	7.70	36.10
	43.80	

Remarks
: Site Survey
: Work in Japan

IC/R: Inception Report
P/R: Progress Report
DF/R: Draft Final Report
F/R: Final Report

EAC: Environment Advisory Committee

Source: Study Team

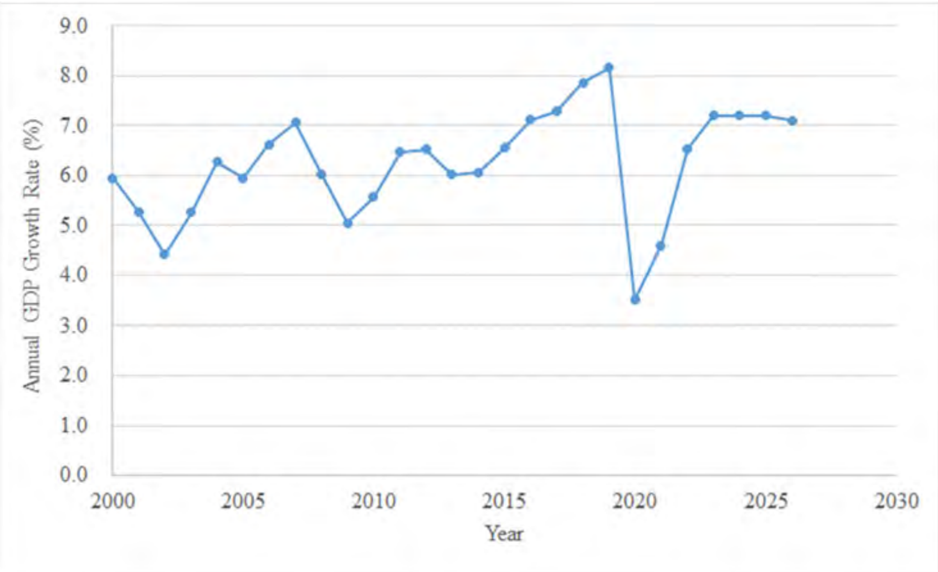
Figure 1.5-1 Study Manning Schedule

Chapter 2 Background and Necessity of the Project

2.1 Economic Overview

The economy of Bangladesh has maintained high economic growth, averaging over 6% since 2000. Figure 2.1-1 shows the trend of the GDP growth rate of Bangladesh from 2000 to 2020.

Due to the impact of Covid-19, the GDP growth rate in 2020 is 3.5% according to the International Monetary Fund (IMF), which is lower than the previous year. However, it is expected to recover to 4.6% in 2021 and 6.4% in 2022, and sustain high growth rates in the 7% range thereafter.

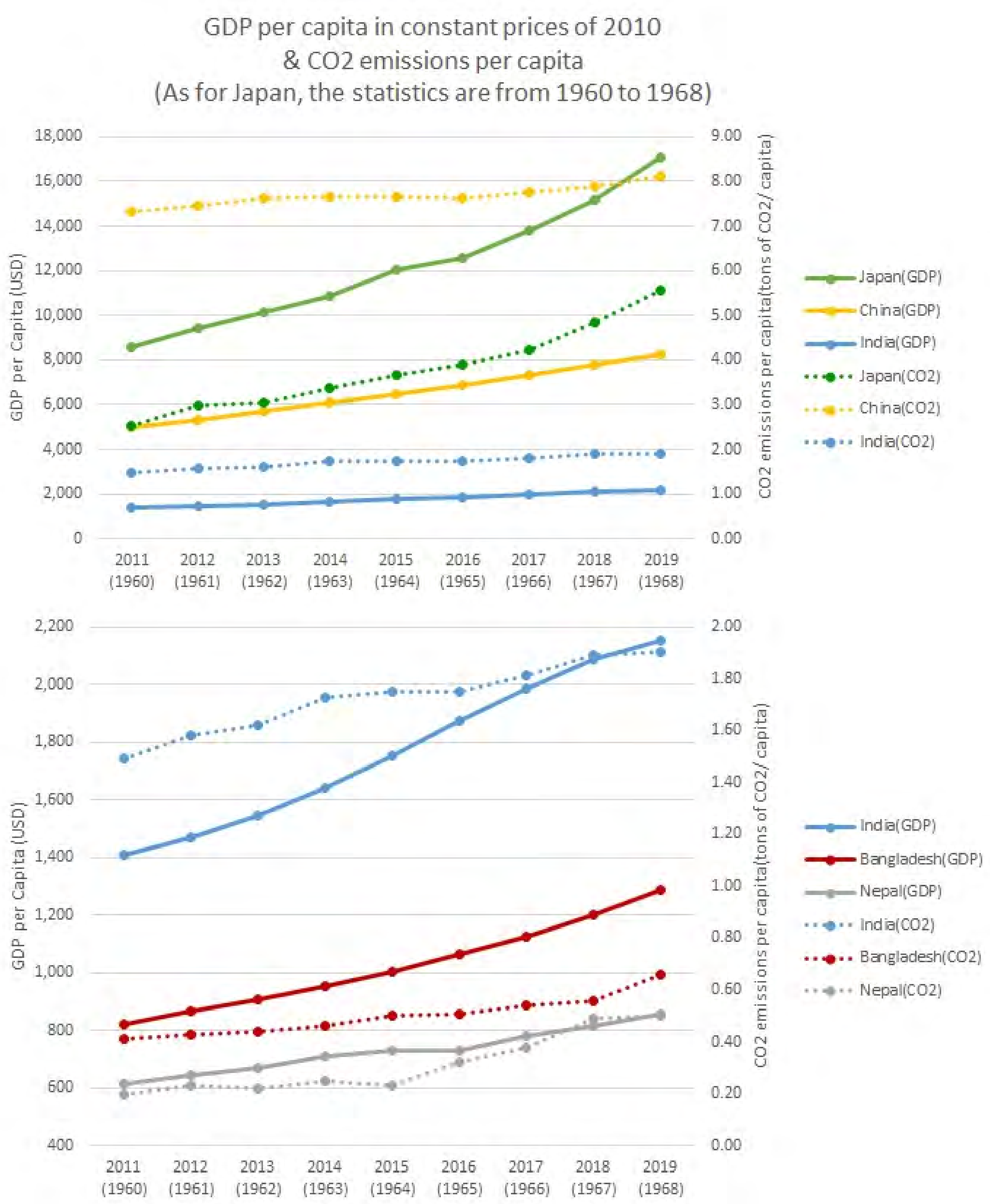


Source: International Monetary Fund (World Economic Outlook Database, October 2021)

Figure 2.1-1 GDP Growth Rate of Bangladesh

Figure 2.1-2 shows the impact of economic growth on CO2 emissions, and it indicates the GDP per capita (in constant prices of 2010) and CO2 emissions per capita of the country and Japan[1], China and India whose economies are developing, and neighboring country Nepal from 2011 to 2019. The CO2 emissions in each country have increased along with the economic growth. To reduce CO2 emissions with achieving economic growth may be the challenge.

[1] The data from 1960 to 1968 during the high economic growth



Source: Study team from World Development Indicators (WDI), World Bank website (GDP per capita (current US$) Data (worldbank.org))

Figure 2.1-2 Correlation between Economic Growth and CO2 Emissions

2.2 The Power and Energy Policy, and the Climate Change Policy

Power and energy policy in Bangladesh is developed with being closely related to climate change as the climate change affects the livelihood, the natural environment and the agriculture by rainfall, flood and increasing sea level because of increasing temperature of atmosphere. The country has been addressing the environmental issue, and signed United Nations Framework Convention on Climate Change (UNFCCC) in 1992, and ratified it in 1994. In 2005, National Adaptation Program of Action (NAPA) which was adaptation plan for climate change was submitted to UNFCCC. In 2006, Awami League announced the manifesto “Vision 2021” which indicated power development outline with considering climate change, and the long-term national plan “Perspective Plan of Bangladesh 2010-2021 (PP2021)” was developed in 2012. The concreted strategies were reflected in the medium-term plan “Five Year Plan” and the climate change adaptation plan was reflected from the 7th Five Year Plan. As the PP2021 focus on the industry development and electrification improvement, high-cost generators increased. Therefore, in the Perspective Plan of Bangladesh 2021-2041 (PP2041） which was developed in December 2020, the strategies for the power and energy sector were the energy cost reduction and the renewable energy introduction. In December 2020, the 8th Five Year Plan was developed based on the strategies of PP2041.

In terms of the Climate Change, Intended Nationally Determined Contributions 2015 (INDC2015) was submitted to UNFCCC in September 2015, and Nationally Determined Contributions 2020 (Interim) (NDC2020) was submitted in December 2020. And then, Nationally Determined Contributions (NDCs) 2021 Bangladesh (Updated) (NDC2021) was submitted in August 2021. In the NDC2020, the action plan to implement mitigation measures certainly is introduced, and in the NDC2021, the new numerical goals and concrete mitigation actions are indicated. Table 2.2-1 shows the policies and plans related to the power, energy and the climate change.

Table 2.2-1 Policies and Plans related to Power, Energy and Climate change

National Plan	MoPEMR	Climate Change
Jan 1995 4th Five Year Plan	1996 National Energy Policy (NEP)	1994 United Nations Framework Convention on Climate Change (UNFCCC) was ratified
Mar 1998 5th Five Year Plan		
	May 2004 National Energy Policy (Revised)	
2006 Vision2021	Nov 2005 National Energy Policy (Revised)	Nov 2005 National Adaptation Program of Action (NAPA) was submitted
	2006 Gas Sector Master Plan 2006	
	Dec 2008 Renewable Energy Policy (Power Division)	Jun 2009 NAPA(Revised)
		Sep 2009 Bangladesh Climate Change Strategy Action Plan (BCCSAP) was approved
Jul 2011 6th Five Year Plan	Feb 2011 Power System Master Plan 2010	
Apr 2012 Perspective Plan of Bangladesh 2010-2021 (PP2021)	Dec 2012 Sustainable and Renewable Energy Development Authority (SREDA) was established	
	2012 Development of Sustainable Renewable Energy Generation (SREPGen) Project (SREDA supported by UNDP) was started	
Dec 2015 7th Five Year Plan	Mar 2015 Energy Efficiency & Conservation Master Plan up to 2030	Sep 2015 Intended Nationally Determined Contributions 2015 (INDC2015) was submitted
	Sep 2016 Power System Master Plan 2016	
	Feb 2018 Gas Sector Master Plan 2017	2018 Roadmap and Action Plan for Implementing Bangladesh NDC
	Nov 2018 Revisiting PSMP 2016	Sep 2018 Bangladesh Delta Plan 2100 (General Economics Division)
Mar 2020 Perspective Plan of Bangladesh 2021-2041 (PP2041)		
Dec 2020 8th Five Year Plan	Dec 2020 National Solar Energy Roadmap, 2021-2041(Draft) (SREDA)	Dec 2020 Nationally Determined Contributions2020(Interim) (NDC2020) was submitted
		Aug 2021 Nationally Determined Contributions (NDCs) Bangladesh (Updated) (NDC2021) was submitted

Source: Study Team

2.2.1 Power and Energy Policy in the 8th Five Year Plan

In the 6th Five Year Plan and 7th Five Year Plan, the social infrastructure development has been priority project. As for the power and energy policy, the target is to realize low and stable price energy supply by supplementing lack of domestic gas with imported gas and coal and petroleum, and making optimum allocation of domestic gas and coal, and imported gas and coal and petroleum, because the domestic gas resource, which is currently the main primary energy, decreases and there are raising concerns of the energy supply shortage for growing energy demand. Under this target, the power and energy sector development has been implemented, especially recent years, the power sector has been developed significantly, and in the energy sector, primary energy decentralization was started by importing LNG and coal. In the 8th Five Year Plan, the good practices in the past are continued and the strategies are strengthened newly in terms of the following 4 points.

First of all, Power System Master Plan 2016 (PSMP2016) is revised. In the new master plan, the efficient use of conventional power plants and introduction of new power plants which can generate low-cost electricity will be considered.

Secondly, the introduction of renewable energy is promoted. In order to introduce renewable energy, the grant of the incentives and the proper fuel price will be set.

Thirdly, the balance sheet of the power and energy sector is improved. The financial situation that the government compensates the deficit which is caused by the tariff setting will be reformed.

Finally, the energy conservation and the thermal efficiency of the power plants are improved. In terms of the energy conservation, the price setting and the taxation regime to introduce high efficiency technologies and to reduce energy consumption will be considered. In terms of the thermal efficiency improvement of the power plants, proper measures and policies for operation and maintenance will be considered.

In terms of the power plant facilities, because the domestic gas price has been low, the incentives for investment to implement the inspection and the repair to maintain thermal efficiency are not as per the standard level, but now the incentives for thermal efficiency improvement of power plants have occurred in terms that the imported LNG and coal price are higher than domestic gas, and in light of the reduction of the dependence on imports and the GHG emissions. And in terms of the reduction of dependence on imports and the energy security by the decentralized power source, the incentives to introduce renewable energy have occurred.

For the power sector, according to 8th Five Year Plan, the following strategies are cited against the backdrop of the stable supply of primary energy, the reduction of dependence on imports, the electrification, the climate change and the implementing balance sheet.

- Move to an efficient, least-cost power production structure based on an optimal and efficient primary fuel mix and the loss reduction in power transmission and distribution.
- Continue to enhance the generation capacity to match expansion of demand from all segments of the economy, particularly industry and manufacturing, so as to boost the power consumption ration to 100%.
- While moving to a least-cost power production system, have regular power tariff adjustments to ensure long-term sustainability of power generation and move away from the budgetary subsidies that are now prevalent.
- In order to leverage higher levels of investments, undertake necessary reforms that can create a more conducive and healthier environment for the participation of the private sector (IPPs and PPPs), both domestic and foreign, in energy sector development under the supervision of an effective regulatory authority.
- Enhance the exploitation of gas, coal, and renewable resources, and increase energy imports - particularly hydropower resources from neighboring Bhutan and Nepal - in order to optimize the energy mix and reduce the dependence on imported furnace oil and HSD. In this regard, hydropower, given its abundance in the neighboring countries and expected cheaper cost of production, will be given prime importance among other renewable resources. The other renewable resources include wind power, solar energy, biomass and waste to power. The core strategic goal of energy mix is to provide energy to all consumers.
- Address the identified issues, including the gas crisis, poor thermal power plant efficiency, adulteration in furnace oil, fiscal prudence and sustainability.
- Improve Energy Efficiency & Conservation through demand side management.
- Establishment of supply line network for the transportation of petroleum in a quick, safe, efficient and environmentally friendly way all over the country.

・ Establishment of a number of energy hubs in the country, including a Matarbari Ultra Super critical Coal-fired Power Plant-centric energy hub.

Concrete examples include shifting from power sources which use high price HSD or Furnace oil to renewable energy, construction of an ultra-super critical coal-fired thermal power plant, and taking a fresh look at the PPAs due to the payment of huge capacity charges. An optimal primary fuel mix should therefore be targeted. The 8th Five Year Plan also says that the issue that there is no long-term strategy for primary energy, especially domestic coal policy, and states that one should be formulated promptly. Furthermore, the plan raises issues such as preventing institutional constraints in barrier energy projects, and the reform of the Public Private Partnership (PPP) system for primary energy investment.

As for the plan on reform of the Power Sector, it aims to establish a system, framework or organization which formulates policy with an overview of the primary energy balance, and the institution of regulations or rules for improving energy efficiency, especially the periodic maintenance of generating facilities.

With regard to power trades with neighboring countries, the plan declares a policy of expanding the import volume from Bhutan, Nepal, and India, and the specific implementation is studied during the term of the plan.

For the energy sector, to achieve the efficient supply of primary energy is the important strategy, as the primary energy shortages expanded and as a result, the dependance on high cost imported LNG and coal was higher. In order to secure the efficient and cost-effective primary energy supply, optimal combination between domestic supply option and import option will be developed. In the 7th Five Year Plan, following policies which are needed in the primary energy sector are developed, and it is taken over to the 8th Five Year Plan.

(1) Domestic Gas Exploration Policy:

Undeveloped resources are likely to be in coastal / transitional areas, hills, or offshore areas and require advanced technology and huge amounts of capital. To address such technical and financial issues, a joint venture or "strategic partnership" between Bangladesh Petroleum Exploration and Production Company Ltd. (BAPEX) and a foreign company or a production sharing agreement with the International Oil Company (IOC)[2] is required. The delineation of the maritime boundary between Myanmar and India has opened up new offshore exploration opportunities. Therefore, both onshore and offshore oil and gas options can be pursued.

(2) Domestic Coal Use:

The country is blessed with abundant bituminous coal deposits, with measured estimated coal reserves totaling 7,962 million tons. Of the five identified coalfields in Barapukuria, Phurbari, Khalaspir, Dighipara and Jamalgan, only in Barapukuria, the coalfield is developed and currently in production.

The 8th Five Year Plan also says that as proposed in 7th plan, it is important to explore the scope of exporting the high quality Barapukuria coal as higher valued coking coal or steam coal, and import lesser quality coal for Barapukuria Coal Power Generation. The feasibility survey for the development in Dighipara has been completed. In addition, the coalfield in Khalaspir and Jamalgan will be developed by 2041. Such use contributes to higher value-added economic activity and should be dictated by a clear domestic coal use policy.

(3) Energy Import

(a) Import LNG/Gas pipeline:

Considering to diversify gas suppliers and jointly purchase natural gas with other countries in order to ease very high unit prices and gain bargaining power. In particular, possible ways to gain additional purchasing power, such as group purchasing with India or other South Asian countries. Regular contract reviews are required to pursue more favorable terms of the contract.

(b) Coal Imports:

[2] The international 4 majors of Chevron, Cairn, Niko, Tullow

The government plans to expand Matarbari deep-sea port which is developed for the Matarbari ultra-super critical coal-fired power plant, and develop a coal center (Coal Trans-shipment Terminal (CTT)) as an "energy hub."

(4) Demand Side Management (DSM) and Energy Conservation

Energy efficiency and energy conservation are recognized as urgent policy priorities in the 7th Plan. Policy efforts include replacing inefficient gas-fired power plants with more energy-efficient plants; incentives for the adoption of technologically improved fuel efficiency and energy savings in the industry; saving household gas consumption through proper measuring. It includes pricing based on the amount of gas consumed, rather than a fixed monthly fee for each stove.

(5) Improved Cooking Stove (ICS)

The government strongly recommends to penetrate "improved cooking stoves (ICS)".

(6) Energy Subsidy and Pricing

Energy imports will increase further, primarily due to imports of LNG, coal and oil for power generation. As a result, energy costs are expected to increase at a rapid pace. Therefore, the government needs to maintain budget discipline and determine the extent to which energy subsidies are allowed in high-priority sectors.

2.2.2 Power and Energy Policy

Ministry of Power, Energy and Mineral Resources (MoPEMR) developed the National Energy Policy (NEP) in 1996. NEP was revised in 2004 and 2005, and Power Division announced the Renewable Energy Policy in 2008, and it continues up to today. In this plan, the policies for the gas field and coal mine development, fuel diversification, implementing electrification, climate change measures, renewable energy adaptation are indicated. In terms of the climate change measures, GoB established the Sustainable and Renewable Energy Development Authority (SREDA) in 2012. In terms of the renewable energy, the numerical targets that the capacity is to be 5% by 2015 and 10% by 2020 of total are indicated.

In terms of the energy sector, Gas Sector Master Plan (GSMP) was developed in 2006 and 2018, and the country is adopting it. In the GSMP, the policies, regulations, investments, gas demand forecast, gas transmission and distribution, LNG import which are required to develop the gas sector are proposed. In terms of LNG import, Floating Storage and Re-gasification Units (FSRU) is proposed and 2 units of FSRU have started the commercial operation in August 2018 and April 2019, and the units are accepting LNG. GSMP is the intelligence infrastructure to develop the whole the energy sector, but there is no defined gas sector policy clearly in the country.

In terms of the power sector development, the Power System Master Plan (PSMP) was developed in 2011 and 2016, and demand forecasts and power development plan were indicated. In the PSMP2016, the climate change was considered, and the power source portfolio ratio of coal fired power as of 2041 was set at 35% (excluding renewable energy). The ratio is the figure that the energy stable supply and climate change and economy are considered. In 2015, Energy Efficiency & Conservation Master Plan up to 2030 was developed, and the efficient use of energy and the demand side management were indicated. The demand forecasts which reflect the results of the Energy Efficiency & Conservation Master Plan were adopted in the PSMP2016. In 2018, Revisiting PSMP2016 was developed, and the demand forecasts and the power development plans were updated. The power source portfolio ratio of the coal fired power in this plan is set at 32% (excluding renewable energy), and it generally follows the coal-fired power ratio of PSMP 2016.

2.2.3 Renewable Energy Policy and Climate Change Policy

The country is implementing the renewable energy introduction as a countermeasure for the energy stable supply which is caused by the domestic gas depletion, and the climate change.

The movement of the climate change measures in the country is that the country ratified the UNFCCC in 1994, and submitted National Adaptation Program of Action (NAPA) in 2005. NAPA was revised in 2009, and in the same year, Bangladesh Climate Change Strategy Action Plan (BCCSAP) was approved. In the BCCSAP, the action plan for the renewable energy development was set, but the numerical goals were not set.

In 2015, Intended Nationally Determined Contributions 2015 (INDC2015) was submitted to the UNFCCC.

In the INDC2015, the numerical goal of the renewable energy introduction was set as “the capacity is to be 5% by 2015 and 10% by 2020 of total” which was same as the goal of the NEP. In terms of the coal fired power, the super critical technology[3] is used for the new introduction power plant which is introduced by 2030, but in terms of the finance, technology transfer and capacity building support, the need for the international support is described. In 2018, Roadmap and Action Plan for Implementing Bangladesh NDC (Transport, Power and Industry Sectors) was developed from Ministry of Environment, Forest and Climate Change as the roadmap to implement INDC2015.

In 2018, Bangladesh Delta Plan 2100 was developed from General Economics Division (GED), Bangladesh Planning Commission in parallel with the roadmap. In the plan, the generation energy from renewable energy is set at least 30%.

In 2020, Nationally Determined Contributions 2020 (Interim) (NDC2020) which was revised INDC2015 was submitted to the UNFCCC. In the NDC2020, although there were no descriptions about the target raise of GHG reductions and coal fired power plant. In terms of the thermal power plant, but only the thermal efficiency improvement of aged thermal power facilities by repowering of turbine is said.

After that, Nationally Determined Contributions (NDCs) 2021 Bangladesh (Updated) (NDC2021) was submitted to UNFCCC on 26th August 2021. In the NDC2021, the goals of GHG emissions which was indicated in the INDC2015 are raised. And in the power sector, the mitigation measure of the introduction of the ultra-super critical coal power technology is indicated with taking over the INDC2015 policy. This project is also included in the NDC2021 as a part of the mitigation actions. The detail explanation of INDC2015, NDC2020 and NDC2021 is mentioned below.

And deputy Director of DoE is taking part in the stakeholder meeting, but the official comments regarding this project will be made after the examination of the Environmental Impact Assessment (EIA) which is already been submitted to DoE.

Under the circumstances like this, Bangladesh has chaired the 48-nation Climate Vulnerable Forum (CVF) and Vulnerable Twenty (V20) Finance Ministers' Group, while prime minister Sheikh Hasina has chaired the CVF since June 2020. The recent activity of CVF and V20 focuses on the necessary funding for measures against climate change. The 1st Climate Vulnerable Finance Summit was held on 8 July 2021, hosted by Bangladesh, which the United Nations agreed on five hundred million dollars funding from all over the world. The financial cooperation is being called on each country.

In terms of the renewable energy development, Sustainable and Renewable Energy Development Authority (SREDA) was established in 2012 under the Ministry of Power, Energy & Mineral Resources (MoPEMR), and the SREDA is in charge of the implementation of the energy conservation, the efficient energy use, and the renewable energy penetration. SREDA also started the Development of Sustainable Renewable Energy Generation (SREPGen) Project under the support of the United Nations Development Programme (UNDP), and developed the National Solar Energy Roadmap, 2021-2041(Draft) in December 2020 as one of the activities. This activity was adopted in the NDC2020 and NDC2021 as one of the action plans. National Solar Energy Roadmap, 2021-2041(Draft) was developed based on the strategies and policies of NEP, Perspective Plan of Bangladesh 2021-2041, 8th Five Year Plan, Roadmap and Action Plan for Implementing Bangladesh NDC (Transport, Power and Industry Sectors), and Bangladesh Delta Plan 2100etc. and 3 scenarios were considered depending on the introduction volume of the solar power (refer to the “2.3.4 Solar Power (PV) Development Plan considered in Power Division” in detail). National Solar Energy Roadmap, 2021-2041(Draft) was submitted to Power Division, and the roadmap is considered by Power Division, and the proper target and the countermeasures will be announced by Power Division.

(1) Over view of the Intended Nationally Determined Contributions 2015 (INDC2015)

In the INDC2015, as a countermeasure for climate change, the following targets were set for reducing greenhouse gas (GHG) emissions.

- Reduce GHG emissions by 12 $MtCO_2e$ or 5% of BAU levels by 2030 in the power, transportation and industrial sectors
- Reduce GHG greenhouse gas emissions by 36 $MtCO_2e$ or 15% of BAU levels by 2030 in the power, transportation and industrial sectors, subject to appropriate international support such as funding, investment, technology development and transfer, and capacity building.

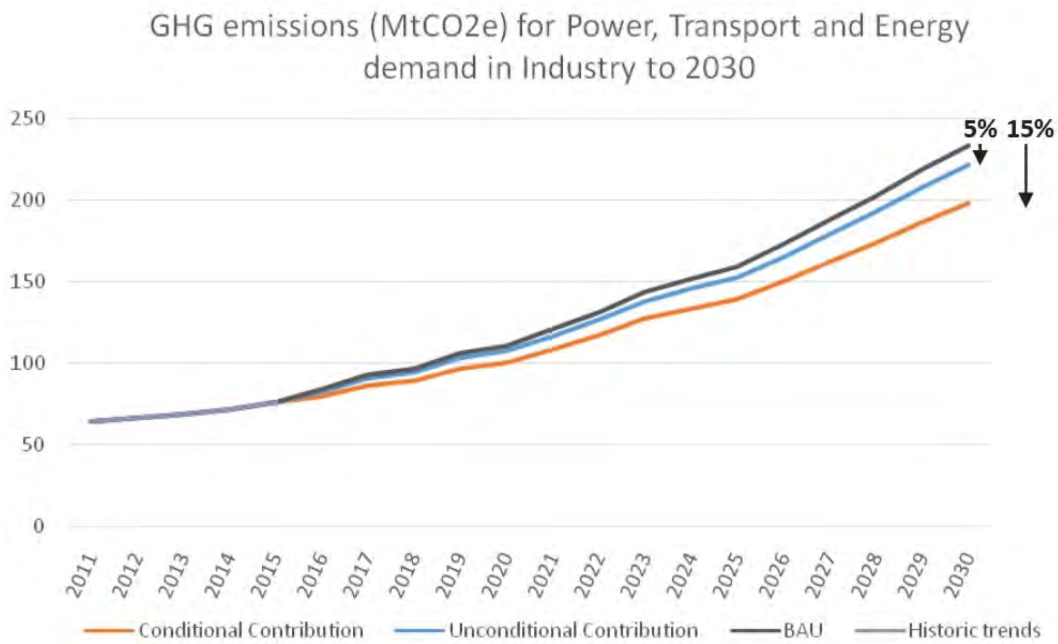
[3] It means use of the super critical or more such as the ultra-super critical

- A number of further mitigation actions, subject to the provision of additional international resources.

Table 2.2-2 Intended Nationally Determined Contributions – Mitigation

Unconditional contribution	Contribution assuming no additional international support	Bangladesh will reduce its GHG emissions in the power, transport, and industry sectors by 12 $MtCO_2e$ by 2030 or 5% below BAU emissions for those sectors.
Conditional contribution	Contribution assuming additional international support	Bangladesh will reduce its GHG emissions in the power, transport, and industry sectors by 36 $MtCO_2e$ by 2030 or 15% below BAU emissions for those sectors.

Source: INDC2015



Source: INDC2015

Figure 2.2-1 Projection of GHG emissions ($MtCO_2e$) on power, transport and industry sectors from 2011 to 2030

Table 2.2-3 Projected emissions reductions in the power, transport and industry (energy) by 2030

Sector	Base year (2011)	BAU Scenario		Unconditional contribution scenario			Condotional contribution scenario		
		Emissions in 2030 (a)	Change from 2011 to 2030	Emissions in 2030 (b)	Change vs BAU	Reduction (a)-(b)	Emissions in 2030 (c)	Change vs BAU	Reduction
	$MtCO_2e$	$MtCO_2e$	%	$MtCO_2e$	%	$MtCO_2e$	$MtCO_2e$	%	MtCO2e
Power	21	91	336%	86	-5%	5	75	-18%	11
Transport	17	37	118%	33	-9%	4	28	-24%	5
Industry (energy)	26	106	300%	102	-4%	4	95	-10%	7
Total	64	234	264%	222	-5%	12	198	-15%	24

Source: INDC2015

However, the quality and availability of data is an issue in Bangladesh, and accurate data is expected in the Brandades Climate Change Strategy Action Plan (BCCSAP) that will be updated next time and National Communication and Biennial Update Report. BCCSAP has not been updated since 2009, but is currently in the final stages of updating according to the NDC2020.

In INDC 2015, the following goals and contribution measures have already been set out.

- A target to reduce energy intensity (per GDP) by 20% by 2030 compared to 2013 levels (E&CC Master Plan)
- Introduction of an Energy Management Programme, including establishment of Energy Management Systems and energy audits for industry by accredited energy auditors
- Introduction of an Energy Efficiency labelling programme to promote sales of high efficiency products in the market
- Introduction of Energy Efficiency measures for buildings, such as heat insulation and cooling measures, and a revised code on energy efficiency of new buildings
- Introduction of the Solar Home System Programme, providing off-grid electricity access to rural areas
- To deliver 5% of energy from renewable sources by 2015, and 10% by 2020 (It has already set in the 2008 Renewable Energy Policy)
- More than 1.5 million Improved Cook Stoves (ICS) and 4.0 million Solar Home Systems (SHS) have already been distributed across the country (6 million ICS and 250MW SHS is the target of NDC2020)
- Introduction of improving kiln efficiency in the brick making industry, composting of organic waste and waste biomass-based thermal energy generation
- Construction of Combined Cycle Power Plant (CCPP) by the Government of Bangladesh and utilities companies
- Under the Solar roof-top program around 14 MW of solar has been installed on the vacant roof-tops of Government and private buildings (1,700MW PV deployment connected to the grid by 2030 is the target of the NDC2020)
- To scale up the potentials of Solar Irrigation Pumps, Solar mini and nano grids to address the energy access issue of off-grid population

In addition to the above measures, INDC 2015 includes the following contributions in the power, transportation and industrial sectors. Provided that, in terms of the finance, technology transfer and capacity building support, the need for the international support is described.

Table 2.2-4 Possible mitigation actions to deliver the conditional contribution

Sector	Description	Objectives of the activity by 2030
Power	▪ Ensure all new coal generation uses super-critical technology ▪ Increased penetration of wind power ▪ Implement grid-connected solar plant to diversify the existing electricity generation mix	▪ 100% of new coal based power plants use super-critical technology by 2030 ▪ 400 MW of wind generating capacity by 2030 ▪ 1000 MW of utility-scale solar power plant
Transport	▪ Modal shift from road to rail, delivered through a range of measures, including underground metro systems and bus rapid transit systems in urban areas. Co-benefits will include reduced congestion, improved air quality and improved traffic safety. ▪ Reduced congestion and improved running of traffic. This will be achieved by a number of measures, including building of expressways to relieve congestion and public transport measures.	▪ To achieve a shift in passenger traffic from road to rail of up to around 20% by 2030 compared to the business as usual. ▪ 15% improvement in the efficiency of vehicles due to more efficient running.
Industry (energy-related)	▪ Carry out energy audits to incentivise the uptake of energy efficiency and conservation measures in the main industrial sectors based on the Bangladesh Energy Efficiency and Conservation Masterplan	▪ 10% energy consumption reduction in the industry sector compared to the business as usual

Source: INDC2015

Other sectors such as households, commercial buildings, agriculture, waste and land use are also set as additional targets.

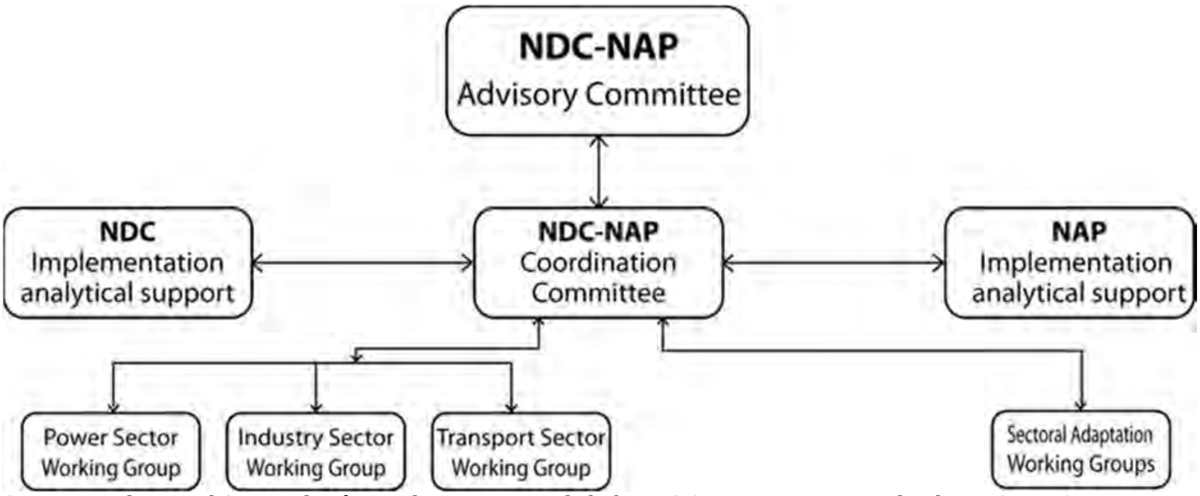
And the achievements in the power sector are indicated in the Nationally Determined Contributions 2020 (Interim) (NDC2020) as follows.

- The country has installed around 5.8 million solar-home systems (SHSs) across the country, meaning that almost 18 million beneficiaries are getting solar electricity which is around 11% of the total population of the country.
- More than 4.5 million improved cook stoves (ICS) have already been distributed to rural household in order to reduce emissions from biomass burning.
- Around 60.6 MW of solar has been installed on the vacant roof-tops of Government and private buildings.
- Nearly 1969 solar irrigation systems have been installed in different parts of the country.
- The Government has extended a re-financing scheme to finance alternative energy generation projects like small scale solar and micro grids, to improve energy access for those living in off-grid areas.

(2) Implementation of NDC

In 2018, the government issued the Roadmap and Action Plan for Implementation Bangladesh NDC (Transport, Power and Industry Securities) to specifically implement NDC.

The roadmap says that the key to successful implementation of the NDC is good governance and coordination among sectors, different stakeholders, and different levels of government and civil society. And the NDC-NAP is operated in the structure shown in Figure 2.2-2 below. This system has been specifically proposed for the implementation of the NDC with the aim of including the implementation of the National Action Plan (NAP) in parallel under a single framework. In the future, review of BCCSAP (Bangladesh Climate Change Strategy Action Plan) may also be linked.



Source: Roadmap and Action Plan for Implementing Bangladesh NDC (Transport, Power and Industry Sectors)

Figure 2.2-2 Governance arrangements for NDC-NAP implementation framework

(3) Summary of NDC2020

Then in 2020, Nationally Determined Contributions 2020 (Interim) was announced. In the NDC2020, the challenges to certainly implement the mitigation actions are shown as follows.

・ Mujib Climate Prosperity Plan up to 2030

Honorable Prime Minister has launched a program in October 2020 to develop “Mujib Climate Prosperity Plan” for Bangladesh. The Plan will be a strategic investment framework to mobilize financing.

・ National Solar Energy Roadmap, 2021-2041

The National Solar Energy Roadmap, 2021 - 2041 has been drafted to frame of a long-term vision for the nation and to set achievable capacity targets for the country’s solar energy initiative as well as outlining the broader strategies required to achieve those targets. See "2.3.4 Solar Power (PV) Development Plan considered in Power Division" for specific solar power generation implementation scenarios.

・ National Action Plan for Clean Cooking, 2020-2030

Following Bangladesh’s Country Action Plan for Clean Cook Stoves 2013 (CAP 2013), a new National Action Plan for Clean Cooking in Bangladesh (2020-2030) is currently being formulated.

・ Forest and Carbon Inventories

Bangladesh Forest Department conducted National Forest Inventory (NFI) during 2016-2019 to identify the status of forest and tree resources, carbon and biomass stock, dependency of local people on trees and forests and the ecology.

・ Bangladesh National Action Plan (NAP) for Reducing Short Lived Climate Pollutants (SLCPs)

The full implementation of the National SLCP Plan is expected to reduce black carbon emissions by 40% and methane emission by 17% in 2030 compared to a business-as-usual scenarios.

・ Energy Efficiency and Conservation Master Plan up to 2030

This is the master plan which was developed in March 2015 related to the efficient energy use and energy conservation.

・ The out of these challenges, Clean Development Mechanism (CDM)/Carbon Trading, Monitoring and Reducing Air Pollution, Renewable Energy Initiatives, Promoting Green Technology are implemented.

Nationally Determined Contributions 2020 (Interim) describes future plans so far as follows:

Planned Actions

- The government has set a target of generating 1700 MW from Utility scale solar plants and 250 MW from solar home system by 2030. Additionally, government is repowering old steam turbines to increase efficiency. Through the six registered CDM projects, approximately 118 MtCO2e will be reduced by 2030. Six million additional improved cook stoves are expected to be distributed in Bangladesh. Commercial buildings in Bangladesh have a 25% potential to reduce the GHG emission through the planned activities.
- The major cities generate substantial amount of solid waste (of which 75% is bio-degradable) and they have the potential to reduce the waste by converting it to energy. Already two city corporations adopted the incineration technology to reduce waste and other two city corporation will also follow them and around 100 municipalities will establish bio-gas plant to reduce emission. These initiatives are gaining momentum and some of them will be implemented over the next few years. Bangladesh has already ratified the Kigali Amendment and by phasing out HCFCs and HFCs, around 2.4 million tons of GHG emission will be reduced by 2030.

Transport sector

- 10000 hybrid and electric vehicles are planned to be introduced.
- Introduction of broad gauge and electric locomotives.
- Introducing good quality fuel and Euro III and IV engines.
- Completing all highways with four lanes.
- Withdrawal of 86,000 unfit vehicles from the roads.
- Introducing Lithium-ion battery in all motor cycles and cars are planned.

(4) Summary of NDC2021

Nationally Determined Contributions (NDCs) 2021 Bangladesh (Updated) (NDC2021) was submitted to UNFCCC on 26th August 2021. NDC2021 was developed with the support of United Nations Development Programme (UNDP). In the NDC2021, the targets of the GHG emissions are raised as per Table 2.2-5.

In INDC2015, the GHG reduction of “Unconditional contribution” was 12MtCO2e and “Conditional contribution” was 24MtCO2e, but the reduction amount has been increased as 27.56MtCO2e (unconditional) and 61.91MtCO2e (conditional) in NDC 2021. It means 53.47MtCO2e was raised in total.

GHG reduction in the power sector was 16MtCO2e (5+11 MtCO2e) in INDC2015, but it became 43.74MtCO2e in NDC2021 and it means that compare with NDC2015, additional 27.74MtCO2e reduction has been mentioned in NDC2021. In terms of the coal fired thermal power, the policy of “100% new coal-based power plants use super-critical technology by 2030” which was proposed in INDC2015 was taken over. And the 12,147MW of the Ultra-super critical coal fired thermal power was included in NDC2021 as “Conditional contribution”. This project was also included in the mitigation measure.

Table 2.2-5 GHG Reduction by Mitigation in the NDC2021

UNFCCC Sector	Sub-sector	GHG Emission		GHG Reduction by Mitigation (2030)							
		BAU 2030		Unconditional			Conditional			Combined	
		MtCO2e	In %	MtCO2e	Reduction MtCO2e	In %	MtCO2e	Reduction MtCO2e	In %	Reduction MtCO2e	In %
Energy	Power	95.14	23.24	87.13	8.01	29.06	51.4	35.73	57.72	43.74	48.9
	Transport	36.28	8.86	32.89	3.39	12.3	26.56	6.33	10.23	9.72	10.86
	Industry (energy)	101.99	24.91	95.33	6.66	24.17	94.31	1.02	1.65	7.68	8.58
	Other energy sub sectors:										
	Households	30.41	7.43	28.78	1.63	5.91	24.77	4.01	6.46	5.64	6.3
	Commercial	3.35	0.82	2.94	0.41	1.49	2.51	0.43	0.69	0.84	0.94
	Agriculture	10.16	2.48	9.37	0.79	2.87	10.13	0.03	0.05	0.82	0.92
	Brick Kilns	23.98	5.86	20.7	3.28	11.9	12.82	7.88	12.73	11.16	12.47
	Fugitive	8.31	2.03	8.31			4.03	4.28	6.91	4.28	4.78
	F Gases	2.92	0.71	0.78	2.14	7.76	0.03	0.75	1.21	2.89	3.23
Total Energy		312.54	76.34	286.23	26.31	95.46	226.56	59.71	96.46	85.98	96.1
IPPU	Cement and Fertilizer	10.97	2.68	10.97			10.97				
AFOLU	Agriculture and Livestock	54.64	13.35	54	0.64	2.32	53.6	0.4	0.65	1.04	1.16
	Forestry	0.37	0.09	0.37			0.37				
Total AFOLU		55.01	13.44	54.37	0.64	2.32	53.97	0.4	0.65	1.68	1.16
Waste	MSW and wastewater	30.89	7.55	30.28	0.61	2.21	28.44	1.84	2.97	2.45	2.74
Total Emission		409.41		381.85			319.94				
Total Reduction					27.56	6.73		61.95	15.12	89.47	21.85

IPPU: Industrial Processes and Product Use
AFOLU: Agriculture, Forestry and Other Land Use
Source: NDC2021

The mitigation actions in the power sector are as follows.

Table 2.2-6 Mitigation actions in power sector in the NDC2021

Mitigation actions in power sector by 2030	Unconditional contribution (MW)	Conditional contribution (MW)
Implementation of renewable energy projects	911.8	4,414.3
Installation of new combined cycle gas based power plant	3,208.0	5,613.0
Efficiency improvement of existing gas turbine power plant	570.0	570.0
Coal power plant with ultra super critical technology	---	12,147.0

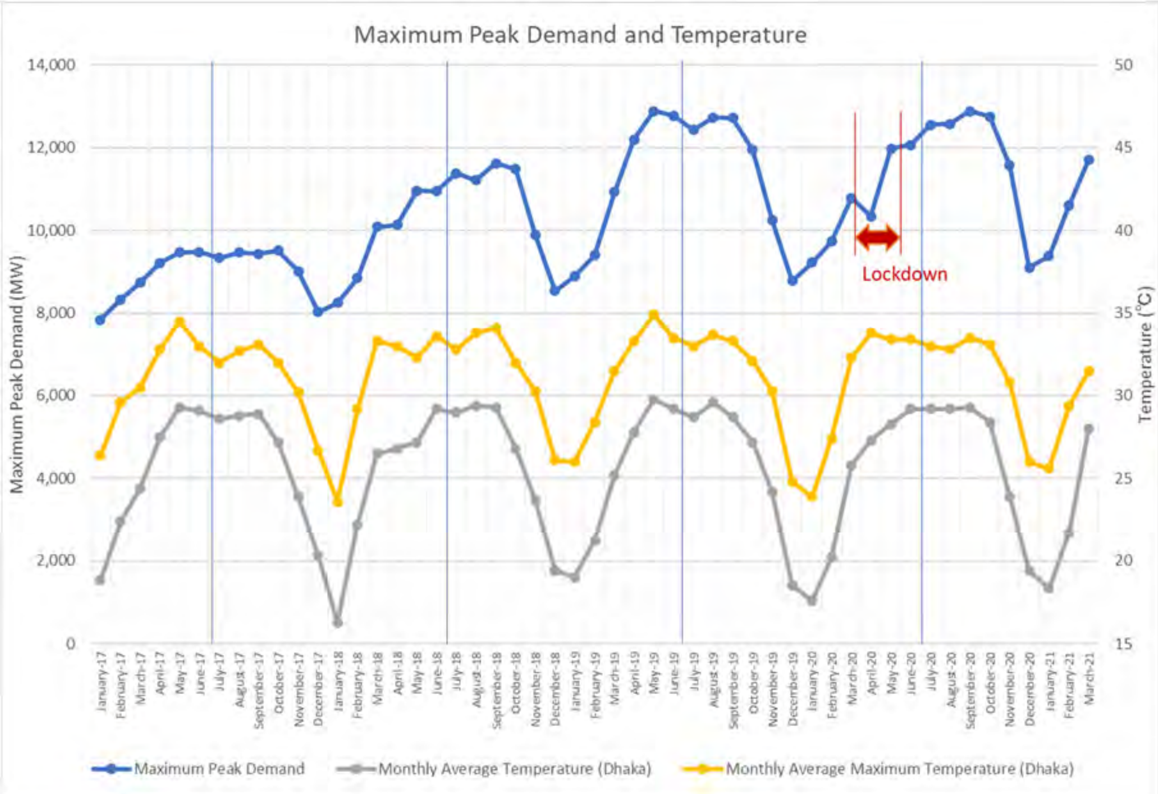
Other than the above table, "Installation of prepaid meter" and "Bring down total T&D Loss to a single digit by 2030" which don't have numerical goal are also indicated.
Source: NDC2021

The others of the mitigation actions in the NDC2020 are taken over in NDC 2020. The new adaptation action plans in NDC2021 are "Sustainable Ecosystem and Livelihood", "Disaster Management", "Agriculture and Food Security", "Water Resources Management", "Surface Water Use and Rainwater Harvesting". And the governance and methodology, challenges and financing are described.

2.3 Current Status of Power Sector

2.3.1 Latest Power Demand

Figure 2.3-1 shows monthly peak demand and monthly average temperature and monthly average maximum temperature from January 2017 to March[4] 2021. The peak demand has been increasing at a good rate, but in 2020, due to the lockdown from 23rd March to 30th May in response to the Covid-19 pandemic, the peak demand was lower than this term of the previous year.



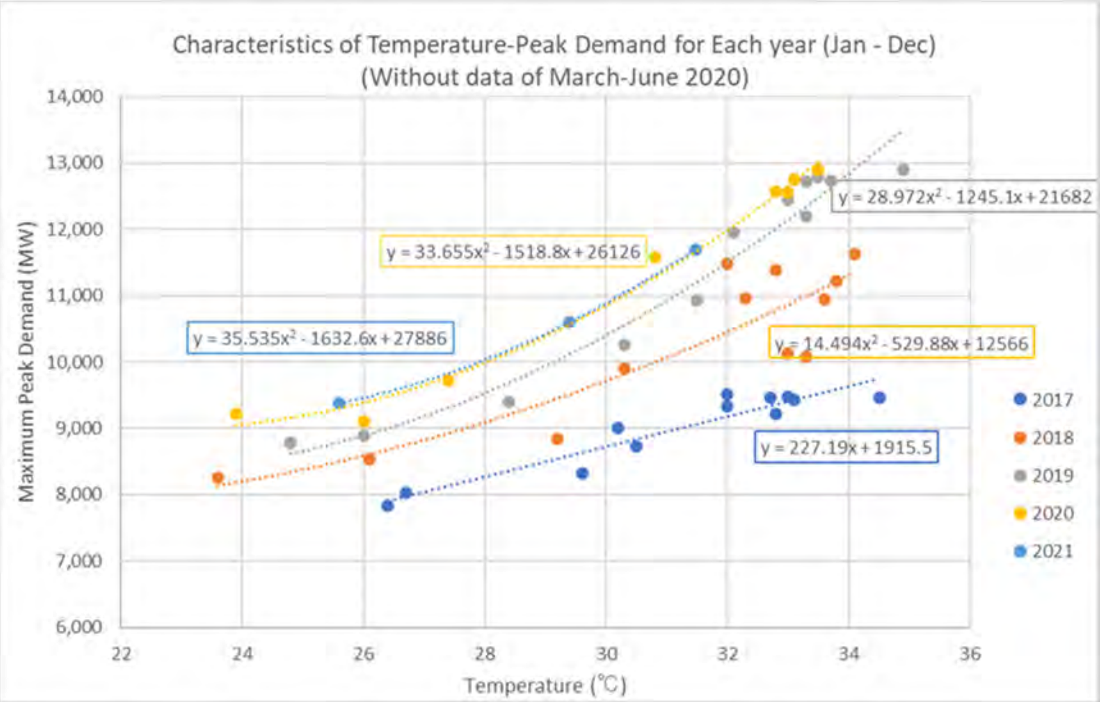
Source: Study Team from PGCB website and Japan Meteorological Agency

Figure 2.3-1 Monthly peak demand and monthly average temperature and monthly average maximum temperature

The trends on the demand-temperature on the same condition of each month is to be examined because the demand data of Figure 2.3-1 are on the different temperatures. Figure 2.3-2 shows the correlation between monthly average maximum temperature (actual record) and monthly peak demand in each year to correct the peak demand with temperature. Provided that, the data from March to June in 2020 which are affected according to Covid-19 are excluded. The demand on the 10 years average maximum temperature can be calculated from the correlation equation of the demand-temperature in each year which are calculated from this figure.

In terms of the demand growth in each year, the figure shows that the power demands in 2020 were affected by Covid-19 but increased than the demand in 2019. Each peak demand of January to March in 2021 almost didn't grow from each demand of the same month in 2020.

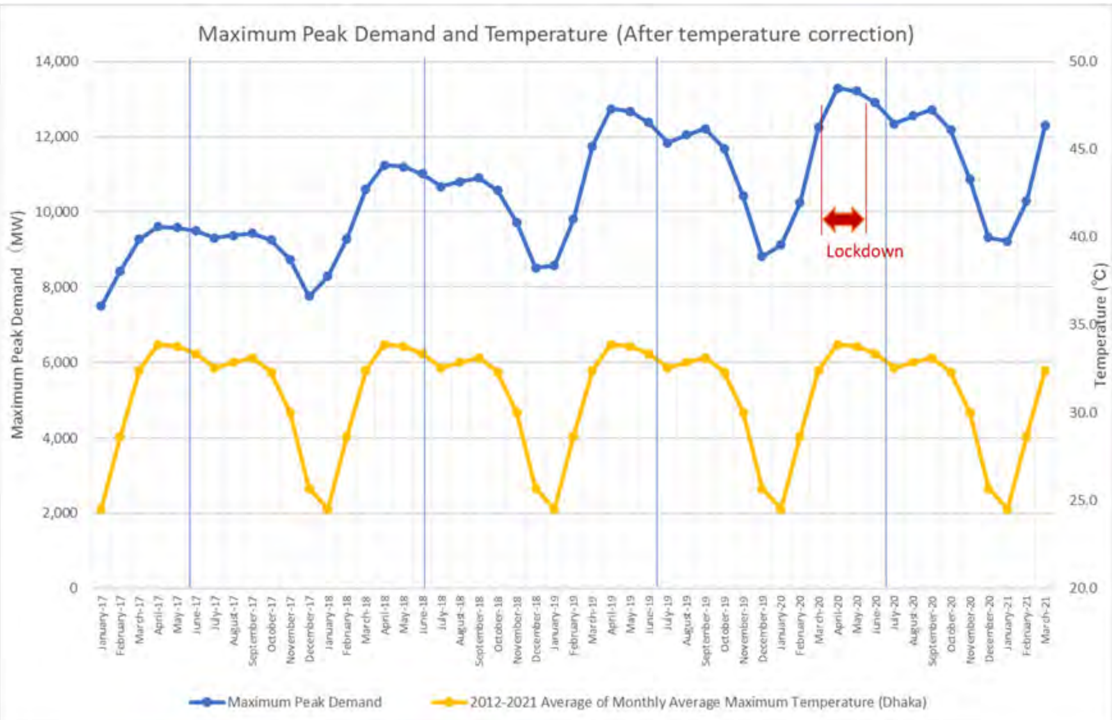
4 In terms of the March 2021, the maximum peak demand is the record of up to 20th March



Source: Study Team from PGCB website and Japan Meteorological Agency

Figure 2.3-2 Correlation between monthly average maximum temperature and monthly peak demand in each year

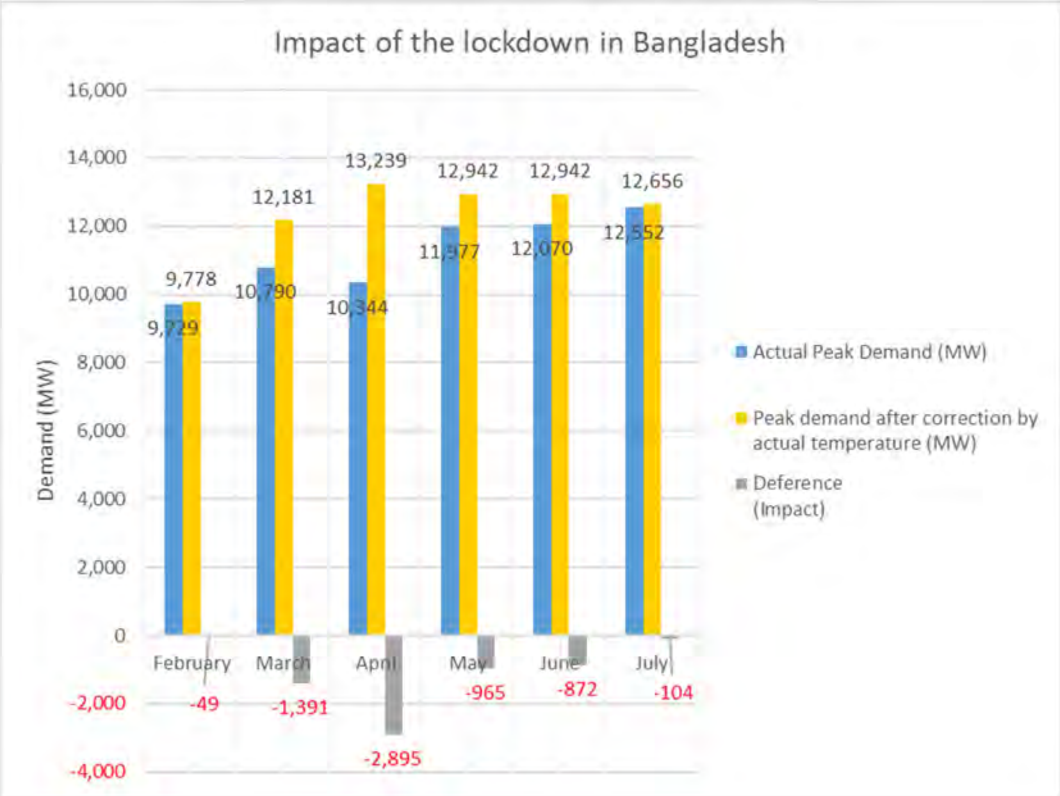
With using correlating equations, peak demand records from 2017 to 2021 are corrected on the normal temperatures. Figure 2.3-3 shows corrected monthly peak demand on the normal temperature, and the normal temperature. The anticipated peak demand record in 2020 (April) is calculated from the correlating equation, and the figure is 13,290MW.



Source: Study Team from PGCB website and Japan Meteorological Agency

Figure 2.3-3 Corrected monthly peak demand on the normal temperature, and the normal temperature

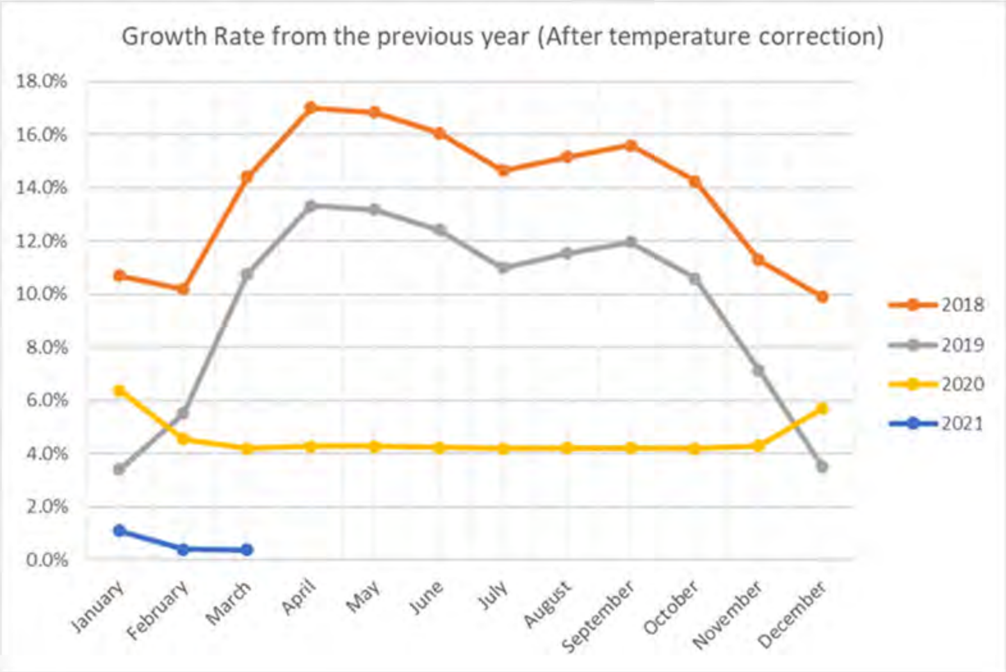
Figure 2.3-4 shows the actual peak demand and the corrected peak demand and the difference of them. The differences are deemed as estimate of the decreased peak demand caused by the lockdown and Covid-19 pandemic in Bangladesh.



Source: JICA Study Team from PGCB website and Japan Meteorological Agency

Figure 2.3-4 Estimate of the decreased peak demand caused by the lockdown in 2020 and Covid-19 pandemic in Bangladesh

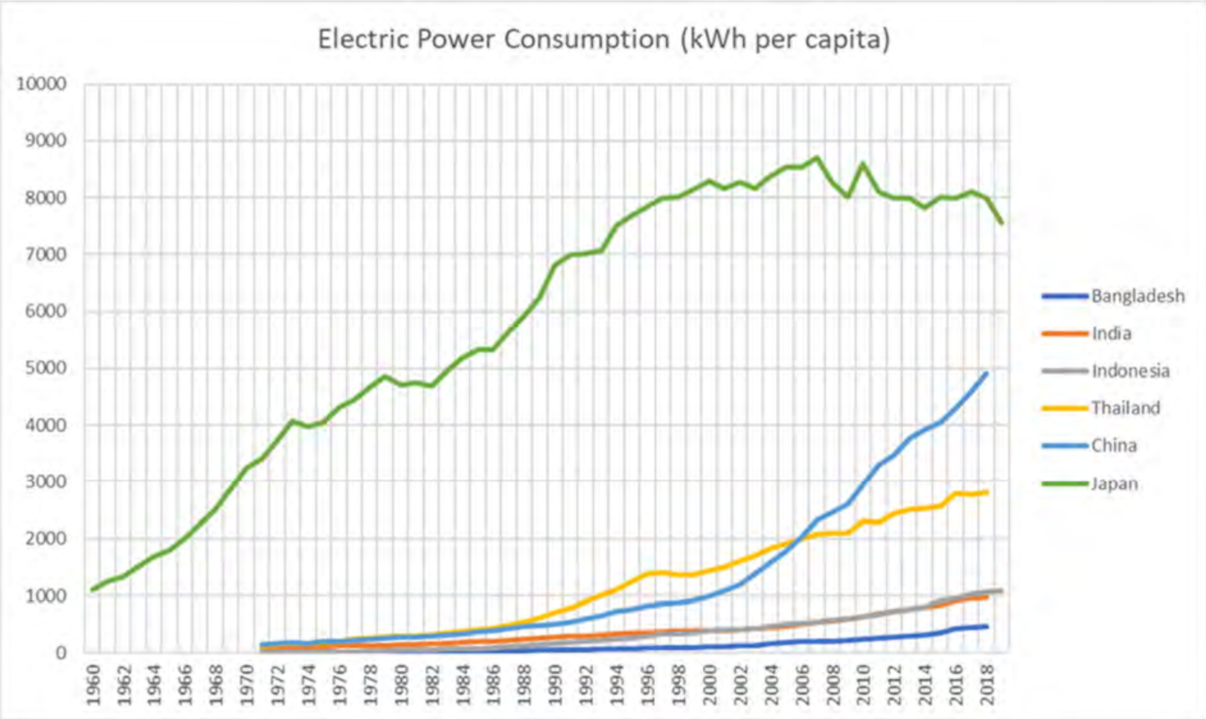
Figure 2.3-5 shows the ratio to the same month of the previous year of the demand growth calculated from corrected peak demand. In this figure, the demand growth was large in 2018, but the growth in 2019 was almost same as the growth of Revisiting PSMP2016. In terms of 2020, the demand growth was affected by Covid-19, and the growth rates from 2019 were dropping at the 4% levels, and the maximum gap was 9% in April. There are only 3 months data in 2021 from January to March, and the growth rates of each month were almost 0%, it means the actual peak demands in 2021 were almost same as the peak demands of previous year.



Source: Study Team from PGCB website and Japan Meteorological Agency

Figure 2.3-5 The ratio to the same month of the previous year of the demand growth calculated from corrected peak demand

Figure 2.3-7 shows the comparison of peak demand of Revisiting PSMP2016 and PSMP2016, and corrected peak demand records. Table 2.3-1 shows the numerical table of Figure 2.3-7. In these data, the growth rates in FY2017-18 and FY2018-19 were surpassing than the anticipated rates, but the growth rate in FY 2019-20 dropped due to the impact of Covid-19, and the peak demand is almost at the levels of PSMP2016 Base Case. The peak demands on February and March in 2021 are at the same levels as the same month of the previous year, but the peak demand growth rates would be recovered to at the 8% levels forecasted in the PSMP2016 base case (with EE&C) or 12% levels forecasted in the Revisiting PSMP2016 low case (with EE&C) in near future, because the peak demands in 2020 have increased and the growth rates were about 4% even under the Covid-19 circumstance. As shown in Figure 2.3-6, the power consumption per capita in the country is still low level, and the increase in the power consumption per capita such as Thailand and China are certainly expected with implementation of the electrification and economy growth in future. These aspects are considered in PSMP2016 and Revisiting PSMP2016.

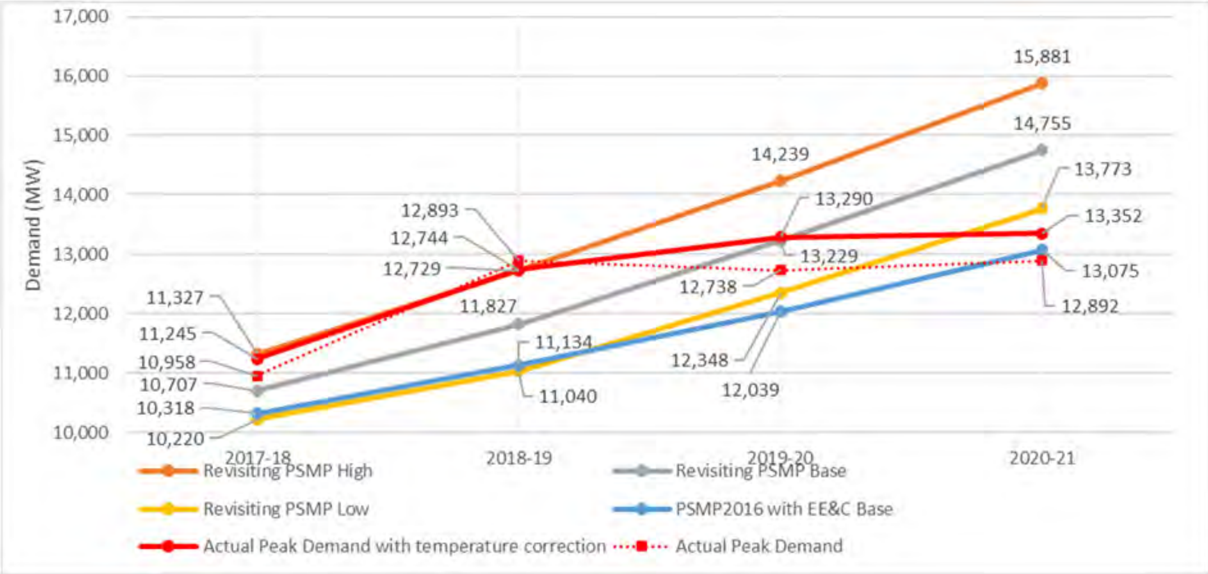


Source: World Bank, International Energy Agency (IEA)

Figure 2.3-6 Electric power consumption (kWh per capita)

In the 8th Five Year Plan, in terms of the gas demand, to study the scenario C mainly which considers the climate change (the renewable energy introduction) among 3 scenarios proposed in the GSMP2017 was described, and the implementation of the energy conservation measures is the one of the goals of the 8th Five Year Plan. Therefore, Revisiting PSMP2016 low case (with EE&C) is assumed to be the main demand forecast.

Figure 2.3-8 shows the comparison of peak demand forecasts between PSMP2016 and the Revisiting PSMP2016 with energy efficiency and conservation (EE&C). Considering the actual demand records and the situation, if the demand increases in accordance with the Low Case of PSMP2016 which is the lowest case of all, the forecasted peak demand as of 2041 will be around 48GW, which is a difference of 35GW compared to the current peak demand. Therefore, the power development and the transmission facility development that is match with the demand forecast should be implemented systematically with securing the stable supply of the power, and this project is important for the stable supply of the power as well. With referring the power development plan, the required power development plan is to be considered in the next section.



Source: Study Team from Revisiting PSMP2016, PSMP2016, BPDB Annual Report, PGCB website, Japan Meteorological Agency

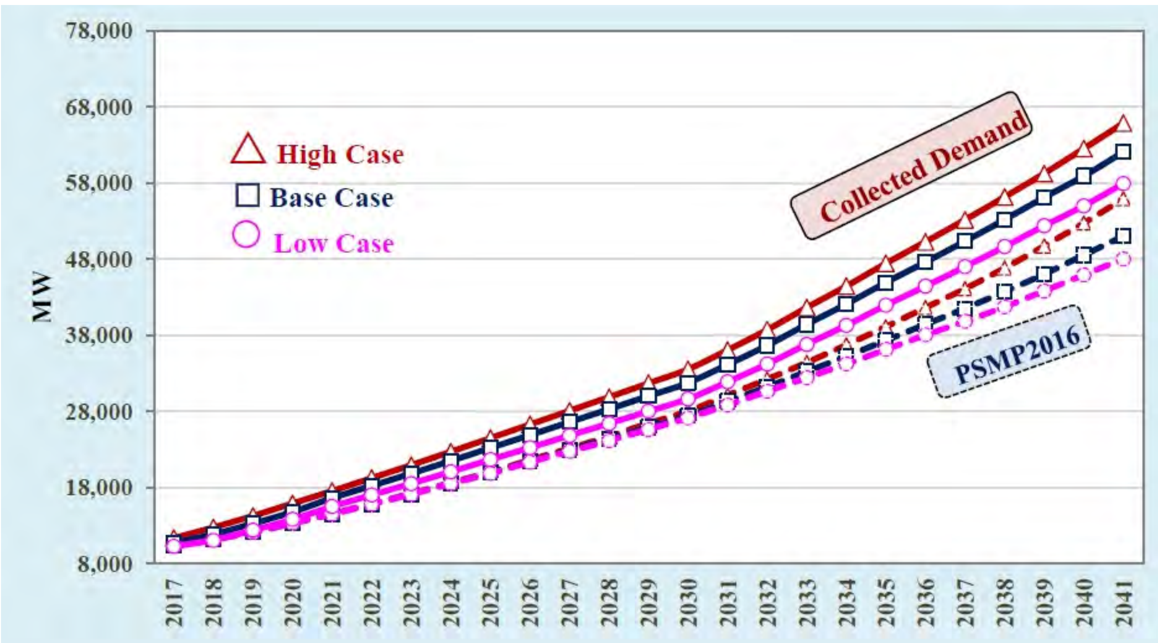
Figure 2.3-7 Comparison of peak demand of Revisiting PSMP2016 and PSMP2016, and corrected peak demand record

Table 2.3-1 The trends in annual maximum peak demand records and the comparison to Two Master Plans

Fiscal Year	Actual Peak Demand (MW)	Growth Rate	Actual Peak Demand with temperature correction (MW)	Growth Rate	Revisiting Master Plan 2016 (With EE&C) (MW)						PSMP2016 (With EE&C)	Growth Rate
					High Case	Growth Rate	Base Case	Growth Rate	Low Case	Growth Rate	Base Case	
2017-18	10,958	15.6%	11,245	18.6%	11,327	19.5%	10,707	13.0%	10,220	7.8%	10,318	8.9%
2018-19	12,893	17.7%	12,744	13.3%	12,729	12.4%	11,827	10.5%	11,040	8.0%	11,134	7.9%
2019-20	12,738	-1.2%	13,290	4.3%	14,239	11.9%	13,229	11.9%	12,348	11.8%	12,039	8.1%
2020-21	12,892	1.2%	13,352	0.5%	15,881	11.5%	14,755	11.5%	13,773	11.5%	13,075	8.6%

The Growth Rate of 2017-18 is the rate against actual peak demand in 2016-17, 9,479MW

Source: Study Team from Revisiting PSMP2016, PSMP2016, BPDB Annual Report, PGCB website, Japan Meteorological Agency



Source: Revisiting PSMP 2016

Figure 2.3-8 Peak demand forecast of PSMP2016 and Revisiting PSMP2016 (with EE&C)

2.3.2 Power Development Situation and Prospect

There has been almost no planned load shedding since around 2017 in the country, and a balanced situation between demand and supply continues. The power development plans were developed in the PSMP2016 and it was revised in the Revisiting PSMP2016 in 2018, and BPDB and Power Cell announced the latest power development plan called Generation Planning up to 2030 in 2019. After that, the power development plan was revised several times, and the latest version was developed by BPDB in June 2021. The coal power plant development policy announced by the government on June 27, 2021 (No.1-No.9 of Table 2.3-3) is different from the latest Power Development Plan by BPDB, but the power development plan as of now is that was developed by BPDB in June. The latest power development plan between 2031 to 2041 is Revisiting PSMP2016.

In terms of the retirement plan of power plant, BPDB annual report 2019-20 is the latest version up to 2025, and the retirement plan as of March 2020 developed by BPDB is the latest version from 2026 to 2041.

In terms of the power demand which is to be a basement of the power development plan, two Low cases in the Revisiting PSMP2016 (Without EE&C, With EE&C) are adopted in the Generation Planning up to 2030 in 2019, and the power development plan is formulated based on the Low Case (Without EE&C) demand. The latest power development plan is formulated based on the Low Cases in the PSMP2016 and Revisiting PSMP2016 with considering Covid-19 impacts now.

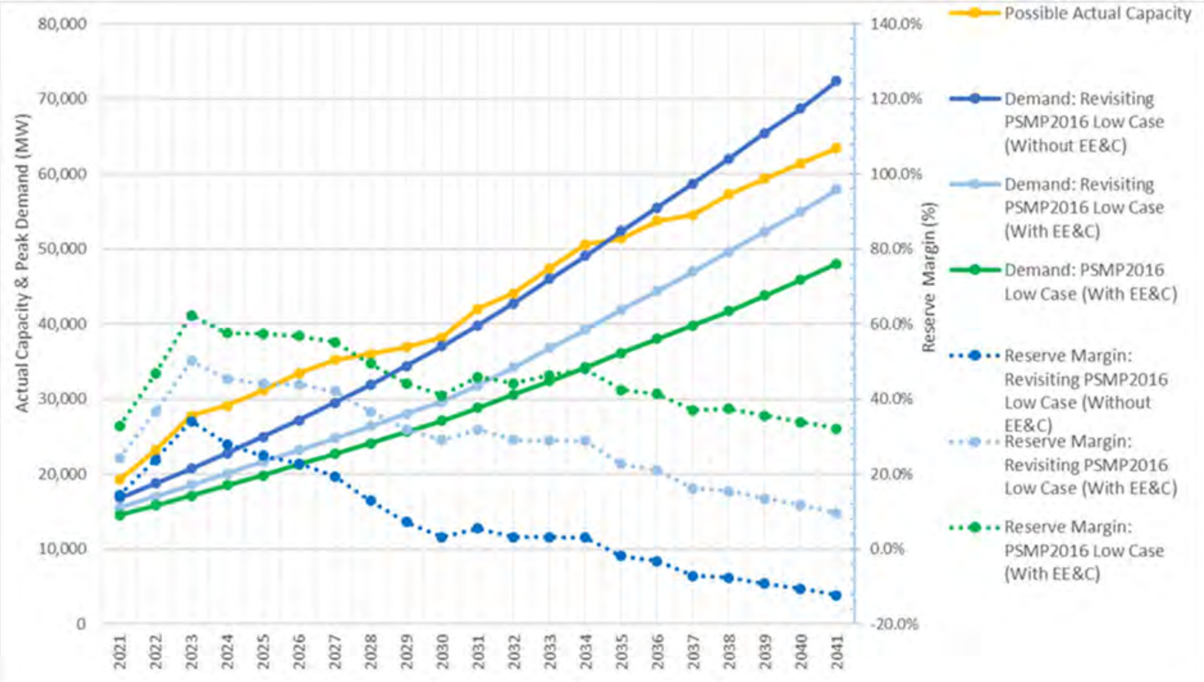
The power demand-supply balance is calculated based on Net Capacity, which does not include renewable energy, on the grounds that there is no PV output at the time of peak demand, which is probably from 21 hours to 23 hours, and that wind power biogas power, and waste power have variable outputs and small capacities in total. Therefore, the capacity of renewable energies is counted as 0MW once renewable energy sources are evaluated as ensured power supply. And the other reasons that the generation from renewable energy is not included in the power development plan are considered that the capacity of the renewable energy is currently small and the renewable energy policy is under formulation, and the data collection for evaluation methodology of renewable energy generation is under preparation, and lack of generation data of renewable energy.

The development plan in which latest information of the power development and retirement plans are merged is shown in Figure 2.3-9. In this power development plan, the cancelled coal fired power plants which were determined by Power Division in June 2021 are cumulated temporarily as an LNG fired power plant. In terms of the cancelled coal fired power plants, Power Division determined that they are to be developed as an LNG fired power plant or renewable energy. In terms of the power supply, the possible actual capacity is 80% of the installed capacity with following the methodology in the Generation Planning up to 2030, and in terms of the peak demand, two low cases in the Revisiting PSMP2016 (Without EE&C and With EE&C) and the low case (With EE&C) in the PSMP2016, and the reserve margin (%) are shown in the figure. Table 2.3-2 shows the numerical data of the figure. The reserve margin of the Revisiting PSMP2016 Low Case (without EE&C) which is the highest demand in 2030 will be 3.2% and in 2041 will be -12.4%, and the reserve margin of the Revisiting PSMP2016 (With EE&C) in 2030 will be 29.0% and in 2041 will be 9.6%. In terms of the evaluation of possible actual capacity is deemed as 80% of the installed capacity as shown in Table 2.3-2. The possible actual capacity is evaluated with considering the performance deterioration of the power plants and planned repair work. In Japan, the actual capacity is evaluated with considering the long-term repair work plan and the derated capacity of the specific power plants submitted by the generation utilities, and the demand supply balance is evaluated. A reserve margin of 10 % is secured in 2041 on the Revisiting PSMP2016. However, the reserve margin is calculated with the net capacity of 80%. Thus, reserve margin falls to negative.

In case of the PPA between BPDB and generation utilities, there is a provision to secure 90% availability of the capacity, and if the availability is lower than 90%, the capacity charge is reduced in proportion to the actual availability. It means that in terms of earning a profit as a power producer, the incentives to operation and maintenance for the generation utilities is enhanced if the availability of the capacity is not maintained, and eventually certainty of the total power supply security and the power development plan is enhanced.

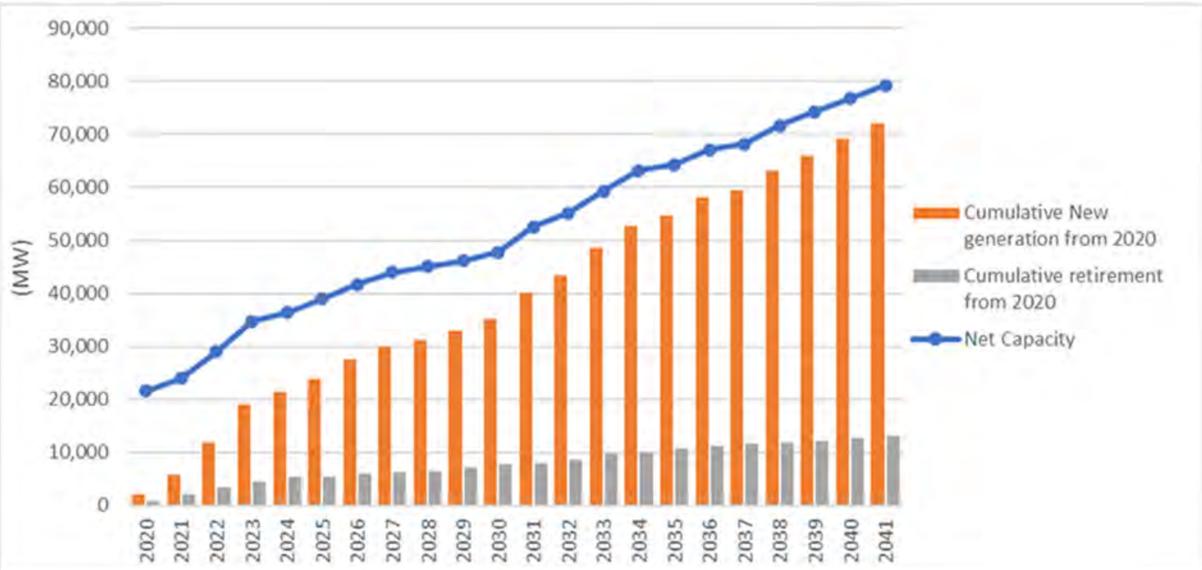
In terms of the reserve margins of the Revisiting PSMP2016 Low Case (with EE&C) are higher than “without EE&C” case because the peak demands of “with EE&C” case are lower and the capacity is based on “without EE&C” case. However, as it takes long time to develop power plant, power development plan should be formulated considering the risks of high demand cases. And it is difficult to make reserve margin stable at the appropriate levels through at the steps of power demand growing every year due to the risks such as project delay or schedule change. Therefore, there are some high reserve margin points on the way to FY2030.

Figure 2.3-10 shows the capacities which are developed and retired, and the total capacity after 2020. The power development plan should be formulated with considering not only new development of power plants but also retired power plants. The growth of the peak demand from 2020 to 2030 will be 22GW, but since the 7.7 GW capacities are retired by 2030, the 35GW capacities are required by 2030, and the growth of the peak demand from 2020 to 2041 will be 58GW, but since the 13.2 GW capacities are retired by 2041, the 72GW capacities are required by 2041.



Source: Study Team from BPDB power development plan as of March 2020 and June 2021, Revisiting PSMP2016, PSMP2016

Figure 2.3-9 Trends in power supply, and peak demands (3 cases) and reserve margin up to FY2030



Source: Study Team from BPDB power development plan as of March 2020 and June 2021, Revisiting PSMP2016, PSMP2016

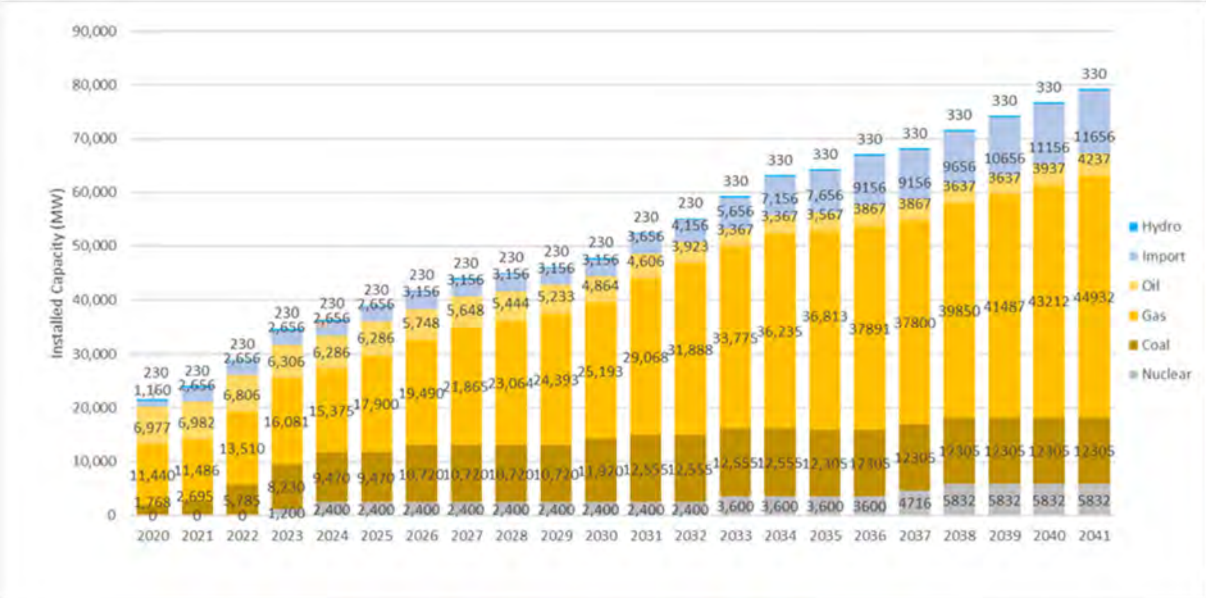
Figure 2.3-10 Capacities which are developed and retired, and the total capacity after 2020

Table 2.3-2 Power development plan in which the latest version power development plans were merged and demand-supply balance up to FY2041 (without renewable energy)

	Capacity					Demand-Supply Balance											
						In case of Peak Demand from Revisiting PSMP-2016								In case of Peak Demand From PSMP-2016			
						Low Case (Without EE&C measures) of Peak Demand				Low Case (With EE&C measures) of Peak Demand				Low Case (With EE&C measures) of Peak Demand			
Year	Net Capacity (MW) (Beginning of the Year)	New power plants (MW)	Retired power plants (MW)	Net Capacity (MW) (End of the Year)	Possible Actual Generation	Peak Demand (MW)	Demand Growth (%)	Reserve Margin (MW/%)		Peak Demand (MW)	Demand Growth (%)	Reserve Margin (MW/%)		Peak Demand (MW)	Demand Growth (%)	Reserve Margin (MW/%)	
	(a)	(b)	(c)	(d)=(a)+(b)-(c)	(e)=80% of (d)	(f)	-	(g)=(e)-(f)	(g)/(f)	(h)	-	(i)=(e)-(h)	(i)/(h)	(j)	-	(k)=(e)-(j)	(k)/(j)
2020	20,345	2,029	799	21,575	**17,260**	14,757	15.9%	2,503	**17.0%**	13,773	8.1%	3,487	**25.3%**	13,300	4.4%	3,960	**29.8%**
2021	21,575	3,810	1,336	24,049	**19,239**	16,823	14.0%	2,416	**14.4%**	15,477	12.4%	3,762	**24.3%**	14,500	9.0%	4,739	**32.7%**
2022	24,049	6,139	1,201	28,987	**23,189**	18,737	11.4%	4,452	**23.8%**	16,983	9.7%	6,206	**36.5%**	15,800	9.0%	7,389	**46.8%**
2023	28,987	6,996	1,279	34,703	**27,762**	20,697	10.5%	7,065	**34.1%**	18,489	8.9%	9,273	**50.2%**	17,100	8.2%	10,662	**62.4%**
2024	34,703	2,440	726	36,417	**29,134**	22,769	10.0%	6,365	**28.0%**	20,037	8.4%	9,097	**45.4%**	18,500	8.2%	10,634	**57.5%**
2025	36,417	2,525	0	38,942	**31,154**	24,952	9.6%	6,202	**24.9%**	21,625	7.9%	9,529	**44.1%**	19,800	7.0%	11,354	**57.3%**
2026	38,942	3,550	748	41,744	**33,395**	27,191	9.0%	6,204	**22.8%**	23,203	7.3%	10,192	**43.9%**	21,300	7.6%	12,095	**56.8%**
2027	41,744	2,400	125	44,019	**35,215**	29,519	8.6%	5,696	**19.3%**	24,796	6.9%	10,419	**42.0%**	22,700	6.6%	12,515	**55.1%**
2028	44,019	1,250	255	45,014	**36,011**	31,912	8.1%	4,099	**12.8%**	26,381	6.4%	9,630	**36.5%**	24,100	6.2%	11,911	**49.4%**
2029	45,014	1,842	724	46,132	**36,906**	34,422	7.9%	2,484	**7.2%**	27,997	6.1%	8,909	**31.8%**	25,600	6.2%	11,306	**44.2%**
2030	46,132	2,150	519	47,763	**38,210**	37,024	7.6%	1,186	**3.2%**	29,619	5.8%	8,591	**29.0%**	27,100	5.9%	11,110	**41.0%**
2031	47,763	5,010	258	52,515	**42,012**	39,812	7.5%	2,200	**5.5%**	31,850	7.5%	10,162	**31.9%**	28,800	6.3%	13,212	**45.9%**
2032	52,515	3,320	683	55,152	**44,122**	42,748	7.4%	1,374	**3.2%**	34,198	7.4%	9,924	**29.0%**	30,600	6.3%	13,522	**44.2%**
2033	55,152	5,150	1,019	59,283	**47,426**	45,976	7.6%	1,450	**3.2%**	36,781	7.6%	10,645	**28.9%**	32,400	5.9%	15,026	**46.4%**
2034	59,283	4,170	210	63,243	**50,594**	49,090	6.8%	1,504	**3.1%**	39,272	6.8%	11,322	**28.8%**	34,200	5.6%	16,394	**47.9%**
2035	63,243	1,900	872	64,271	**51,417**	52,389	6.7%	-972	**-1.9%**	41,911	6.7%	9,506	**22.7%**	36,100	5.6%	15,317	**42.4%**
2036	64,271	3,450	572	67,149	**53,719**	55,521	6.0%	-1,802	**-3.2%**	44,417	6.0%	9,302	**20.9%**	38,000	5.3%	15,719	**41.4%**
2037	67,149	1,366	341	68,174	**54,539**	58,718	5.8%	-4,179	**-7.1%**	46,974	5.8%	7,565	**16.1%**	39,800	4.7%	14,739	**37.0%**
2038	68,174	3,666	230	71,610	**57,288**	62,032	5.6%	-4,744	**-7.6%**	49,626	5.6%	7,662	**15.4%**	41,700	4.8%	15,588	**37.4%**
2039	71,610	2,800	163	74,247	**59,398**	65,436	5.5%	-6,038	**-9.2%**	52,349	5.5%	7,049	**13.5%**	43,800	5.0%	15,598	**35.6%**
2040	74,247	3,300	775	76,772	**61,418**	68,708	5.0%	-7,290	**-10.6%**	54,966	5.0%	6,452	**11.7%**	45,900	4.8%	15,518	**33.8%**
2041	76,772	2,850	330	79,292	**63,434**	72,379	5.3%	-8,945	**-12.4%**	57,903	5.3%	5,531	**9.6%**	48,000	4.6%	15,434	**32.2%**
	Total	**72,112**	**13,165**														

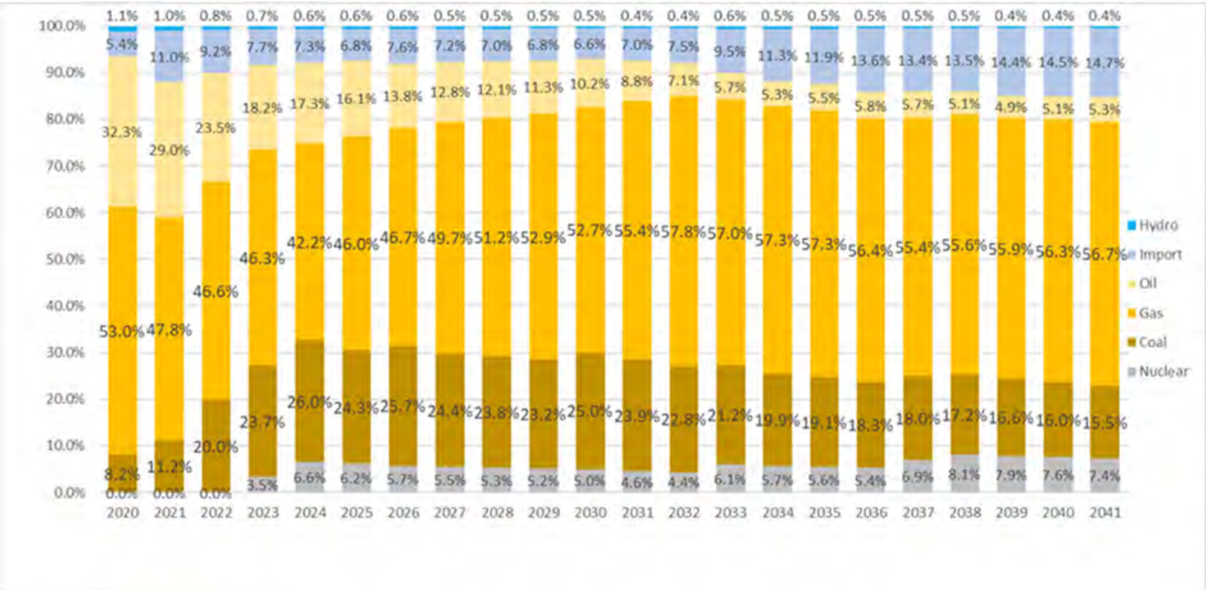
Source: Study Team from BPDB power development plan as of March 2020 and June 2021, Revisiting PSMP2016, PSMP2016

Figure 2.3-11 and Figure 2.3-12 shows the fuel wise power source portfolio capacity and ratio. In terms of the coal fired thermal power, the government announced the power development policy in which coal power development projects are significantly reduced on June 27, 2021 in response to the world trends of the climate change. But in the latest Power Development Plan including existing power plants, as following Table 2.3-3 , the total capacity of the coal fired thermal power projects as of 2030 is 11,920MW and as of 2041 is 12,305MW. And the ratio of the coal fired thermal power as of 2030 is 25.0% and as of 2041 is 15.5% as shown in the Figure 2.3-12.



Source: Study Team from BPDB power development plan as of March 2020 and June 2021, Revisiting PSMP2016, PSMP2016

Figure 2.3-11　Trends in the fuel wise power source portfolio capacity



Source: Study Team from BPDB power development plan as of March 2020 and June 2021, Revisiting PSMP2016, PSMP2016

Figure 2.3-12　Trends in the fuel wise power source portfolio ratio

Table 2.3-3 shows the latest power development plan. In the government policy of the coal power development announces on 27 June 2021, the projects from No.10 and No.11 are not developed as coal fired power, but these projects are not included in the suspended projects determined by Power Division.

Matarbari coal fired thermal power phase 2 (3/4 unit) project will be developed as a coal fired power plant. According to the interviews to Power Division and BPDB, this project was confirmed as the required project in terms of the environment, cost reduction for Matarbari coal fired thermal power 1/2 unit, energy security, investment reduction of the gas transmission and distribution.

Table 2.3-3 Revision of the coal fired thermal power development projects by the government (Gross and some are net)

No.	Name of the Coal Power Project	Developed as a coal power (MW)	Cancelled project as a coal power (MW)	Fuel Type	Ownership	Expected Commissioning Date	Remarks	Status
1	Payra, Potuakhali 1320 Coal Fired Power Plant (1st Phase)	1,244		I. Coal	BCPCL (NWPGCL)	1st Unit: Feb, 2020 2nd Unit: June, 2020	Under Commercial Operation	
2	BIFPCL, Rampal, Coal Fired Power Plant	1,240		I. Coal	BIFPCL	1st Unit: January, 2022	• Progress: 69 %	Ongoing
3	Chittagong 2 x 612 MW Coal Fired Power Project (S.Alam	1,224		I. Coal	IPP	Dec, 2022	•Progress:80 %	Ongoing
4	Payra, Potuakhali 1320 Coal Fired Power Plant (2nd Phase)	1,244		I. Coal	BCPCL (NWPGCL)	3rd Unit: June, 2023 4th Unit: Dec, 2023	•Progress:20 %	Ongoing
5	Borisal 307 MW Coal Fired Power Plant	307		I. Coal	IPP	June, 2022	•Progress: 58 %	Ongoing
6	Matarbari 1200 MW USCPP (Phase 1: Unit 1&2)	1,200		I. Coal	CPGCBL	1st unit: January 2024 2nd unit June 2024	•Progress: 46 %	Ongoing
7	**Matarbari 1200 MW USCPP (Phase 2: Unit 3&4)**	**1,200**		**I.Coal**	**CPGCBL**	**December, 2030**	**• Under Feasibility study**	**Planning**
8	Patuakhali 1320 (2x660) MW USCPP (Phase-1)	1,247		I. Coal	RNPCL	1st Unit: Feb, 2023 2nd Unit: August,	• Progress:36 %	Ongoing
9	Mirshorai 1320 MW Coal Fired PP (Hangzhou Group)	1,240		I. Coal	IPP	June, 2025	• LOI Issued	Ongoing
10	Moheskhali 1200 MW USCPP (ECA)	1,250		I. Coal	BPDB	June, 2027	• Consultant Appointed	Ongoing
11	635MW plant in Dhaka (Gozaria)	635		I. Coal	---	December, 2025	---	Contract signed
	Total	**12,031**						
12	Patuakhali 1320 (2x660) MW USCPP (Phase-1)		1,250	I. Coal	APSCL	December, 2031	•Cancelled on June 2021	Planning
13	Uttarbongo Thermal		1,200	D. Coal	APSCL	After 2030	•Cancelled on June 2021	Planning
14	Moheskhali 1200 MW USCPP (KEPKO)		1,250	I. Coal	JV	After 2030	•Cancelled on June 2021	Planning
15	Matarbari 700 MW USCPP (JV of Symcorp & CPGCBL)(Phase-		650	I. Coal	JV CPGCBL	June, 2029	• Feasibility & EIA done •Cancelled on June 2021	Planning
16	CPGCBL-Sumitomo 2x600 MW USC Power Plant		1,200	I.Coal	JV CPGCBL	June, 2028	• MoU Signed •Cancelled on June 2021	Planning
17	Moheshkhali 1200 MW USCPP(Phase-2)(Bay of Bengal)		1,250	I.Coal	JV BPDB	December, 2029	• Company formed •Cancelled on June 2021	Planning
18	522MW plant in Mawa		522				Already announced as a cancelled coal power	
19	282MW plant in Dhaka		282				Already announced as a cancelled coal power	
20	282MW plant in Chittagong		282				Already announced as a cancelled coal power	
21	565MW plant in Khulna		565				Already announced as a cancelled coal power plant.	
	Total		**8,451**					

Source: Study team from the government policy of the coal power development on 27 June 2021

2.3.3 Renewable Energy Development Plan

The installation plan for renewable energy in the Revisiting PSMP2016 is shown in Table 2.3-4. Aggressive installation plan cannot be seen after FY 2022. The capacity of renewable energy will be 2,583MW as of FY 2030. The capacity as of the end of FY2019-20 was PV: 38MW, Wind: 2MW, 40MW in total, and per the progress in renewable energy construction in BPDB's annual report, delays from the Revisiting PSMP2016 are confirmed. According to the interview from Power Division, the renewable energy development is delaying due to the bid failure or Covid-19 impacts, and as the 10% of the renewable energy introduction by 2020 which is set in NAP and INDC2015 has not been achieved yet, the 10% of the renewable energy introduction is to be a priority challenge, and the penetration of the roof top solar (commercial and industrial premises, public premises such as MRT station), irrigation facilities (connected to the power grid), floating solar system, solar system on the river bank will be enhanced.

Table 2.3-4 Installation Plan for Renewable Energy up to FY2030

Year	2020 (MW)	2021 (MW)	2022 (MW)	2023 (MW)	2024 (MW)	2025 (MW)	2026 (MW)	2027 (MW)	2028 (MW)	2029 (MW)	2030 (MW)
Solar	1,822	1,922	2,222	2,222	2,222	2,222	2,222	2,222	2,222	2,222	2,222
Wind	160	310	310	310	310	310	310	360	360	360	360
Waste	1	1	1	1	1	1	1	1	1	1	1
TOTAL	1,983	2,233	2,533	2,533	2,533	2,533	2,533	2,583	2,583	2,583	2,583

Source: Revisiting PSMP2016

In the 8th Five Year Plan, in order to expand the renewable energy, adopting of the Feed-in Tariff (FIT) which is the worldwide good practice to expand the renewable energy introduction is cited, and the expand of the renewable energy in the country is expected.

2.3.4 Solar Power (PV) Development Plan considered in Power Division

As described in the "2.2.2 Power and Energy Policy", for renewable energy installation plans in the country, National Energy Policy set an overall goal of 5% of generation capacity from renewable energy up to 2015, and 10% up to 2020, and the goal is cited in the INDC2015. On the other hand, in the Perspective Plan of Bangladesh 2021-2041, 8th Five Year Plan, and Bangladesh Delta Plan 2100, the ambitious introduction targets were cited, and based on this, SREDA developed the National Solar Energy Roadmap, 2021-2041 (Draft) in December 2020. According to this, 3 scenarios have been proposed for PV installation, and Power Division has started the study for the main scenario. National Solar Energy Roadmap, 2021-2041 (Draft) was discussed in the committee for the renewable energy introduction which was held on 21 June 2021, but the High Case has negative opinions like that it is not realistic scenario, therefore Medium Case or Low Case will be discussed in the next discussion. In terms of the location for the solar power, river bank, water surface, reclaimed area, rooftop of commercial and industrial and public premises is proposed, and the development plan will be implemented based on this policy.

This road map indicates various issues and challenges to introduce PV, as representative examples are land acquisitions, land reinforcement, distance from power system, power system augmentation, and the term and cost for them.

The following (1) to (3) are the explanations of the 3 scenarios proposed in the National Solar Energy Roadmap, 2021-2041 (Draft).

(a) Business as usual (BAU) based solar PV deployment scenario (Low Case)

This scenario assumes that 6,000MW capacity is installed by 2041 which is 10% of the peak demand of 60,000MW for 2041 based on INDC2015 & 2008 Renewable Energy Policy "A target to deliver 5% of energy from renewable sources by 2015, and 10% by 2020". The scenario is set to be realized by ensuring the use of current rules and access to the current system.

Table 2.3-5 PV deployment scenario: BAU (Low Case)

Component	until 2020	2021-2030	2031-2041	Cumulative
	MW	MW	MW	MW
Solar Power Hub (Utility + IPP)	0	500	1200	1700*
Solar PV power capacity addition by Utilities	15	400	800	1215
Solar PV power capacity addition by solar IPPs	160	450	800	1410
Rooftop solar PV systems	50	250	405	705**
Solar irrigation pumps	40	300	205	545**
Solar mini-/micro-/nano-grids	6	10	0	16
Solar home systems	252	5	0	257***
Solar-powered telecom towers	9	10	14	33
Solar street lights	11	8	10	29
Solar charging station	1	25	54	80
Other solar-powered systems	2	3	5	10
Total	**546**	**1961**	**3493**	**6000**

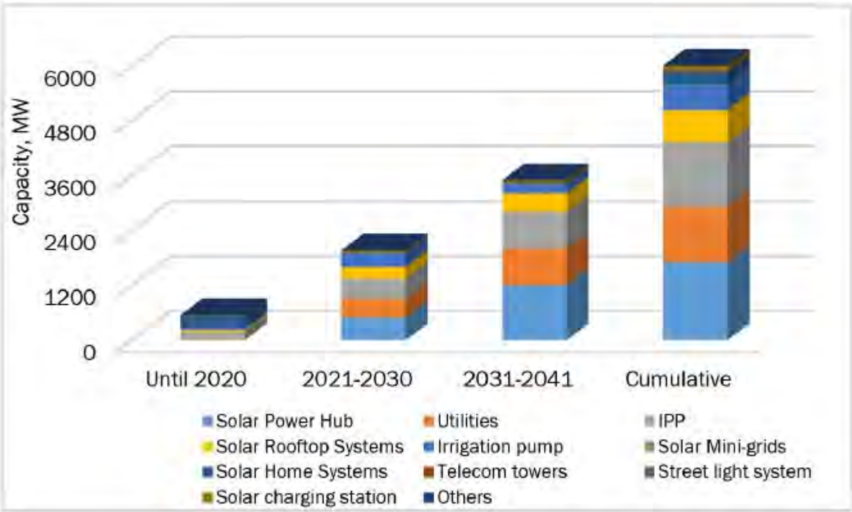
Notes:

** The PSMP 2016 identified this component as 'Solar Park'.*

*** Capacities correspond to the numbers specified in the PSMP 2016. However, the document clearly states that these do not reflect the theoretical potential, but are based on the planned projects.*

**** The PSMP 2016 mentioned a much lower value (100MW). This value mainly corresponds to the sector-wise RE roadmap set by SREDA (targets to be achieved until 2020).*

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



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

Figure 2.3-13 PV deployment scenario: BAU (Low Case)

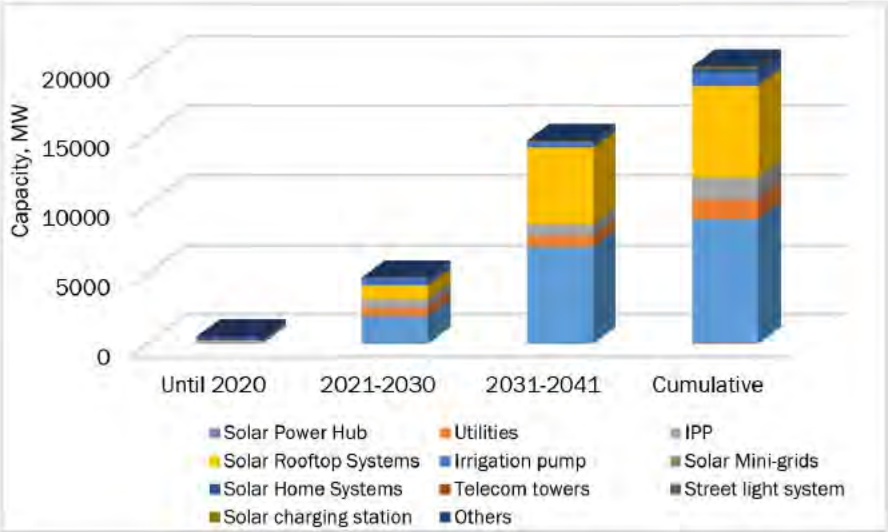
(b) Medium solar PV deployment scenario

This scenario assumes that 20,000MW capacity is installed by 2041, which is 33% of the total. In addition to the BAU scenario's conditions, it assumes various conditions such as the updating of existing policies & guidelines, utilization of minimum purchase obligation for utilities like the Renewable Purchase Obligation (RPO), support and cooperation from the relevant ministries on resource (especially land and water bodies) utilization, development of storage facilities, upgrading of the national grid, and support from international agencies.

Table 2.3-6 PV deployment scenario: Medium Case

Component	until 2020	2021-2030	2031-2041	Cumulative
	MW	MW	MW	MW
Solar Power Hub (Utility + IPP)	0	2000	7000	9000
Solar PV power capacity addition by Utilities	15	585	800	1400
Solar PV power capacity addition by solar IPPs	160	640	800	1600
Rooftop solar PV systems	50	1000	5550	6600
Solar irrigation pumps	40	500	400	940
Solar mini-/micro-/nano-grids	6	10	0	16
Solar home systems	252	6	0	258
Solar-powered telecom towers	9	10	16	35
Solar street lights	11	10	18	39
Solar charging station	1	30	70	101
Other solar-powered systems	2	4	5	11
Total	546	4795	14659	20000

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



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

Figure 2.3-14 PV deployment scenario: Medium Case

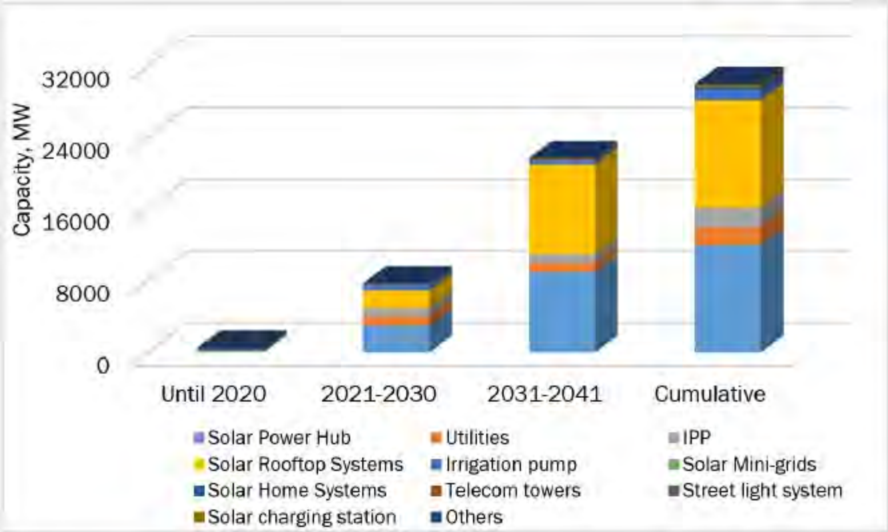
(c) High solar PV deployment scenario

This scenario assumes that 30,000MW capacity is installed by 2041 which is 50% of the total. In addition to the Medium scenario's conditions, it assumes more conditions such as the availability of more advanced technology, which could be used ancillary services for peak demand and surplus power in the market, commercialization of solar cells with higher efficiencies and cheaper and more reliable storage technologies, imports of solar power from neighboring countries, and allocation of the required land and water bodies for the development of solar power, maximum utilization of industrial rooftop solar, and the utilization of planned reclaimed lands in river banks and the Meghna estuary of which it occupies 5%. Therefore, it is a very ambitious scenario.

Table 2.3-7 PV deployment: High Case

Component	until 2020	2021-2030	2031-2041	Cumulative
	MW	MW	MW	MW
Solar Power Hub (Utility + IPP)	0	3000	9000	12000
Solar PV power capacity addition by Utilities	15	985	1000	2000
Solar PV power capacity addition by solar IPPs	160	1000	1040	2200
Rooftop solar PV systems	50	3950	8000	12000
Solar irrigation pumps	40	700	460	1200
Solar mini-/micro-/nano-grids	6	10	0	16
Solar home systems	252	8	0	260
Solar-powered telecom towers	9	10	20	39
Solar street lights	11	13	20	44
Solar charging station	1	60	165	226
Other solar-powered systems	2	7	6	15
Total	**546**	**9743**	**19711**	**30000**

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



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

Figure 2.3-15 PV deployment: High Case

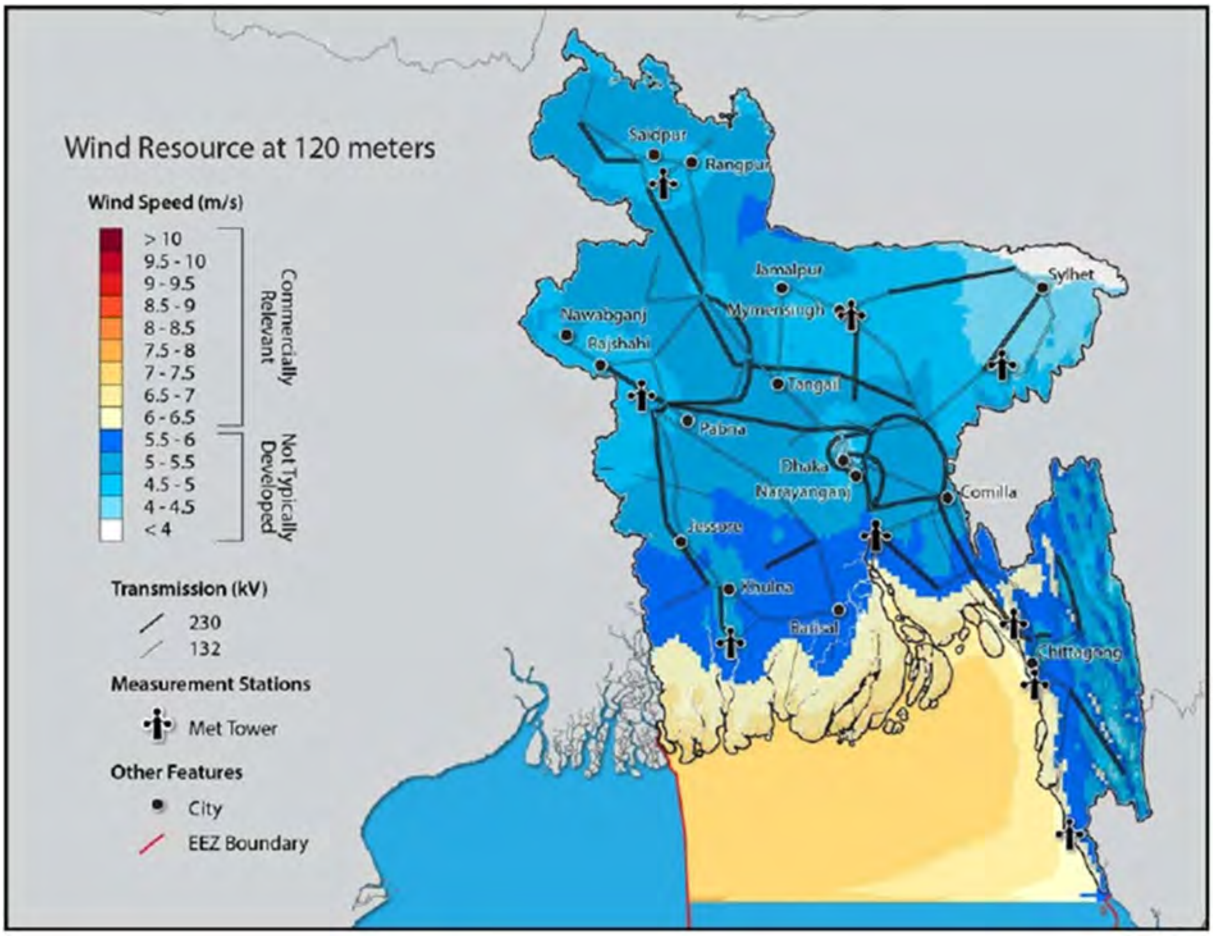
2.3.5 Potential of the Wind Power

In terms of wind power, SREDA has been implementing the study including off-shore wind, and the poor potential is identified as of now. SREDA is also considering to formulate the roadmap for the wind power like PV in future. The government identifies that the data collection for several years is required to develop the roadmap for the wind power, therefore the data will be collected from ongoing project in Chattagram and Khulna, and wind meter which was placed by National Renewable Energy Laboratory (NREL), and the road map will be developed after obtaining adequate data. The announcement of the roadmap is anticipated from 2022 to 2024.

In the past, the wind power potential survey was implemented by the National Renewable Energy Laboratory (NREL), USA, under the cooperation with the government of the country, as one of the USAID Bangladesh Wind Resource Assessment Project, and “Assessing the Wind Energy Potential in Bangladesh” was published in September 2018. According to this, there is the 30 GW wind power potential in 20,000km^2 land, subject to the wind speeds of 5.75–7.75 m/s, but this estimate does not consider any filters of the land use such as the environmental protection area, the developed land, allocation with PV etc... This report aims to provide the wind information and the tool to promote the investment for the wind power development, and the proposal for the wind policy is not described.

Figure 2.3-16 shows the one example of the wind potential in the country which is calculated from the actual data at 9 points and the wind simulator. According to this, the right spots of the onshore wind are limited to the coastal area of Bay of Bengal, and the poor inland wind potential is indicated.

The Bangladesh government considers the development of the offshore wind power but the development of the offshore wind power costs more than the one of the onshore wind power. Thus, the government pays attention to the price drop due to the spread of offshore wind power and waits for the right time in development.



Source : Assessing the Wind Energy Potential in Bangladesh (NREL)
Figure 2.3-16 Wind potential in the country

In terms of waste power and biomass power, the development plans are only the listed plan in the power development plan proposed by PowerCell, and the roadmap like PV is not considered.

2.3.6 Restriction for the renewable energy introduction

The use of farmland for renewable energy is restricted in Bangladesh. Renewable energy power generated by using farmland is permitted only for self-consumption and power transmission is prohibited. The equipment needed for agriculture such as solar irrigation system is assumed for the use of agricultural land for renewable energy. The renewable energy other than in the agricultural land such as roof top or mega solar system is approved to transmit to the power system.

The rules for the use of agricultural land is notified by the government internal direction instead of the rule listed in electric power related regulations. As this direction includes confidential matters, it cannot be obtained.

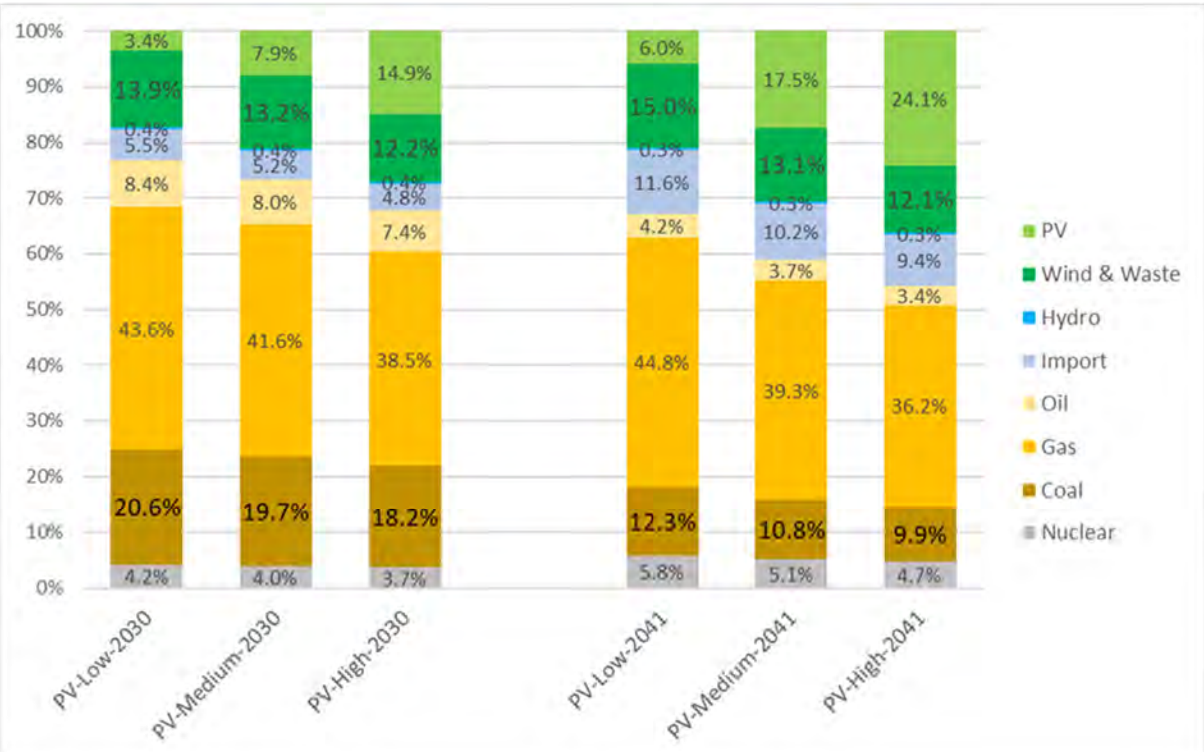
2.3.7 Consideration of the Solar Power Development Plan in case that the National Solar Energy Roadmap, 2021-2041 (draft) by Power Division and the wind power potential are reflected

(1) The introduction capacity of the PV and the wind power to study power development plan including the renewable energy.

In Bangladesh, the strengthening of the renewable energy introduction is the policy as one of the countermeasures for the decrease in the energy import dependance and the climate change, but the concrete numerical goals is under consideration and has not been set yet. In order to study the power development plan including the renewable energy, the study set the hypotheses.

The PV is developed in accordance with 3 scenarios listed in the National Solar Energy Roadmap, 2021-2041 (Draft). In terms of the wind power, in the Assessing the Wind Energy Potential in Bangladesh, there is the 30 GW wind power potential in 20,000km2 land without considering any filters of the land use, but the study hypothesizes that the wind power capacity of 8GW by 2030, 15GW by 2041 was developed with considering the development of the offshore wind power, because 20,000km^2 is so wide, the area with good potential is limited to the coastal area of the Bay of Bengal. In terms of the waste power, the figure is the 1MW which is indicated in the Revisiting PSMP2016.

Then, Figure 2.3-17 shows the power source portfolio reflecting the renewable energy introduction on the above hypotheses. The power source portfolio ratio of the renewable energy excluding hydro power in case of the high case of the PV introduction scenario is 27.1% in 2030, and 36.2% in 2041. In terms of the coal fired thermal power ratio, it is 18.2% in 2030 and 9.9% in 2041.



Source: Study Team from BPDB power development plan as of March 2020 and June 2021, Revisiting PSMP2016, National Solar Energy Roadmap, 2021 – 2041 (Draft), Assessing the Wind Energy Potential in Bangladesh

Figure 2.3-17 Power source portfolio reflecting the renewable energy introduction

From here, in terms of the PV introduction capacity, the study adopts the high case scenario in which the highest introduction capacity of the PV is assumed in order to confirm the required volume of the thermal power and the operational status of the coal-fired thermal power.

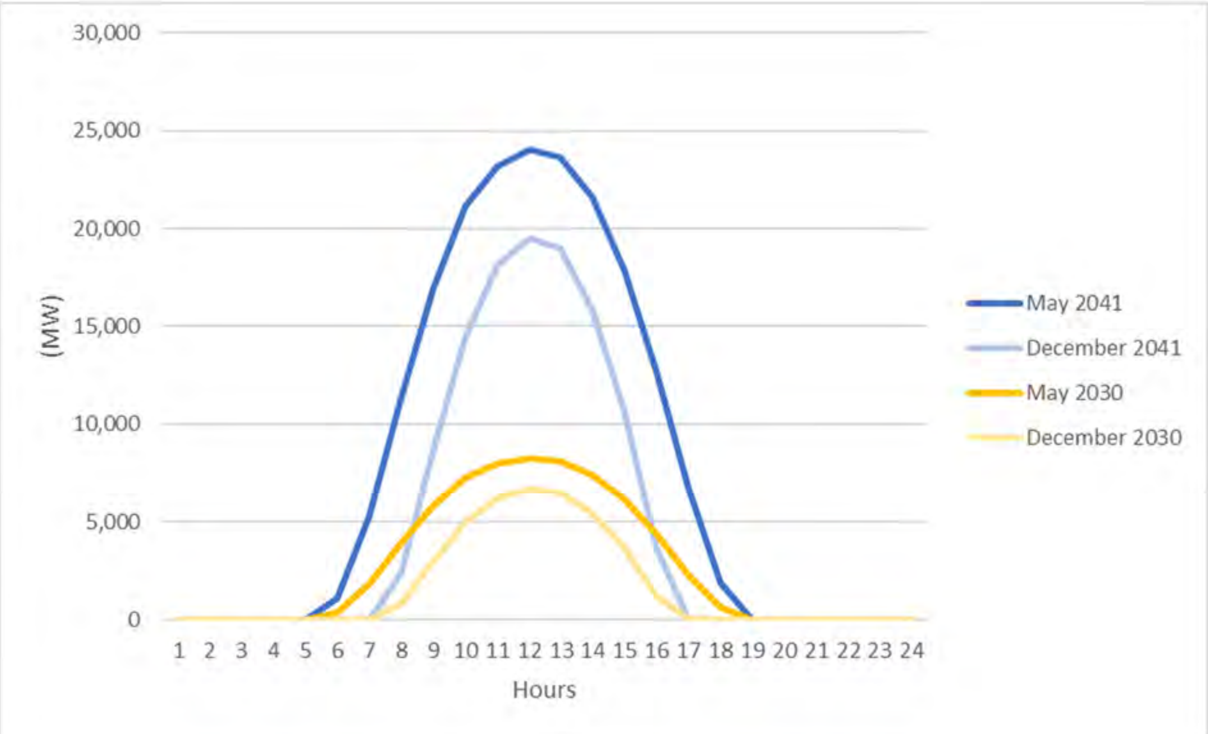
(2) Power supply evaluation of the PV and wind power

The peak demand in Bangladesh occurs when it is clear and less wind and the temperature is high. The same situation occurs in Japan, generally PV output is high and wind output is low. But, once the power supply is estimated, with considering a certain level of the output change risks, the PV capacity is deemed from 70% to 80% of the actual full output, and the wind capacity is estimated at the lowest output level from the actual record in the past. In this study, PV power output is considered at actual full output, and wind power output is considered at the lowest level output when the wind conditions are not good, which is similar evaluation method to Japanese evaluation method.

In terms of the maximum output of the PV power, the full capacity cannot be output and the actual output is delated from the full capacity due to the captive consumption of rooftop PV, the incident angle of the irradiation, the decrease in the conversion efficiency due to the thermal or the defacement/ deterioration of the panel etc. The derated ratio which the study used was calculated from the actual record in the TEPCO Power Grid area.

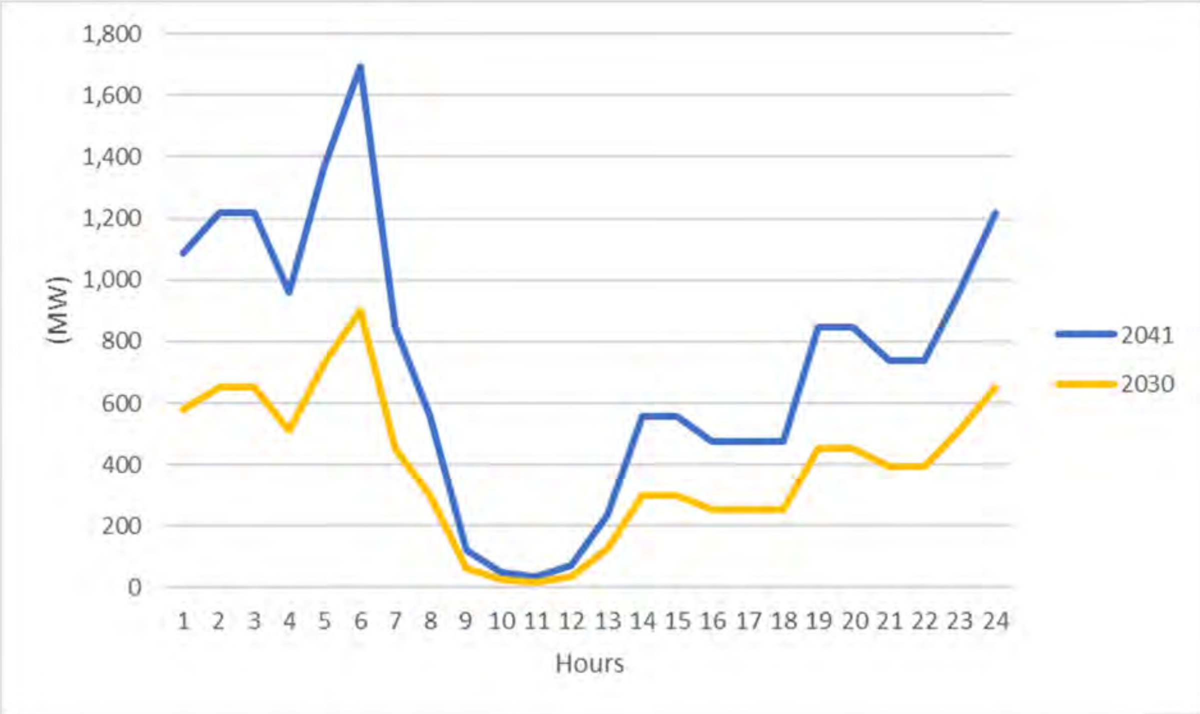
In terms of the output of the wind power, the low wind conditions are calculated at the same revel of the lowest 10^{th} level in the past or the level of the 3 σ , and the calculated wind conditions are converted to the power.

Figure 2.3-18 and Figure 2.3-19 shows the calculated the PV and the wind outputs which are used for the study.



Source: Study Team from National Solar Energy Roadmap, 2021 – 2041 (Draft), TEPCO PG data

Figure 2.3-18 PV power outputs used for the study



Source: Study Team from Assessing the Wind Energy Potential in Bangladesh

Figure 2.3-19 Wind power outputs used for the study

(3) Demand supply balance in case of reflecting the renewable energy introduction

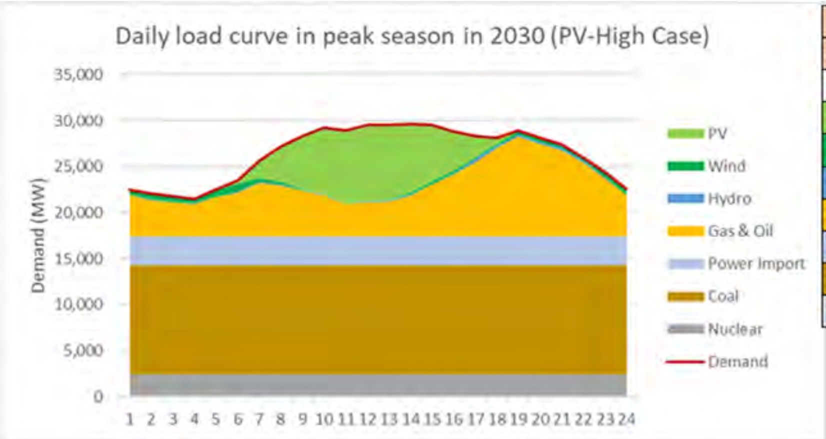
The conditions for the study are as follows.

- 6 cases which are the peak season (May, weekday) and off-peak season (December, weekday and holiday), and 4 cases of the weekly operations using the storage system (the peak season and the off-peak season in 2030 and in 2041) are studied.
- Peak demand in 2030 is 29,619MW, and in 2041 is 57,903MW which are the demands in the Revisiting PSMP2016.
    - The reason why the demand of Low Case (With EE&C) in the Revisiting PSMP 2016 was adopted. In the 8th Five Year Plan, in terms of the gas demand, to study the scenario C (low demand case) mainly which considers the climate change (the renewable energy introduction) among 3 scenarios proposed in the GSMP2017 was described, and the implementation of the energy conservation measures is the one of the goals of the 8th Five Year Plan. And in order to check the dependence of the thermal power even in the low demand situation.
- The off-peak demand in 2041 is calculated from 55% of the peak demand. (Bangladesh's peak demand in 2041 is similar to the peak demand in TEPCO area, and the configuration and portfolio of the current demand in Bangladesh are assumed to be different from the one in 2041. Thus, the ratio of weekday and holiday in Bangladesh is not used)
- The off-peak demand in 2030 is calculated from 57% of the peak demand, which is intermediate revel between current weekday-holiday ratio and 55% adopted in 2041.
- The load curves in May are calculated from the forecasted load curve in the PSMP2016.
- The load curves in December are calculated from the actual holiday load curve records in December 2020.
- PV output efficiencies are 80% in May, and 65% in December based on the actual records in TEPCO area.
- Biomass and waste are counted as 0MW due to small capacity and unstable fuel supply.
- Import power is counted as baseload power due to uncertain power source, and in case of the surplus power of the renewable energy, it is suppressed.

(a) In 2030 (PV capacity: 10,289MW, Wind capacity: 8,000MW)

1) Peak in 2030 (May)

The daily demand-supply balance is shown in Figure 2.3-20. The PV generation at 14 hours is 7,407 MW, but a sudden load increase in the thermal power generation is required for the evening time with the decreasing PV generation, and the maximum generation from thermal power is 10,788MW + 11,920MW = 22,708MW at 19 hours. The coal-fired thermal power is running as a base load.



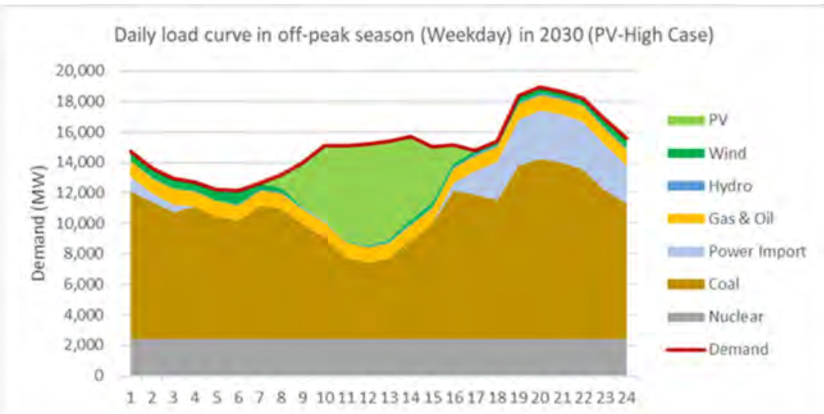
2,030	Hour	
Generation	14	19
Demand	29,619	28,947
PV	7,407	2
Wind	296	451
Hydro	50	230
Gas & Oil	4,389	10,788
Power Import	3,156	3,156
Coal	11,920	11,920
Nuclear	2,400	2,400

Source: Study Team from BPDB power development plan as of March 2020 and June 2021, National Solar Energy Roadmap, 2021 -2041 (Draft), PSMP2016, Revisiting PSMP2016, PGCB website, Assessing the Wind Energy Potential in Bangladesh, data from TEPCO

Figure 2.3-20 Daily demand-supply balance in peak season in FY2030

2) Off-Peak in 2030 (December, weekday)

The daily demand-supply balance is shown in Figure 2.3-21. The PV generation is 0 MW at 20 hours of the peak demand time, and the demand-supply balance has to rely on the thermal power in the evening time. The generation from thermal power is 1,000 MW + 11,850 MW = 12,850 MW at 20 hours and the maximum generation of the day. On the other hand, the thermal generation at 12 hours is 1,000MW + 5,036 MW = 6,036 MW due to high generation from PV, and it is required to decrease the generation from thermal power and stop some thermal power units. The coal fired thermal power also suppresses 6,814 MW output, but if the repair work is planned in the season, the remainders can be run at the base load. The suppression of import is required. The curtailment of the renewable energy is not required. A sudden load change of thermal power generation and imported electrical power is required from morning to daytime and from daytime to the peak demand time.



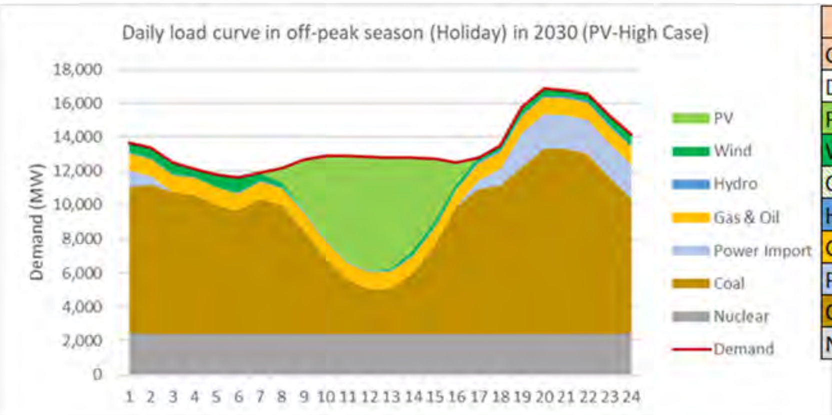
2,030	Hour	
Generation	12	20
Demand	15,211	18,956
PV	6,688	0
Wind	37	451
Curtail	0	0
Hydro	50	100
Gas & Oil	1,000	1,000
Power Import	0	3,156
Coal	5,036	11,850
Nuclear	2,400	2,400

Source: Study Team from BPDB power development plan as of March 2020 and June 2021, National Solar Energy Roadmap, 2021 -2041 (Draft), PSMP2016, Revisiting PSMP2016, PGCB website, Assessing the Wind Energy Potential in Bangladesh, data from TEPCO

Figure 2.3-21 Daily demand-supply balance in off-peak season (weekday) in FY2030

3) Off-Peak in 2030 (December, holiday)

The daily demand-supply balance is shown in Figure 2.3-22. The PV generation is 0MW at 20 hours of the peak demand time, and the demand-supply balance has to rely on the thermal power in the evening time. The generation from thermal power is 1,000MW + 10,932MW = 11,932MW at 20 hours and the maximum generation of the day. On the other hand, the thermal generation at 12 hours is 1,000MW + 2,651MW = 3,651MW due to high generation from PV, and it is required to decrease the generation from thermal power and stop some thermal power units. The coal fired thermal power also suppresses 8,281MW output, and a level of the suppression is required on the holiday even if the repair work is planned in the season. The suppression of import is required. The curtailment of the renewable energy is not required. A sudden load change of thermal power generation and imported electrical power is required from morning to daytime and from daytime to the peak demand time, and in terms of the coal fired power, high-level balancing regulation such as Flex-USC is required.



2,030	Hour	
Generation	12	20
Demand	12,826	16,883
PV	6,688	0
Wind	37	451
Curtail	0	0
Hydro	50	100
Gas & Oil	1,000	1,000
Power Import	0	2,000
Coal	2,651	10,932
Nuclear	2,400	2,400

Source: Study Team from BPDB power development plan as of March 2020 and June 2021, National Solar Energy Roadmap, 2021 -2041 (Draft), PSMP2016, Revisiting PSMP2016, PGCB website, Assessing the Wind Energy Potential in Bangladesh, data from TEPCO

Figure 2.3-22 Daily demand-supply balance in off-peak season (holiday) in FY2030

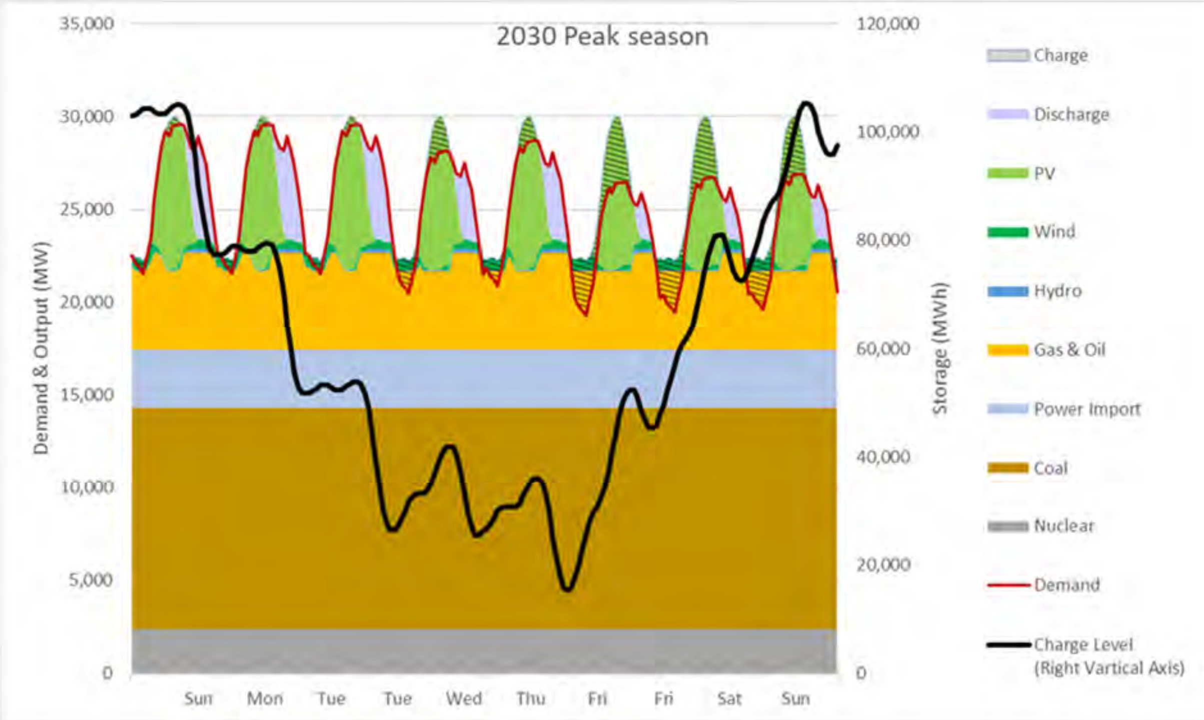
4) Weekly operations with using the storage system (battery) in 2030

On the operations on the above from 1) to 3), the load change of the thermal power and imported electric power becomes large due to especially PV output change, and the availability factor of the thermal power drops largely. However, the energy from renewable energy can be charged in the storage system such as pumped storage hydro power, battery, Vehicle to Grid (V2G) by using Electric Vehicle (EV), then the operation of the thermal power can be optimized. Although more renewable energy is installed in High Case but the thermal power is still needed even if the battery is used. The following section describes the required capacity of thermal power.

In terms of the battery system and the V2G operation, there are many technical challenges, but the technical research and development should be implemented for the energy efficient use.

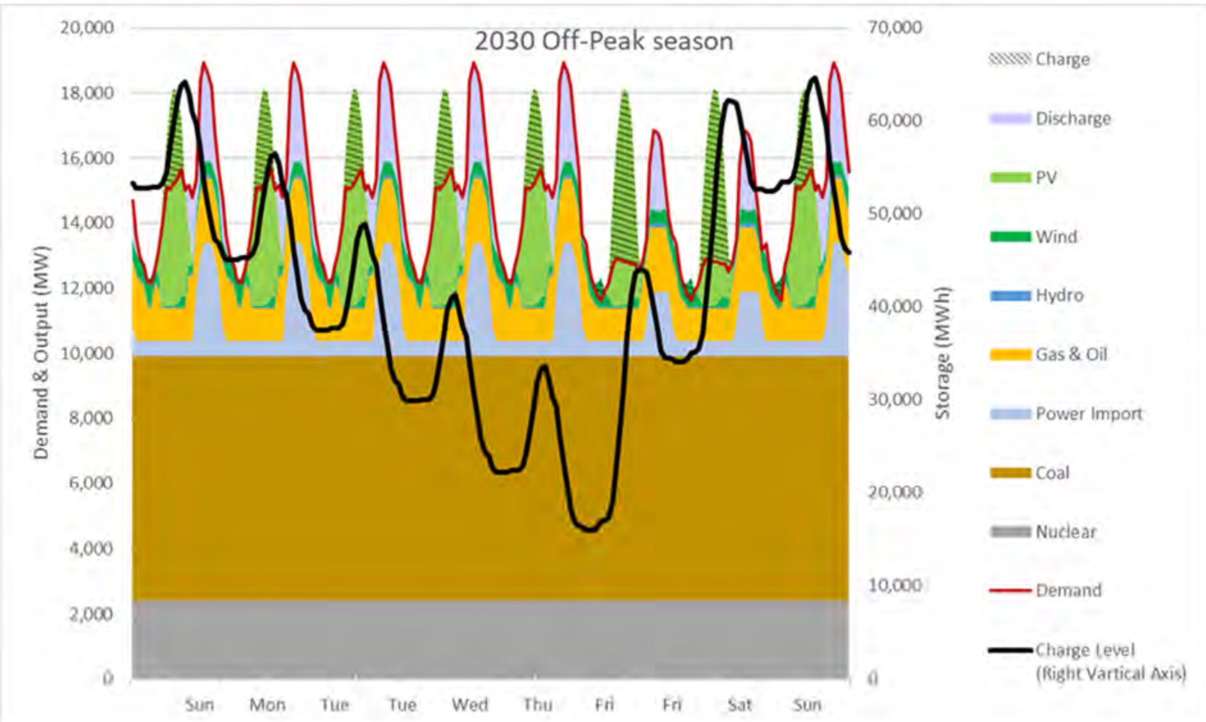
Figure 2.3-23 and Figure 2.3-24 shows the weekly operation with using storage system in the peak season and the off-peak season. The storage system is assumed as the battery, and the charge-discharge efficiency is set at 95%. If the battery system is used, the output of the thermal power will be almost maintained constant throughout the week in every season, and the thermal power is used as a base load but the volume of the thermal power depends on the demand level. In the figure, the battery is charged by excess electricity that is surplus electrical energy for the demand.

“Charge Level” in the figures shows the charge and discharge of the battery. The battery is fully charged at the beginning of the week, and the charge level is decreasing over the weekend while the battery is repeatedly charged and discharged. Then, the battery is almost fully charged again with the surplus electricity in the weekend. The capacity of the charged/discharged battery is large in the peak season. Thus, it requires the battery of which the largest load is 5,588 MW and the charge capacity is 105,314 MWh. Therefore, the optimal storage capacity on this demand supply balance including a certain operational margin is approximate 6,000 MW and 120,000 MWh. Even if there are more batteries, the thermal power is the only power source for charging. In order to cope with further climate change and secure the stable energy supply, more renewable energies or alternate power sources instead of the conventional thermal power must be installed. It is also required to increase the battery storage facility and convert the fuel for thermal power generation to the fuel that does not emit CO_2 (Ammonia, hydrogen, etc.). On the other hand, if the battery storage facility suited for the introduction capacity of renewable energy is not installed, the large load change in thermal power generation may be induced as shown in the Figure 2.3-20 and Figure 2.3-21. Thus, it requires to ensue enough load change and speed for coal-fuel power generation.



Source: Study Team from BPDB power development plan as of March 2020 and June 2021, National Solar Energy Roadmap, 2021 -2041 (Draft), PSMP2016, Revisiting PSMP2016, PGCB website, Assessing the Wind Energy Potential in Bangladesh, data from TEPCO

Figure 2.3-23 Weekly operation with using storage system in the peak season in 2030



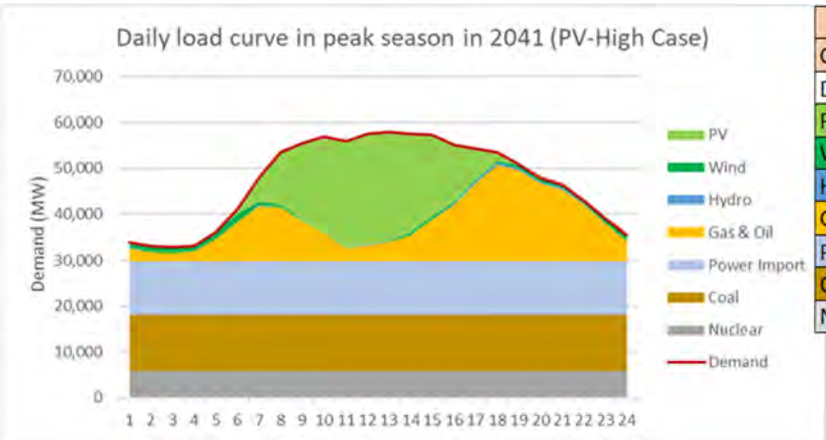
Source: Study Team from BPDB power development plan as of March 2020 and June 2021, National Solar Energy Roadmap, 2021 -2041 (Draft), PSMP2016, Revisiting PSMP2016, PGCB website, Assessing the Wind Energy Potential in Bangladesh, data from TEPCO

Figure 2.3-24 Weekly operation with using storage system in the off-peak season in 2030

(b) In 2041 (PV capacity: 30,000MW, Wind capacity: 15,000MW)

1) Peak in 2041 (May)

The daily demand-supply balance is shown in Figure 2.3-25. The PV generation at 13 hours is 23,608 MW, but a sudden increase in thermal power generation is required for the evening time with the decreasing PV generation, and the maximum generation from thermal power is 20,979MW + 12,305MW = 33,284MW at 18 hours. The coal fired thermal power is running as a base load.



2,041	Hour	
Generation	13	18
Demand	57,903	53,446
PV	23,608	1,868
Wind	234	476
Hydro	50	330
Gas & Oil	4,218	20,979
Power Import	11,656	11,656
Coal	12,305	12,305
Nuclear	5,832	5,832

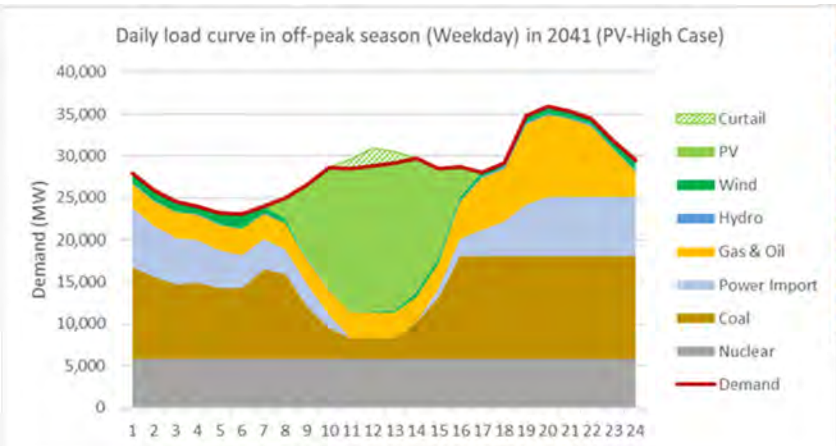
Source: Study Team from BPDB power development plan as of March 2020 and June 2021, National Solar Energy Roadmap, 2021 -2041 (Draft), PSMP2016, Revisiting PSMP2016, PGCB website, Assessing the Wind Energy Potential in Bangladesh, data from TEPCO

Figure 2.3-25 Daily demand-supply balance in peak season in FY2041

2) Off-Peak in 2041 (December, weekday)

The daily demand-supply balance is shown in Figure 2.3-26. The PV generation is 0 MW at 20 hours of the peak demand time, and the demand-supply balance has to rely on the thermal power in the evening time. The generation from thermal power is 9,768 MW + 12,305 MW = 22,073 MW at 20 hours and the maximum generation of the day. On the other hand, the thermal generation at 12 hours is suppressed at the minimum load due to high generation from PV, and the import is suppressed to 0 MW. The nuclear power is running as a base load. In this situation, the curtailment of the renewable energy shown as "Curtail" in the figure is required of 2,106 MW. In addition, a sudden load change of thermal power and imported electrical power is also required from morning to daytime and from daytime to the peak demand time. In terms of the coal fired power, high-level balancing regulation such as Flex-USC is required due to suppression of 9,844 MW.

The effective use of the curtailed renewable energy is considered to be charged in a battery system such as pumped storage hydro power plant and battery, and discharged in the night peak time.



2,041	Hour	
Generation	12	20
Demand	28,806	35,900
PV	19,500	0
Wind	69	845
Curtail	-2,106	0
Hydro	50	150
Gas & Oil	3,000	9,768
Power Import	0	7,000
Coal	2,461	12,305
Nuclear	5,832	5,832

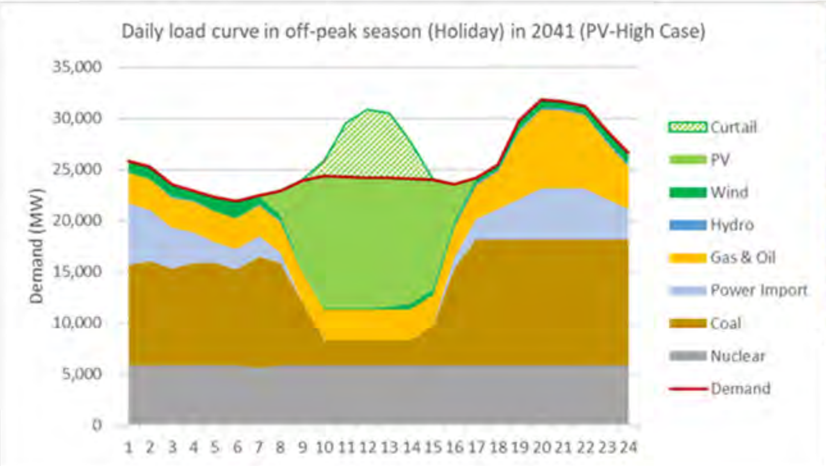
Source: Study Team from BPDB power development plan as of March 2020 and June 2021, National Solar Energy Roadmap, 2021 -2041 (Draft), PSMP2016, Revisiting PSMP2016, PGCB website, Assessing the Wind Energy Potential in Bangladesh, data from TEPCO

Figure 2.3-26 Daily demand-supply balance in off-peak season (weekday) in FY2041

3) Off-Peak in 2041 (December, holiday)

The daily demand-supply balance is shown in Figure 2.3-27. The PV generation is 0MW at 20 hours of the peak demand time, and the demand-supply balance has to rely on the thermal power in the evening time. The generation from thermal power is 7,715MW + 12,305MW = 20,020MW at 20 hours and the maximum generation of the day. On the other hand, the thermal generation at 12 hours is suppressed at the minimum load due to high generation from PV, and the import is suppressed to 0MW. The nuclear power is running as a base load. In this situation, the curtailment of the renewable energy is required of 6,718MW. In addition, a sudden load change of thermal power generation and imported electrical power is also required from morning to daytime and from daytime to the peak demand time. In terms of the coal fired power, high-level balancing regulation such as Flex-USC is required due to suppression of 9,844 MW.

The effective use of the curtailed renewable energy is considered to be charged in a battery system such as pumped storage hydro power plant and battery, and discharged in the night peak time.



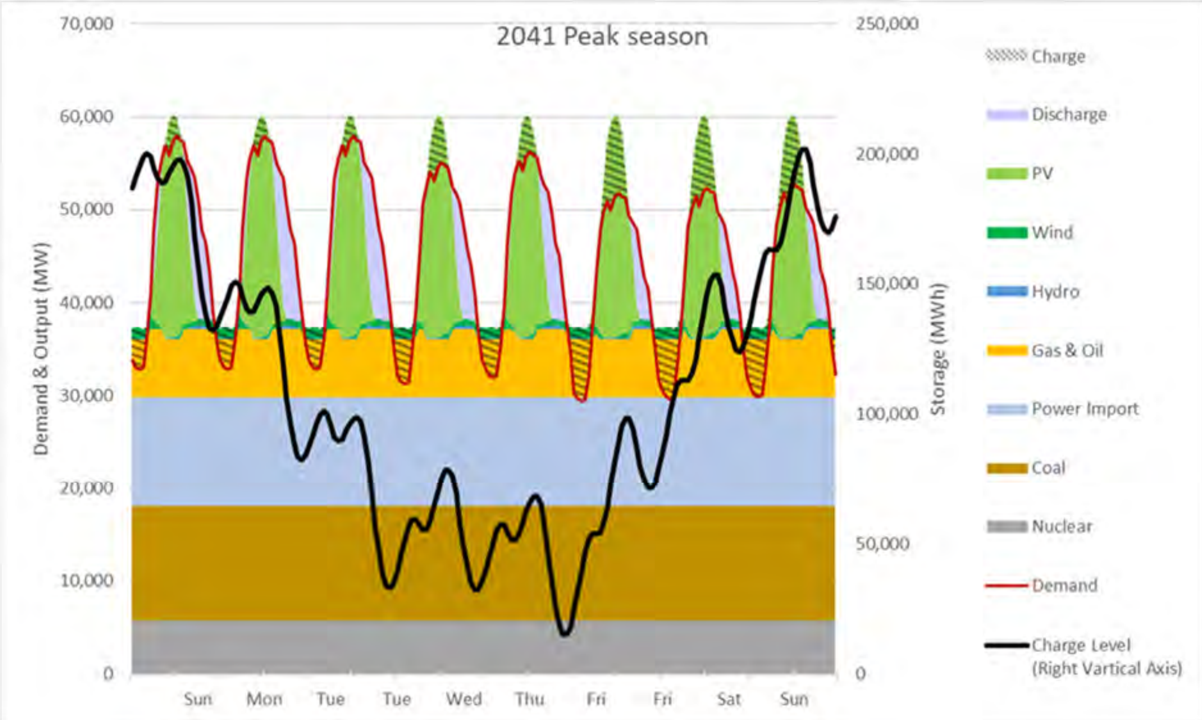
2,041	Hour	
Generation	12	20
Demand	24,195	31,847
PV	19,500	0
Wind	69	845
Curtail	-6,718	0
Hydro	50	150
Gas & Oil	3,000	7,715
Power Import	0	5,000
Coal	2,461	12,305
Nuclear	5,832	5,832

Source: Study Team from BPDB power development plan as of March 2020 and June 2021, National Solar Energy Roadmap, 2021 -2041 (Draft), PSMP2016, Revisiting PSMP2016, PGCB website, Assessing the Wind Energy Potential in Bangladesh, data from TEPCO

Figure 2.3-27 Daily demand-supply balance in off-peak season (holiday) in FY2041

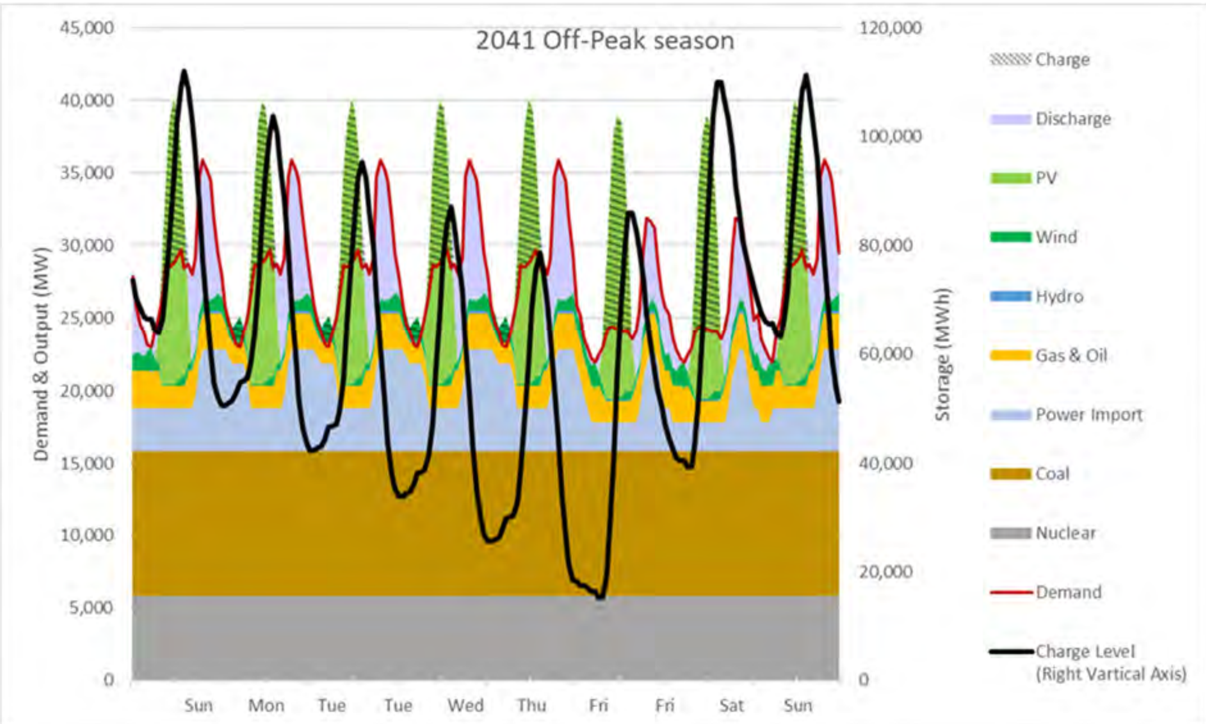
4) Weekly operations with using the storage system (battery)

On the operations on the above from 1) to 3), the load change of the thermal power and imported electric power becomes large due to especially PV output change, and the availability factor of the thermal power drops largely, and the curtailment of the renewable energy is required in the daytime of off-peak season due to the surplus power from the renewable energy. However, the energy from renewable energy can be charged in the storage system such as pumped storage hydro power, battery, Vehicle to Grid (V2G) by using Electric Vehicle (EV), then the operation of the thermal power can be optimized. Figure 2.3-28 and Figure 2.3-29 shows the weekly operation with using storage system in the peak season and the off-peak season. In 2041, the output of the thermal power will be also almost maintained constant depending on the demand level, and the thermal power is used as a base load to use the battery system. The required capacity of the battery in the peak season is 13,659MW and 201,677MWh, and in the off-peak season is 9,583MW and 112,157MWh. Therefore, the optimal storage capacity on this demand supply balance including a certain operational margin is approximate 16,000MW and 220,000MWh.



Source: Study Team from BPDB power development plan as of March 2020 and June 2021, National Solar Energy Roadmap, 2021 -2041 (Draft), PSMP2016, Revisiting PSMP2016, PGCB website, Assessing the Wind Energy Potential in Bangladesh, data from TEPCO

Figure 2.3-28 Weekly operation with using storage system in the peak season in 2041



Source: Study Team from BPDB power development plan as of March 2020 and June 2021, National Solar Energy Roadmap, 2021 -2041 (Draft), PSMP2016, Revisiting PSMP2016, PGCB website, Assessing the Wind Energy Potential in Bangladesh, data from TEPCO

Figure 2.3-29 Weekly operation with using storage system in the off-peak season in 2041

(c) Reevaluation of thermal power development volume with considering renewable energy

As a guideline that the reserve capacity is maintained for Low case (With EE&C) of Revisiting PSMP2016 shown in Table 2.3-2 “Power development plan in which the latest version power development plans were merged and demand-supply balance up to FY2041 (without renewable energy)”, the introduction capacity of thermal power generation facilities is reevaluated in accordance with the introduction capacity of renewable energy. The introduction capacity of each renewable energy is as follows. The PV is 9, 743 MW, wind power is 8,000 MW, and waste power is 1 MW in 2030, and the PV is 30,000 MW, wind and waste power is 15,000 MW, and waste power is 1 MW in 2041. The plan for the capacity of imported electricity, nuclear power, and water power is not changed from the original power supply plan. Table 2.3-11 shows the reduction from the original plan of thermal power equipment due to the introduction of renewable energy. Two cases are considered (the battery storage facility is installed or not).

The loads of the thermal power shown in the column “a” are maximum loads of the thermal power generation in the peak season when the renewable energy is introduced, which shown in the aforementioned Figure 2.3-20 ” Daily demand-supply balance in peak season in FY2030” and Figure 2.3-23 “Weekly operation with using storage system in the peak season in 2030”. They are the maximum and minimum required loads of thermal power. Adding the loads to the reserve margin shown in the column “b” means the required thermal power capacity (shown in the column “c”). The reserve margin is a value that is calculated by subtracting the demand in Low case of revisiting PSMP2016 (With EE&C) shown in the column “h” in the Table 2.3-2 from the net capacity at the end of a business year (shown in the column “d”). In this case, the reserve margin is secured due to the thermal power generation.

However, the difference of net demand must be considered because of the correlations between the PV generation and net demand that renewable energy load is subtracted from total demand. That is to say, the margin must be set as the difference of the annual maximum power load of thermal power. Figure 2.3-30 shows an example of the correlation for surveying the margin. This figure shows the correlation between the daily maximum net demand which deducts the PV generation of the same day from the demand, and the PV generation of the same day in TEPCO area in August 2020, in order to reconsider the thermal power introduction volume for the PV deployment. It indicates almost the net demands are bigger when the PV generations are bigger, but in terms of the points circled by red line, net demand is big of 1,022MW at the point that the PV generation is lower than the top record. Therefore, the margin in this case is 1,100MW as shown in the column “e” in the Table 2.3-8.

As the result of this, the thermal capacities which can be reduce from the power development plan cannot be reduced due to only 25 MW in 2030, but in 2041 are 5,701 MW. In case of “Use of storage facility”, the capacities can be reduced at 5,612 MW in 2030, and 19,344 MW in 2041. Moreover, if the half of the reserve margins are secured by the battery and the other half are secured by the thermal power, the thermal power development reduction can be larger at 14,738 MW in 2030 and 30,093 MW in 2041. And the volume of the thermal power development reduction is the introduction volume of the storage system. The optimum capacity indicated in the item (a) and (b) above is secured.

Figure 2.3-31 shows the power source portfolio reflecting the introduction capacity of thermal power in consideration of the aforementioned introduction capacity of renewable energy, which is with or without storage facility.

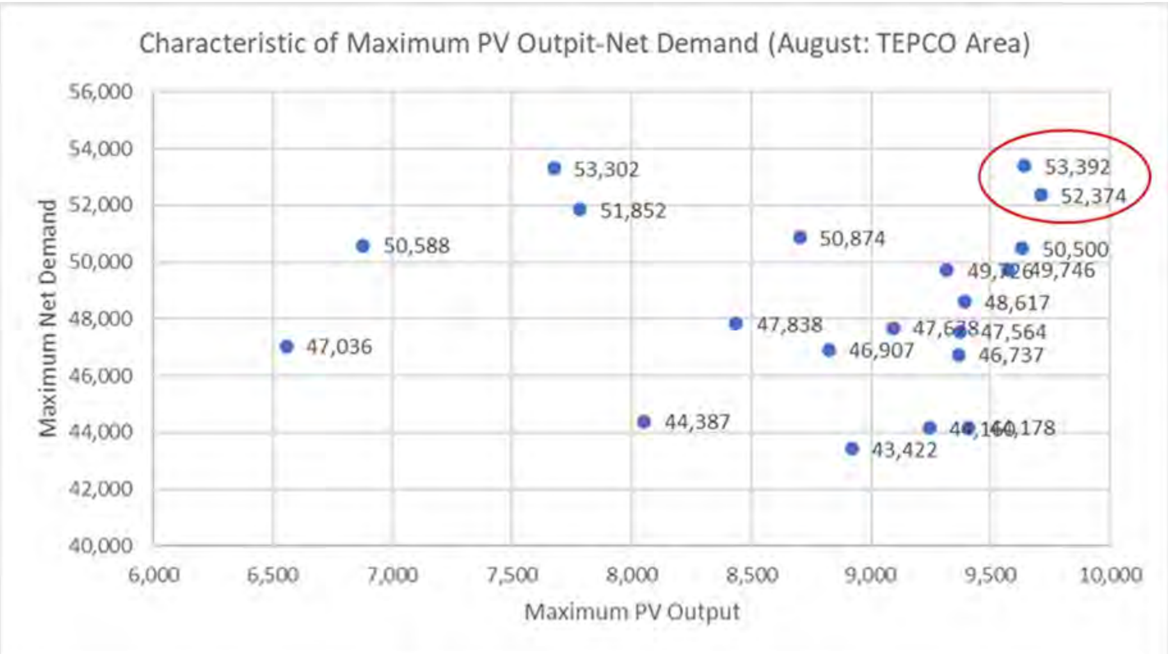
Provided that, this is an example of the way of power supply evaluation, and actually, in terms of the correlations between the net demand and the PV generation, the altitude of the sun and the trends in the Bangladesh’s demand should be duly considered, and the study should be evaluated for each month.

Table 2.3-8 Reevaluation for the thermal power introduction volume by the PV deployment

No use of storage facility	Required Thermal Generation on the study (3)-(a)-1) & (3)-(B)-1) (MW)	Reserve Margin of Power Development Plan (MW)	Required Thermal Power Capacity (MW)	Thermal Power Capacity of Power Development Plan (MW)	Margin of Characteristic error of Net Demand-PV output (MW)	Possible Capacity Reduction by PV Installation (MW)
	a	b	c=a+b	d	e	f=d-c-e
2030	22,708	18,252	40,960	42,085	1,100	25
2041	33,284	21,497	54,781	61,582	1,100	5,701

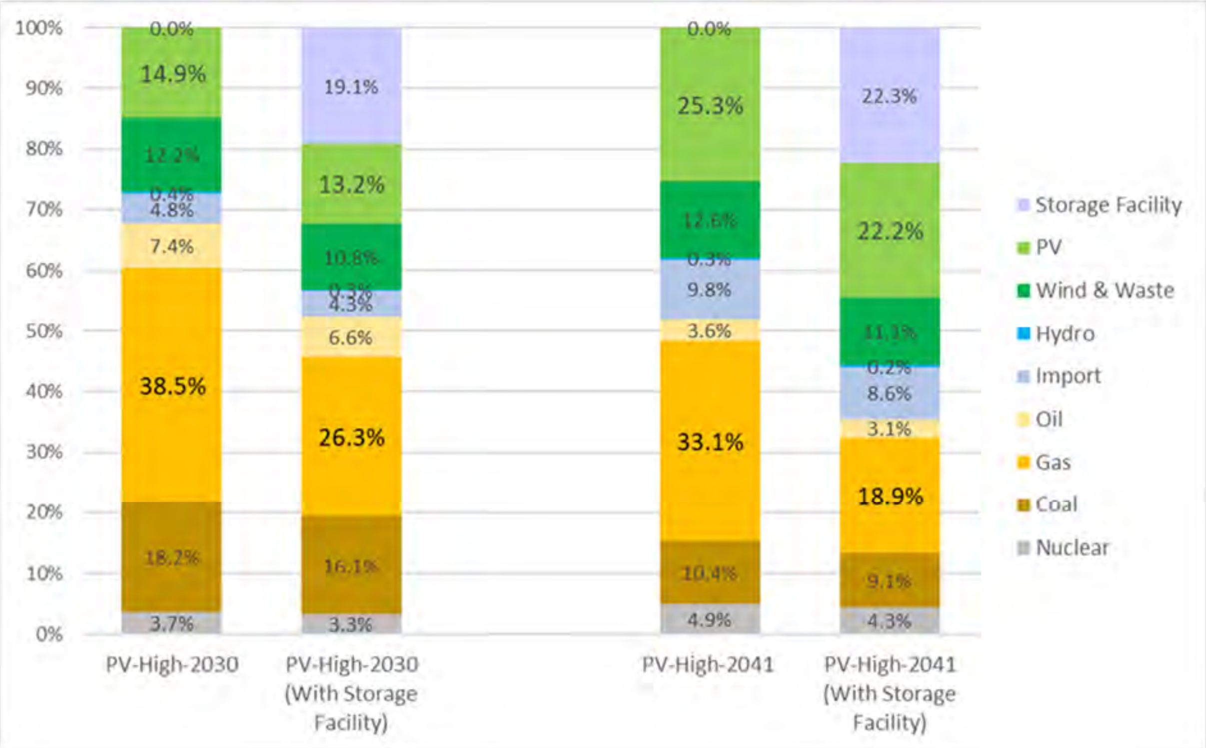
Use of storage facility	Required Thermal Generation on the study (3)-(a)-1) & (3)-(B)-1) (MW)	Reserve Margin of Power Development Plan (MW)	Required Thermal Power Capacity (MW)	Thermal Power Capacity of Power Development Plan (MW)	Margin of Characteristic error of Net Demand-PV output (MW)	Possible Capacity Reduction by PV Installation (MW)
	a	b	c=a+b	d	e	f=d-c-e
2030	16,940	18,252	35,192	42,085	1,100	5,793
2041	19,560	21,497	41,057	61,582	1,100	19,425
	↓Half of reserve margin is secured by Storage Facility					
	2030	9,126	26,066	42,085	1,100	14,919
	2041	10,749	30,309	61,582	1,100	30,174

Source: Study Team from BPDB power development plan as of March 2020 and June 2021, the government policy of the coal power development in June 2021, National Solar Energy Roadmap, 2021 -2041 (Draft), PSMP2016, Revisiting PSMP2016, PGCB website, Assessing the Wind Energy Potential in Bangladesh, data from TEPCO



Source: Study Team from the area demand data and PV data from TEPCO

Figure 2.3-30 Correlation between the daily maximum net demand and the PV generation (August 2020, TEPCO area)



Source: Study Team from BPDB power development plan as of March 2020 and June 2021, National Solar Energy Roadmap, 2021 -2041 (Draft), PSMP2016, Revisiting PSMP2016, PGCB website, Assessing the Wind Energy Potential in Bangladesh, data from TEPCO

Figure 2.3-31 Power source portfolio ratio in case that the storage system is available or not

(d) The demand which the thermal power bears in case of no use of the storage system

In the demand-supply studies without using storage system, the results indicate that the thermal power has to increase the generation as a regulation provider from 12 hours which the PV generation is the maximum to evening peak time when the PV is not generated, with response to the decrease in the PV generation and the demand movement. Table 2.3-9 shows the required regulations of thermal power. Especially, in the off-peak season, the burden of the thermal power becomes heavy, as the demand increases in the evening time with the decrease in the PV generation. The thermal power plants require high maneuverable function and high-speed response to the National Load Dispatch Center (NLDC) where controls the output of generators.

Table 2.3-9 Required regulation from 12 hours to evening peak time

	Volume of Regulation Up from 12:00 to Evening Peak (MW)		
	Peak Season	Off-Peak Season (Week day)	Off-Peak Season (Holiday)
2030	7,349	6,814	8,281
2041	18,229	17,479	15,426

Source: Study Team from BPDB power development plan as of March 2020 and June 2021, the government policy of the coal power development in June 2021, National Solar Energy Roadmap, 2021 -2041 (Draft), PSMP2016, Revisiting PSMP2016, PGCB website, data from TEPCO

In Japan and USA and the European countries, electric power utilities are unbundled into Transmission System Operator (TSO)/ Independent System Operator (ISO) and generation utilities. TSO secures the balancing regulations depending on the generator's response speed in order to maintain appropriate power demand-supply balancing. In the country, NLDC needs to secure the appropriate balancing regulations as TSO, with the renewable energy deployment.

In Japan and USA and the European countries, since the power trade between generation utilities and retail/distribution utilities are done by the time blocks form 5 minutes to 30 minutes time block, TSO has to secure the balancing regulations (Δ kW) in order to compensate the power for instant change of the demand, the schedule errors of utilities, and the generation drop by the accident, in addition to the difference between the time block and the actual electrical power supply-demand. Table 2.3-10 shows the balancing regulation menus in Japan. The balancing regulations are classified as the primary, secondary, and tertiary in response to the response speed. Especially, as of now, the primary and the secondary are mainly provided from rotating generators such as conventional hydro power generators or thermal power generators. In the country, the thermal power is the main generation since the hydro power potential is low.

Table 2.3-10 Balancing regulation menus in Japan

	Primary	Secondary		Tertiary	
	Frequency containment Reserves (FCR)	Synchronized Frequency Restoration Reserves (S-FRR)	Frequency Restoration Reserves (FRR)	Replacement Reserve (RR)	Replacement Reserve -for FIT (RR-FIT)
Instruction /control	–	instruction/control (LFC signal)	instruction/control (EDC signal)	instruction/control	instruction
Monitoring	offline	online	online	online	Online/ Offline
Telecommunication Method	–	Dedicated line	Dedicated line	Dedicated line or VPN	VPN
Response speed	Within 10 sec	Within 5 min.	Within 5 min.	Within 15 min.	Within 45 min.
Length of sustention	5+ min.	30+ min.	30+ min.	3+ hour	3+ hour
Instruction interval	- (Automatic)	0.5sec to tens of seconds	1minute to some minutes	1minute to some minutes	30minutes
Upper Limit of Bidding	Amount of increase or decrease within 10 sec. AND bandwidth of governor-free mode	Amount of increase or decrease within 5 min. AND bandwidth of LFC mode	Amount of increase or decrease within 5 min. AND bandwidth of online control	Amount of increase or decrease within 15 min. AND bandwidth of online control	Amount of increase or decrease within 45 min. AND bandwidth of online control
Minimum bit amount (Bid increase)	1 MW (1kW)	5 MW (1kW)	5 MW (1kW)	5 MW (1kW)	1 MW (1kW)
Potential participants / bidder	Generator, battery and DR etc.	Generator, battery and DR etc.	Generator, battery and DR etc.	Generator, DR, surplus of self generator etc.	Generator, DR, surplus of self generator etc.
Regulating direction	up and down	up and down	up and down	up and down	up and down

Source: Organization for Cross-Regional Coordination of Transmission Operators, Japan (OCCTO), 6th small working committee for regulation market, material 2

In Bangladesh, although the electricity liberalization has not been implemented, the balancing regulations required for the country are to be temporarily calculated (Table 2.3-11). For the calculation, the equations which are used in Japan are used. The parameters of the fluctuation figures of the demand as of 2030 and 2041 is adopted in accordance with the Japanese records because the same capacity levels of PV as Japan will be deployed in the country. The power source portfolio and the range of the power demand are corrected with the range of the country. The required balancing regulations are not so different, but the big capacities are required such as 6GW in 2030 and 11GW in 2041.

Table 2.3-11 Temporarily calculations for the required balancing regulations

	Required Regulation	
Peak	In 2030	In 2041
Primary	962	1,880
Secondary-Fast	842	1,646
Secondary	776	1,517
Tertiary	3,350	6,549
Total	5,930	11,593

	Required Regulation	
Off-Peak	In 2030	In 2041
Primary	962	1,880
Secondary-Fast	842	1,646
Secondary	776	1,517
Tertiary	2,932	5,732
Total	5,512	10,776

Source: Study Team from the area demand data from TEPCO

Current situation for the balancing regulations in the country, the primary regulation which is mainly provided from Free Governor Mode of Operation (FGMO) of conventional generators is not secured adequately, but only from 2 or 3 generators. The secondary regulation which is mainly secured from conventional generators to be controlled directly from NLDC through dedicated communication lines is not secured at all. The control of the output of generators is done by the operator’s communication through telephone and the operator in the power station controls the output. This is the tertiary regulation. According to the calculation, since the 1.9GW of the primary regulation and 3.2GW of the secondary regulation are required in 2041, in terms of securing the certain balancing regulations, the development of power generation facility which can secure maneuverability for the primary and secondary, and response to the NLDC, and the development of EMS (Energy Management System) which can secure the secondary regulation and communication networks are required.

2.3.8 The necessity of conventional synchronous generator, and various issues by introduction of renewable energy

In this section, the requirement of the conventional rotating generation which has inatia such as thermal power plant or hydro power plant.

To introduce the renewable energy, mainly PV is mandate in the country for the reduction of the CO2 emissions. Among the various renewable energies, the PV and wind power that generate DC power and power with irregular frequencies convert their power to the 50Hz AC power with an inverter (DC-AC converter: Power Conditioning Subsystem (PCS)) to connect to the main power grid. While the hours when the power from power source via inverters increases, the number of the running units of the conventional synchronous generator such as thermal power or hydro power decreases, therefore, it is necessary to take new measures for system stability.

The conventional synchronous generators have some functions to contribute system stability such as the Free Governor Mode of Operation (FGMO) which the generator controls the output automatically in response to the frequency fluctuation to recover to the rated frequency 50Hz, and the inertia which the generator maintains the frequency and increases the output by the inertia of generator rotation in the event of the sudden change of the demand due to the blackout and so on. The renewable energies which require the inverter don't have such functions and characteristics to contribute system stability.

In terms of the other functions for the system stability, the power system transient stability which the ability to adjust the frequency deviation occurred in the event of the system contingency, the reactive power supply to control the voltage, the fault current supply which flows in the event of the system contingency etc. are required, but the power sources which require the inverter don't have these functions.

Table 2.3-12 is a table summarizing the issues caused by the increase in the inverter power source.

Table 2.3-12 The issues caused by the increase in inverter power source

	Item	Functions of synchronous generator	Functions of inverter power source	An example of issues
Frequency Fluctuation	Governor free & LFC	suppressing long-period and short-period frequency fluctuations by controlling output	The output is constant, even if disturbances such as load fluctuations occur.	[Lack of Regulation] ■frequency stay rate is worsened by frequency variation
Frequency Fluctuation / Transient stability	Inertia	Contribution of required effective power from inertia during frequency fluctuations (suppression of frequency change rate)	Inability to contribute active power for frequency fluctuations due to no inertia	[Lack of inertia (Increase in frequency change rate)] ■ Increase in the risk of frequency degradation due to unnecessary action of frequency change rate detection relay for islanding operation detection. ■ Getting Difficult to operate protection relay due to steep frequency drop speed (control speed and technology limitations)
Transient stability	Synchronization force	suppressing system fluctuation by synchronization force in the event of a system contingency, etc.	The output is constant due to no synchronization force, even if disturbances such as load fluctuations occur.	[Lack of synchronization power] ■ Destabilized power system due to expansion of disturbances in the event of system accident.

Voltage	Reactive Power	Maintaining the system voltage by controlling reactive power (AVR)	following system voltage by controlling current (not controlling voltage)	[Reduction of capability of maintaining voltage] ■ Rise of voltage due to increase in reverse current on distribution system. ■ Expansion of voltage drop area and the drop range, and destabilized power system.
Contingency	Short circuit current/ Overload	・Over Load is possible ・Suppressing the frequency change rate by supplying several times rated output rapidly in the event of power drop, etc., ・Providing short-circuit current for operation of protection relay	・Overload operation is basically impassible. ・Output is constant even when the power drop. ・It is difficult to supply the short-circuit current for operation of present protection relay.	[lack of Short-circuit capacity] ■Voltage flicker occurs when short-circuit capacity is small due to the function of single operation detection of new active system (wide-area flicker occurred in Kyushu area in 2017) ■Getting difficult to operate protection relay due to reduction of accident current.

Source: Study Team

Since these issues are greatly involved in facility formation, power quality, and equipment protection, study of countermeasures and demonstration tests are to be conducted to solve these issues in Japan. Here, individual efforts are omitted, but it is important to grasp the number of synchronous generators that match the situation properly with the degree of these technical solutions, and conversely, to grasp the amount that inverter generators can be introduced.

2.4 Analysis of Alternatives (including zero option)

(1) Consideration about power generation method

Based on the recent international trends, JICA Study Team will consider what kind of power generation method is most suitable, assuming that the project will be implemented in the project site.

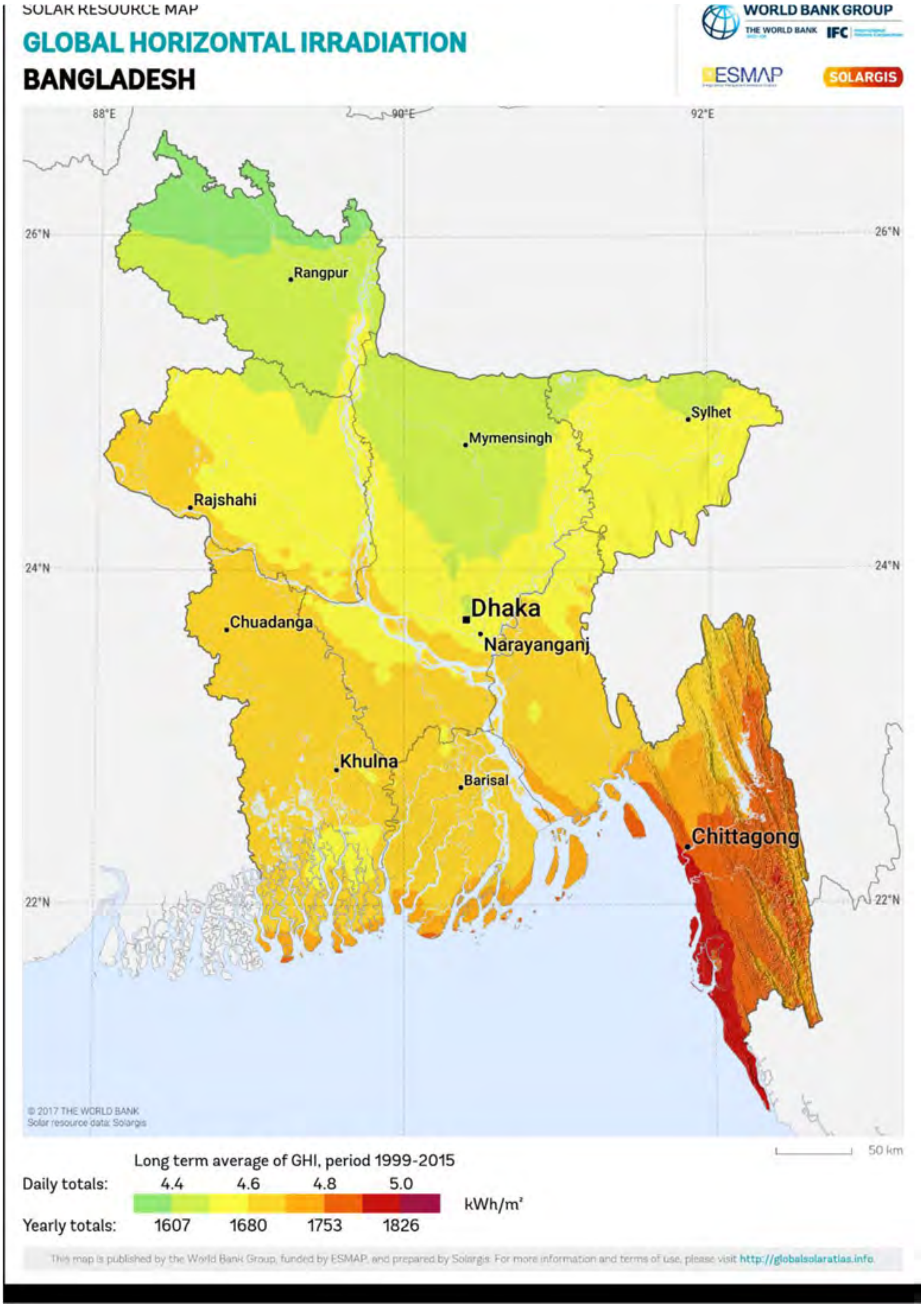
Regarding the location, it is assumed that the project will be implemented at the project site currently selected.

The reason is that the land acquisition procedure is already underway in the Units 1/2 project, so if the land is used, social impacts such as additional land acquisition and resident relocation can be avoided, it will be the great advantage when compared with another alternative site.

In recent years, electricity demand has increased sharply in Bangladesh against the backdrop of stable economic growth and progress in industrialization, but there is the view that unstable power supply is constraint on economic growth according to “7th Five-Year Plan”.

As for hydroelectric power generation, most of the country's land is in the lowlands less than 9 m at sea level, and this project site is located in the coastal area, so there is almost no potential for hydroelectric power generation using the height difference.

As for PV (Photovoltaics) power generation, horizontal irradiation is estimated 5kWh/m^2 around project site according to ”Renewable Energy for Sustainable Growth and Development: An Evaluation of Law and Policy of Bangladesh” (Alimul Haque Khan, Maidul Islam,Asif Islam, Energy and Power 2015, 5(1): 10-16).



Source: Renewable Energy for Sustainable Growth and Development: An Evaluation of Law and Policy of Bangladesh (Sustainability 2019, 11, 5774)

Figure 2.4-1 Global horizontal solar irradiation in Bangladesh

According to New Energy and Industrial Technology Development Organization (NEDO), the amount of PV power generation from the amount (Figure 2.4-1) of solar radiation is given by the following formula.

Ep = H x K x P x 365 = 5.0 x 0.73 x 365 = 1,332 kWh/m^2 (In case of P=1)

Ep (Expected annual power generation)

H (Average annual solar radiation per day)

K (Loss coefficient: Loss due to temperature rise, loss due to power conditioner, loss due to wiring, dirt on the light receiving surface, etc.: About 0.73)

P (System capacity of PV power generation (kW))

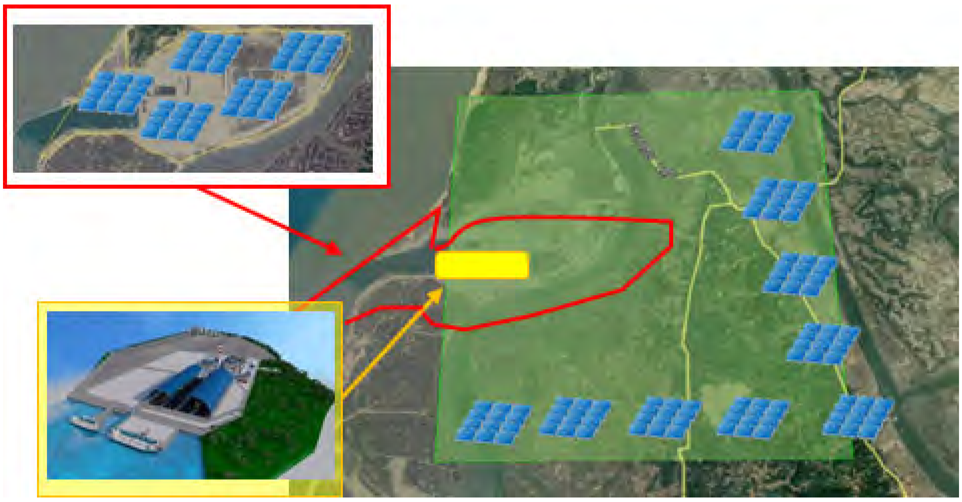
Currently, the total site area of Units 1/2 under construction and planed Units 3/4 is about 700ha (Red frame in Figure 2.4-2). Of this, the site area of Units 3/4 (coal storage yard, power plant site (moreover, land for the ash disposal site has been prepared within construction for Units 1/2)) is about 60ha (Yellow parts in Figure 2.4-2).

The annual power generation of 600 MW x 2 = 1,200 MW for this project is 1,200 MW x 24 hours x 365 days x 80% = 8,410 GWh/year, assuming the capacity factor of 80%.

With reference to the above-mentioned power generation amount of 1,332 kWh/m2 per unit area, the site area required to generate the annual power generation (8,935 GWh/year) of this project by photovoltaic power generation is 8,410 GWh/year / 1,332 kWh/m^2 = 631ha (in case the capacity factor is 1kW/m^2), which is equivalent to the total site area of 700ha required for the Units 1/2 project and this project.

However, in fact, it is said that 10 to 15m^2/kW is required to install a solar panel (1kW). According to "NEDO PV Challenges 2020", the capacity factor of photovoltaic power generation for business use is 18%[5], and with reference to these values, the required site area is calculated as 700ha x 8,410 GWh/year / [7,000,000m^2 / 10$m^{2/}$/kW / 1,000,000 x 8,760 x 18%] = 5,333 ha (Green part in Figure 2.4-2).

When considering photovoltaic power generation, it is necessary to select the site in consideration of topography, weather, diurnal fluctuations, etc. It is not realistic because project owner has to secure the vast land.



Source: Study Team

Figure 2.4-2 The site area required for photovoltaic power generation

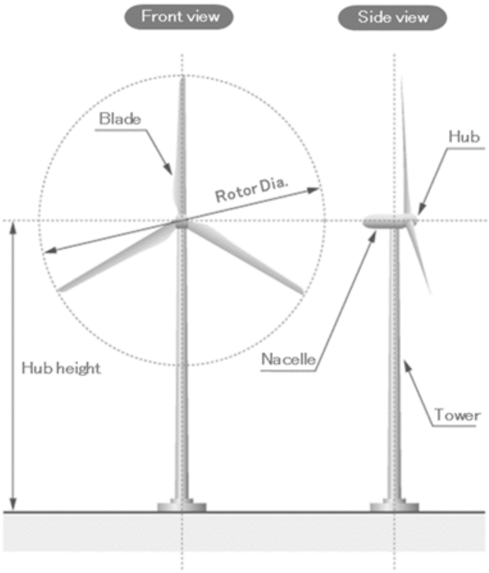
This paper considers wind power as well as photovoltaic power.

In study for the actual introduction, detailed wind condition analysis is required, but this study was conducted with reference to existing materials.

In the "2013 Basic Information Development Report for Zoning on Renewable Energy" (Ministry of Environment, Japan), it was organized based on in case onshore wind power generation is assumed by 2,000 kW scale (hub height 80 m), and in case offshore wind power generation is assumed by 5,000 kW scale (hub height 90 m).

Offshore wind power tends to be larger than onshore wind power.

[5] NEDO PV Challenges 2020 (https://www.nedo.go.jp/content/100926249.pdf)



Source: VENTI JAPAN Inc (http://www.venti-japan.jp/index.html)
Figure 2.4-3 Wind power generation facility

The capacity factor is estimated from the average wind speed on the ground. The average annual wind speed of Kutubdia around the project site in 2020 is 5.1 m/s, and the average annual wind speed of the project site based on the meteorological model is 3.4 m/s (see 5.1.1 (1) Meteorology (1-2-2-2) wind conditions).

The average annual wind speed is 5.1 m/s, and the average wind speed at hub heights of 2,000 kW and 5,000 kW is about 6.4 m/s from the following equation.

V = V1 x (z/z1)^(1/n)

V: Wind speed at Z (m)
V1: Wind speed at Z1 (m) on the ground
1/n: Power exponent

Surface condition	1/n
Cloistral area	0.10 – 0.14
Cultivated area	0.17 – 0.25
Sea	0.1

From Table 2.4-1 and the estimation results of the average wind speed, it is assumed that the capacity factor of the wind power generation facility is about 29%.

Table 2.4-1 The capacity factor at each wind speed

Wind speed	Capacity factor	
	2,000kW	5,000kW
5.0 m/s	16.2%	Not applicable
5.1 m/s	17.1%	
5.2 m/s	18.0%	
5.3 m/s	18.9%	
5.4 m/s	19.8%	
5.5 m/s	20.7%	
5.6 m/s	21.6%	
5.7 m/s	22.5%	
5.8 m/s	23.5%	
5.9 m/s	24.4%	
6.0 m/s	25.3%	
6.1 m/s	26.3%	
6.2 m/s	27.2%	
6.3 m/s	28.1%	
6.4 m/s	29.1%	
6.5 m/s	30.0%	29.5%
6.6 m/s	30.9%	30.5%
6.7 m/s	31.8%	31.4%
6.8 m/s	32.8%	32.3%
6.9 m/s	33.7%	33.2%
7.0 m/s	34.6%	34.1%
7.1 m/s	35.5%	35.0%
7.2 m/s	36.4%	35.9%
7.3 m/s	37.2%	36.8 %
7.4 m/s	38.1%	37.6%
7.5 m/s	39.0%	38.5%
7.6 m/s	39.8%	39.3%
7.7 m/s	40.7%	40.2%
7.8 m/s	41.5%	41.0%
7.9 m/s	42.3%	41.8%
8.0 m/s	43.1%	42.6%
8.1 m/s	43.9%	43.4%
8.2 m/s	44.7%	44.2%
8.3 m/s	45.5%	45.0%
8.4 m/s	46.3%	45.8%
8.5 m/s	47.0%	46.5%
8.6 m/s	4 7.8%	47.3%
8.7 m/s	4 8.5%	48.0%
8.8 m/s	4 9.2%	48.8%
8.9 m/s	4 9.9%	49.5%
9.0 m/s	5 1.0%	50.2%
9.1 m/s	5 1.3%	50.9%
9.2 m/s	5 2.0%	51.6%
9.3 m/s	5 2.7%	52.2%
9.4 m/s	5 3.4%	52.9%
9.5 m/s	5 4.0%	53.6%

Source: 2013 Basic Information Development Report for Zoning on Renewable Energy (Ministry of Environment, Japan)

According to the Japan Wind Power Association, the area occupied above the 2,000kW-scale wind power generation facility is about 0.5ha, but if these facilities are simply laid out, it is calculated that 200 wind power generation facilities can be installed at 1 km2.

However, in reality, mutual interference between adjacent wind turbines causes a decrease in the amount of energy acquired due to competition for wind, so the appropriate separation distance is required.

According to "Introduction Potential regarding Japan's Renewable Energy (Overview Material for Introduction)" (Ministry of Environment), the basic calculation of the introduction potential of onshore and offshore wind power generation is 1 unit / 0.25km2 (4 units/km2).

The site area required to generate the annual power generation (8,410 GWh/year) of this project by onshore wind power generation (2,000 kW scale, capacity factor 29%, 4 units/km2 installed) is 8,410 GWh/year / (2,000kW scale x 24 hours x 365 days x 29% x 4 units) = 41,379ha, and the required onshore wind power generation facilities will be 1,655 units.

In the case of offshore wind power generation (5,000 kW scale, capacity factor 29%, 4 units/km2 installed), the site area is 16,552 ha, and 662 units of offshore wind power generation facilities are required.

In order to cover the annual power generation amount of this project with onshore wind power generation, it is necessary to secure the vast land larger than photovoltaic power generation, so it is not realistic.

In the case of offshore wind power generation, according to "100% RENEWABLE ENERGY FOR BANGLADESH (2019)" (INSTITUTE FOR SUSTAINABLE FUTURES), the sea of Bengal Bay is shown as the potential suitable place (Figure 2.4-5).

16,552 ha at sea has a possibility that the same amount of annual power generation as this project can be generated by securing and performing offshore wind power generation.

In order to carry out wind power generation business over vast ocean, but there are many technical issues.

It is necessary to resolve the selection of the type (fixed-foundation type or floating type), the effect on the navigation route, the effect of the monsoon cyclone) and so on.

Regarding the damage to wind power generation facilities caused by monsoon cyclones, the damage[6] to wind power generation facilities caused by typhoons has been reported in Japan as well. On the other hand, Japanese manufacturers are dealing with improving[7] the strength of their equipment.

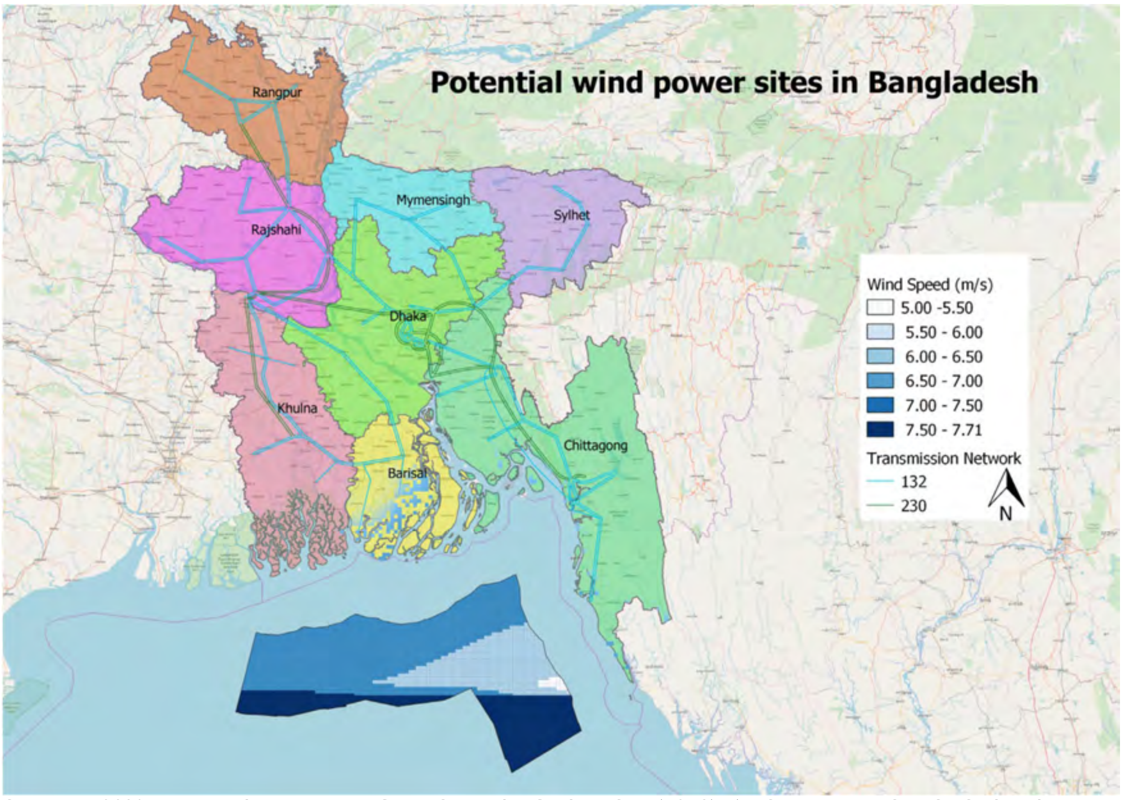
Note; Offshore wind power generation on the left and onshore wind power generation on the right.
Source: Study Team

Figure 2.4-4 The site area required for wind power generation

Unlike thermal power generation including coal-fired power generation, solar power generation and wind power generation can be installed on small scale as decentralized / dispersed facilities. However, since there are times when electricity cannot be supplied, battery storage facility is indispensable.

In addition, based on the analysis solar irradiation, wind conditions, and land use for the proposed site etc., suitable sites must be selected.

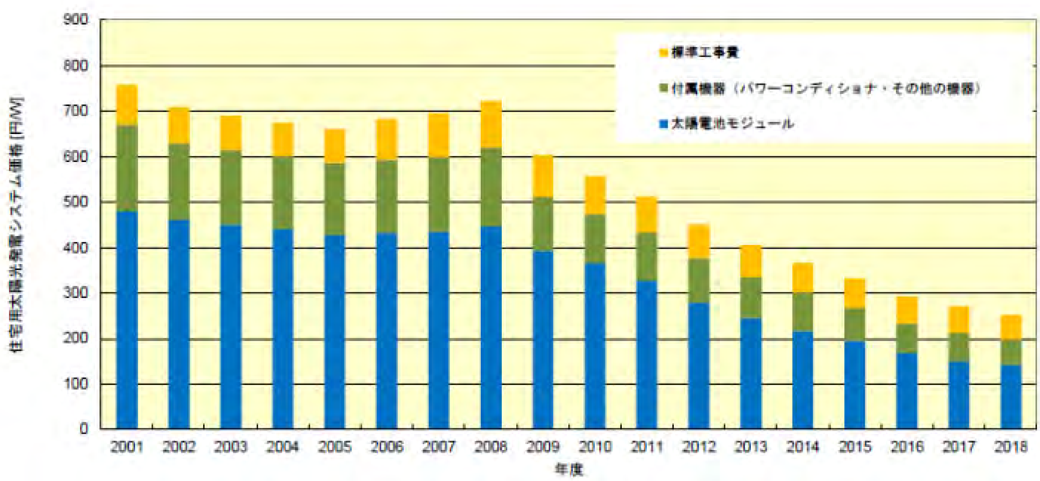
[6] Recent trends of wind power generation facilities and the direction of correspondence (2019) (Ministry of Economy, Trade and Industry, Japan)
[7] TSC Foresight Seminar: Offshore Wind Power Generation Initiatives (Establishment of Safety Against Typhoons, etc.) _2018 (Hitachi, Ltd.)



Source: 100% RENEWABLE ENERGY FOR BANGLADESH (2019) (INSTITUTE FOR SUSTAINABLE FUTURES University of Technology Sydney)

Figure 2.4-5 On- and offshore wind energy generation potential in Bangladesh

Figure 2.4-6 shows the trend of investment cost for photovoltaic power generation systems for residence in Japan. The cost in 2001 was 750,000 yen/kW, but that in 2018 was dropped to about 250,000 yen/kW.



Source: NEDO PV Challenges 2020

Figure 2.4-6 Average investment cost of PV system for residence, Japan

According to the "Future of Solar PV" published by International Renewable Energy Agency (IREA), the investment cost of PV systems in 2018 is 1210 ($ / kW), that in 2030 is 340 to 834 ($ / kW) and that in 2050 is 165 to 481 ($ / kW), the cost is expected to be reduced in the future.

According to “100% RENEWABLE ENERGY FOR BANGLADESH (2019)” [8] mentioned about

[8] Prepared the scenario of BAU, 1.5°C-rise and 2°C-rise, energy demand in 2050 will increase 4.2 times (compared to 2015)

Bangladesh, the investment cost and the power generation costs (operation and maintenance costs) for 2015, 2020, and 2030 are shown in Table 2.4-2.

According to the report, as following table, the investment cost for coal fired power plant is almost same that of PV. The cost of PV power generation and wind turbine are expected to decrease in the future.

In the use of renewable energy, in case of photovoltaic power generation, power storage system is required for nighttime power supply. In clause 2.3.6, the scenario of introducing renewable energy is described. But the combination with the power storage system will increase the equipment cost.

Operation and maintenance costs for power generation technologies is shown in Table 2.4-3. Operation and maintenance cost for coal fired power plant is almost same that of PV. The cost of PV power generation is expected to decrease in the future.

Table 2.4-2 Investment costs for power generation technologies

Power generation technologies	Investment costs ($/kW)		
	2015	2020	2030
Coal power plant	1,411	1,390	1,356
PV (Photovoltaics) power plant	1.817	1,682	1,305
Solar thermal plant	5,787	4,705	3,799
Wind turbine offshore	5,631	3,876	3,072
Wind turbine onshore	1,519	1,316	1,305

Source: 100% RENEWABLE ENERGY FOR BANGLADESH (2019) (INSTITUTE FOR SUSTAINABLE FUTURES University of Technology Sydney)

Table 2.4-3 Operation and maintenance costs for power generation technologies

Power generation technologies	Operation and maintenance costs ($/kW/year)		
	2015	2020	2030
Coal power plant	30.8	29.7	29.7
PV (Photovoltaics) power plant	38.7	21.9	15.4
Solar thermal plant	350.9	270.0	233.8
Wind turbine offshore	209.5	1645.5	133.6
Wind turbine onshore	56.5	55.9	56.8

Source: 100% RENEWABLE ENERGY FOR BANGLADESH (2019) (INSTITUTE FOR SUSTAINABLE FUTURES University of Technology Sydney)

Table 2.4-4 summarizes the results of the study of power generation methods based on the project site. In Bangladesh, the introduction of PV power generation, wind turbine can be expected in the future from the viewpoint of cost. However, it is difficult to secure sufficient power within the project site. As a result, it is judged that the construction of thermal power plant is appropriate.

Table 2.4-4 Consideration of generation method in the project site

Item	No action	Renewable energy			Thermal power generation
		Hydro power generation	PV power generation	Wind power generation	
Power supply	－	×	－	－	＋
Land acquisition	＋	×	－	－	＋

in case of BAU, 3.5 times (compared to 2015) in case of 2℃-rise ,referring to various statistic reports. Electricity demand will also achieve 380TW/year in 2050. Bangladesh has abundant potential area for renewable energy such as PV, Wind farm. In case of PV it is 6,250km2(156GW), in case of wind farm is 3,200km2(150GW). Renewable energy will be the important role in this country and will increase in future. Until 2030, the development of power plants will mainly be the power plants that use fossil fuel. But after 2030, the development of power plants will move that of renewable energy due to saving money for fuel procurement. This movement will give influence against thinking of electricity network, and renewable energy become widely use in private sector.

Economical (Cost)	−	×	±	±	＋
Natural/Social Environment	±	×	±	±	−

Note:

1) If the project is not implemented, there will be loss of employment opportunities. As relative comparison, ＋: superior, ±: medium, −: inferior, ×: non-matching.
2) Regarding Economical (Cost) of PV power generation; ±, investment cost and maintenance cost will be decreased in future. But it is necessary to consider that photovoltaic power generation need power storage system for nighttime power supply.
3) Regarding Natural/Social Environment for Thermal power generation, please refer detailed study in Chapter 13. As the result, it was judged “Thermal power generation” inferiors to “Renewable energy” from impact concerning air/water pollution.
4) The detailed result of “No action” is as below.

Item	Positive impact	Negative impact
Power supply Economical (Cost)	N/A	・It cannot correspond future electricity demand in Bangladesh.
Natural/Social environment	There are no impact concerning air/water pollution and so on.	・When any developments of coal fired power plant will be planned in other areas, it may not be sufficiently corresponded environmental countermeasures. Moreover, in case CO_2 emission intensity is higher than this project, CO_2 emission amount will increase. ・It may occur land acquisition and resettlement in case of developments of coal fired power plant planned in other areas. ・It may lose job opportunity, not creating new business.

Source: Study Team

(2) Comparison with thermal power generation method

Regarding primary energy consumption for electricity in Bangladesh based on World energy balance (International Energy Agency), as shown in Figure 2.4-7, gas-fired power generation is 89%, oil-fired power generation is 9% and coal-fired power generation is 2%.

About gas-fired power generation, the amount of domestically produced natural gas depends on 60% of power generation. And the domestically production amount of natural gas has peaked, and Bangladesh has been importing expensive LNG from 2018.

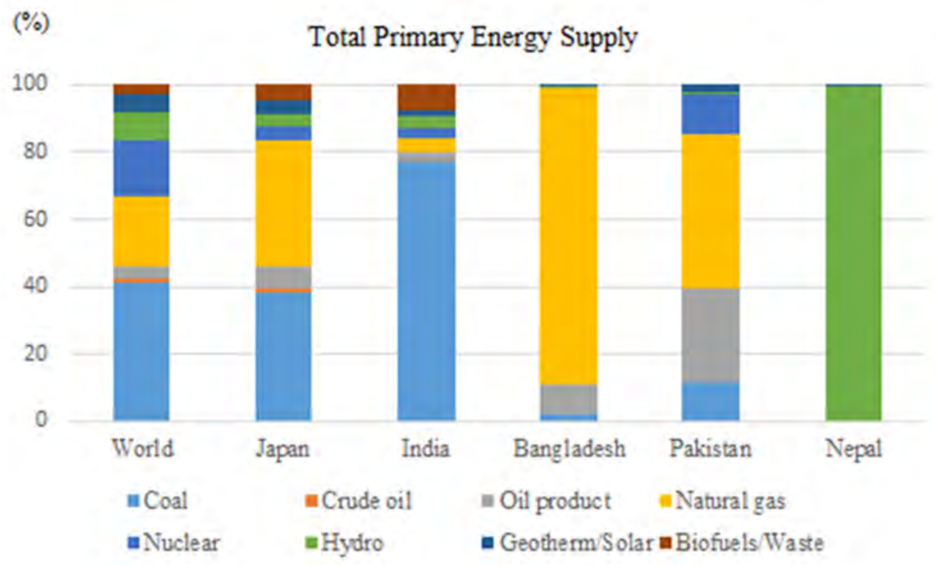
This raises concerns about the risk of energy security problems such as power supply shortages and rising fuel supply costs due to fuel shortages.

7th Five Year Plan [FY 2016-FY2020] (Government of the People’s Republic of Bangladesh) states that unstable power supply is a constraint on economic growth.

8th Five Year Plan [2020-2025] (Government of the People's Republic of Bangladesh) also states that the electricity sector will continue to be the main sector of gas consumption and will face strategic challenges. Therefore, from a medium-term perspective, it can be said that the introduction of coal-fired power plants is an effective option.

When considering the introduction of gas-fired power generation in the project site, it may be necessary to consider land acquisition for the equipment for gas-fired power generation, such as the gas pipeline, gas storage equipment on underway the construction of Units 1/2.

Therefore, considering the situation in Bangladesh, from necessary to diversify the power source composition and the possibility of new land acquisition, coal-fired power generation is desirable.



Source: Study Team

Figure 2.4-7 Primary energy consumption for electricity (2017)

As mentioned above, while the construction of coal-fired power generation facilities for Units 1/2 project is progressing, it is possible to carry out the project on the same site without the need for new land acquisition (in other words, time, labor and expenses related to land acquisition are not incurred), and the project will proceed with the technical backing of the preceding Units 1/2 project, so coal-fired power generation will be selected for this case.

The Intended Nationally Determined Contributions (INDC) (September 2015) stipulates that technology (Ultra Super Critical) above supercritical pressure will be used in the construction of new coal-fired power plants on condition of financial support.

And Nationally Determined Contributions (NDCs) (26 August 2021) also states “Coal power plant with Ultra super critical technology 12,147MW”.

In addition, CO_2 emission of the project is estimated 7,319,280 t-CO_2/y. If CO_2 emission based on operation by coal-fired power plants in Bangladesh instead of this project is estimated 9,890,606 t-CO_2/y. The difference of both values is 2,571,327 t-CO_2/y. As a result, it is deemed contribution by implementation of this project is reasonable. Potential reduction ratio is 26.0%. It is confirmed the contribution of CO_2 emission efficient by this project adopted advance technology is guided.

Table 2.4-5 shows the results of comparative studies on thermal power generation. For comparison, we organized them from the viewpoints of location, electricity demand, economy (cost), technology (power generation method), and natural / social environment.

Table 2.4-5 Analysis of alternatives

Item	Consideration	Gas fired power plant	Coal fired power plant
Location	Securing the site	± (−)	+
Power supply	Responding to increasing power demand and energy diversification	+	+
Economical (Cost)	Situation surrounding the power sector and power generation costs	−	+
Technology	Power generation technology development trends and their feasibility	+	+
Natural/Social environment	Impact on the surrounding environment, necessity of relocation of residents, etc.	±	−

Note; As relative comparison, ＋: superior, ±: medium, －: inferior
Source: Study Team

2.5 Conclusion

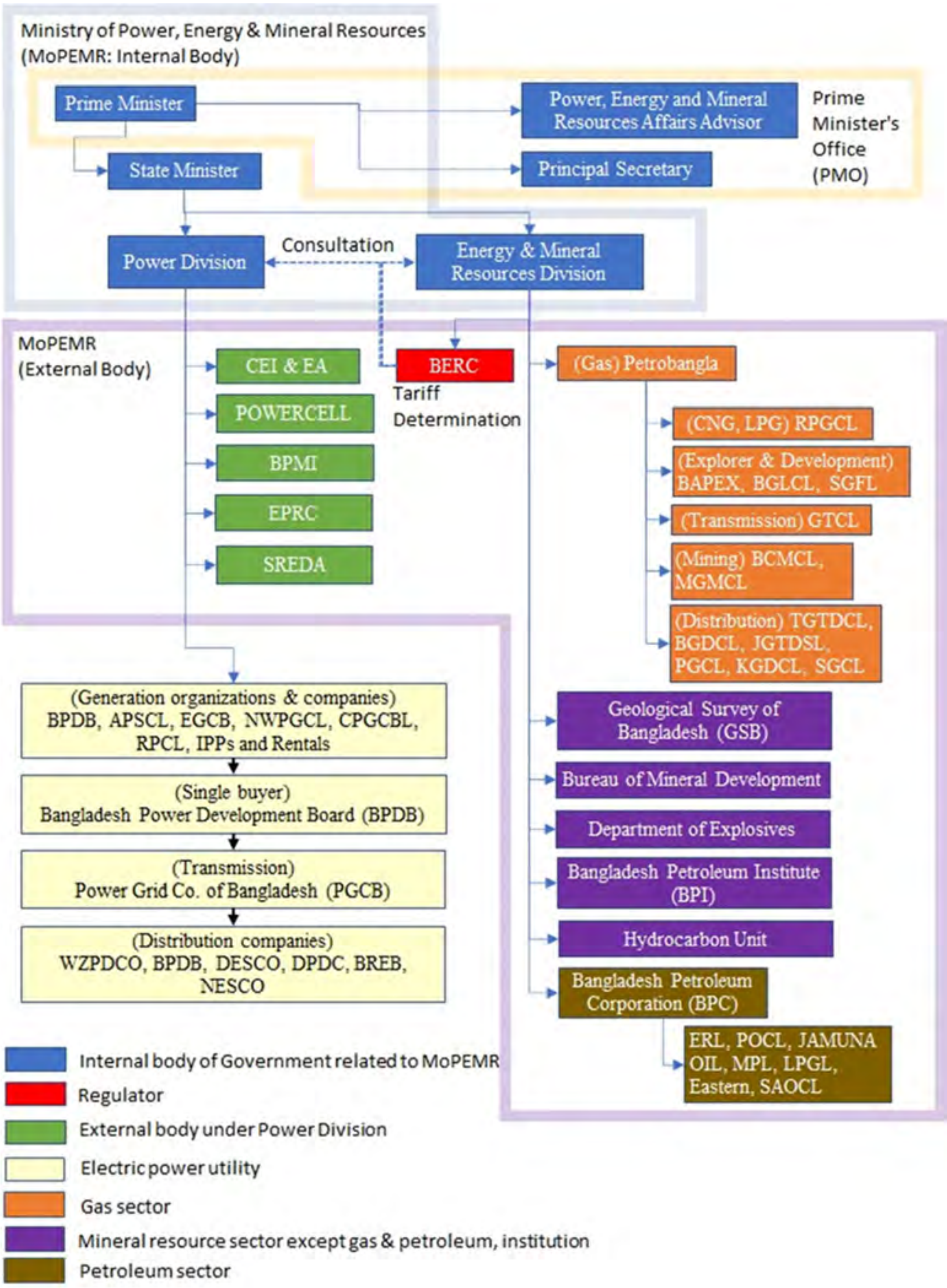
As the result of arranging as follows concerning above-contents explained, it was concluded that it is necessary to introduce ultra-super critical coal-fired power plant with flexible load technology in this project.

(1) It is necessary to systematically develop new power sources in consideration of the increase in electricity demand in the country and the abolition of aging thermal power generators.
(2) Bangladesh's policy on thermal power generation indicates the introduction of inexpensive energy, diversification of fuels, and the introduction of high-efficiency technology for thermal power generation.
(3) Bangladesh government is actively confronting climate change countermeasures, and as part of this, has announced the review of development plan of the coal-fired power plants on June 27, 2021. Development projects of 10(ten) coal-fired power plants have been canceled, but Units 3/4 project is not included in this. And this project is not included in the "List of Suspended Coal Based Power Project" which is determined by Power Division as well, then this project will be developed.
(4) It was confirmed with the DoE that the latest NDC has been submitted to the UNFCCC on 26 August 2021 which has included this project.
(5) In Bangladesh, renewable energy centered on solar and wind power has been planned to be introduced. Considering the case of the largest introduction of renewable energy or the daily load curve, it is necessary to secure electricity generating capacity by thermal power in 2030 and 2041.
(6) Furthermore, from the viewpoint of ensuring the quality of electricity (frequency, voltage) and protecting equipment, the generator using a conventional rotating machine (synchronous generator) is required for the time being. It is also necessary to secure electricity generating capacity by thermal power in the case of Bangladesh.
(7) Even electricity is also supplied by utilizing storage batteries during times when electricity cannot be supplied by renewable energy, it is necessary to secure electricity of thermal power generation in order to cover the supply capacity. However, the introduction of storage batteries will contribute to certain reduction in the introduction of thermal power equipment.
(8) While renewable energy is expanding, if storage batteries are not sufficiently maintained, it will be necessary to follow the demand from thermal power generation (supply and demand adjustment ability) according to changes in the output of renewable energy. The larger increase of the introduction of renewable energy, it will be required thermal power generation with supply and demand adjustment capacity with high and large output change rate. In terms of the coal fired power plant, the power plant with Flex-USC technology which meets requirements for them is desirable.
(9) The total site area of the Unit 1/2 project and this project is about 700ha, of which the site area of this project is about 60ha. The site area is 5,333ha (53km^2) if procuring the electric power equivalent of this project by solar power generation, and 41,400ha (414km^2) (on land) and 16,600ha (166km^2) (offshore) in the case of wind power generation. Therefore, substitution by renewable energy is difficult in reality.
(10) Currently, most of the primary energy consumption for electricity in Bangladesh is thermal power generation, of which gas-fired power generation accounts for 90%*. Because LNG has been importing from 2018, there are concerns from the perspective of energy security. Furthermore, regarding the site planned, construction for Units 1/2 project has already started, and in the case of gas-fired power generation, it is necessary to install new gas receiving equipment, gas storage equipment, etc.,. And it may occur new land acquisition.
* According to BPDB annual report 2020-21, gas-fired power generation accounts for 60.19%.

Chapter 3 Overview of Energy sector and Power sector

3.1 Structure of Energy sector and Power sector

In the 8th 5 Year Plan which is following 7th 5 Year Plan, Bangladesh's energy sector and power sector are cited as the most important infrastructure, and the Honorable prime minister is the Minister of Ministry of Power, Energy & Mineral Resources. An Advisor related to energy and power is placed in the prime minister's office (PMO) to take care of the energy and power sectors. And a state minister is placed for practical work of Ministry of Power, Energy & Mineral Resources. Figure 3.1-1 shows organogram of the Energy and Power Sector under the prime minister.



Source: Study Team from MoPEMR website

Figure 3.1-1 Overview of Energy and Power Sector under MoPEMR

3.1.1 Ministry of Power, Energy and Mineral Resources: MoPEMR

MoPEMR is an important ministry which makes and implements policies for power, energy and mineral resources. The Energy & Mineral Resources Division and Power Division are placed under MoPEMR. The Energy and Mineral Resources Division is responsible for the policy and management related to an import and storage of oil and LNG, distribution and retail of gas and oil with its tariff. And the Power Division is responsible for the policy and management related to electric power from generation to distribution and retail.

(1) Energy and Mineral Resources Division

The Energy and Mineral Resources Division is responsible for energy policy and develops comprehensive and integrated energy development plans from the short-term to the long-term. The division has jurisdiction over organizations and companies related to gas, petroleum and mineral resources, which are external entities. As described before, the development of long-term plan for primary energies is the challenge for the energy and mineral resources division.

In 2006, the Gas Sector Master Plan (GSMP) was developed with support from The World Bank, and an updated one was announced officially in 2017. As of now, there is no update plan for GSMP according to the information from Petrobangla.

(2) Power Division

Power Division is responsible for generation and transmission, and distribution business. Its scope covers coordination with other divisions and ministries to promote public-private partnerships (PPP), private investment, rural electrification, renewable energy, and energy efficiency and conservation. The target utilities (Generation, Transmission and Distribution) under Power Division are as follows:

- Bangladesh Power Development Board (BPDB)
- Bangladesh Rural Electrification Board (BREB)
- 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)
- Power Grid Company of Bangladesh Limited (PGCB)
- Electricity Generation Company of Bangladesh Limited (EGCB)
- Ashuganj Power Station Company Limited (APSCL)
- North West Power Generation Company Limited (NWPGCL)
- Rural Power Company Limited (RPCL)
- Coal Power Generation Company Bangladesh Limited (CPGCBL)
- B-R Powergen Limited

3.1.2 Bangladesh Energy Regulatory Commission: BERC

BERC was established in 2003 in accordance with the BERC Act 2003. BERC is responsible for management and operation and tariff decision of the power and domestic natural gas and petroleum sectors, and the rules and regulations related to these sectors are enacted by BERC. The board consists of a chairman and four members (Admin & Finance, Gas, Power, Petroleum). The commission protects consumers' and industries' interests, and promotes a competitive market, and the BERC Act 2003 sets the functions of the commission as per the below.

(1) to determine efficiency and standards for the machinery and appliances of institutions using energy and to ensure through energy audits the verification, monitoring and analysis of energy, and its economic use and the enhancement of its efficiency;
(2) to ensure efficient use and, quality services, determine tariffs and enhance the safety electricity generation and transmission, and energy-related marketing, supply, storage and distribution
(3) to issue, cancel, amend and determine conditions of licences, provide exemption for licences and to determine the conditions to be followed by such exempted persons;
(4) to approve schemes on the basis of the overall program of the licencee and to make decisions in this regard taking into consideration the load forecast and financial status;
(5) to collect, review, maintain and publish statistics on energy;
(6) to frame codes and standards and make enforcement of those compulsory with a view to ensuring quality of service;
(7) to develop uniform methods of accounting for all licencees;
(8) to encourage the creation of a congenial atmosphere to promote competition amongst the licencees;
(9) to extend co-operation and advice to the Government, if necessary, regarding electricity generation and, transmission, and energy-related marketing, supply distribution and storage;
(10) to resolve disputes between the licencees, and between licencees and consumers, and refer these to arbitration if considered necessary;
(11) to ensure appropriate remedies for consumer disputes, dishonest business practices or monopolies;
(12) to ensure control of environmental standards for energy under existing laws; and
(13) to perform any incidental functions if considered appropriate by the Commission for the fulfillment of the objectives of this Act for electricity generation and energy transmission, marketing, supply, storage, efficient use, service qualities, tariff fixation and safety improvement.

The BERC Act 2003, Chapter 7 Article 34 Tariffs (1) says that 'Notwithstanding anything contained in any other law for the time being in force, the price of power generation in wholesale, bulk and retail, and the supply of energy at the level of end-user, shall be determined in accordance with the policy and methodology made by the Commission in consultation with the Government:'.

Currently, the Energy & Mineral Resources Division determines the tariffs for petroleum, except LPG. The tariff for LPG is determined based on market price. However, some regulations for consumer protection are to be adopted. And in 2016, BERC established Feed-in Tariff (FIT) regulations to promote renewable energy taking responsibility for the following two points.

- Establishment of regulations and standards for high quality power supply
- Energy efficiency for generators and energy audits and the establishment of standards for these

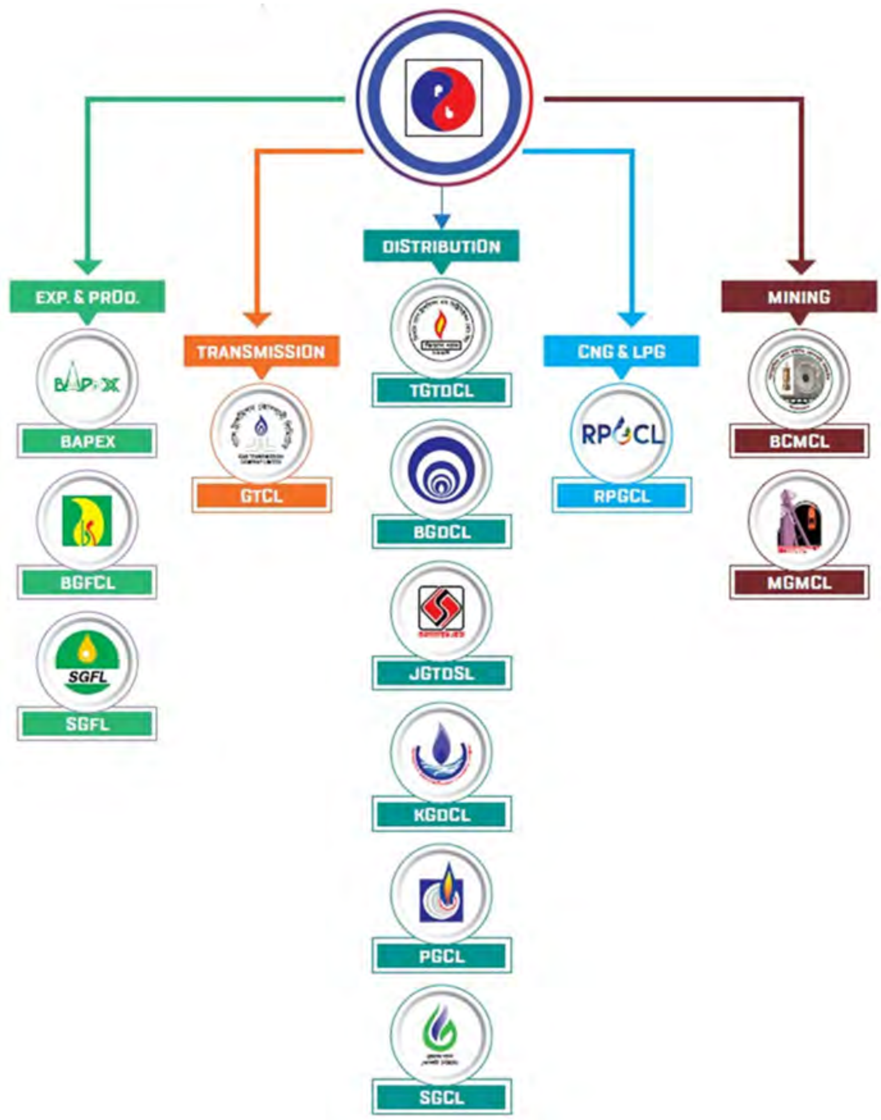
3.1.3 Overview of Energy Sector

The energy sector consists of organizations and public companies in which gas and petroleum and mineral resources are managed and operated under the Energy and Mineral Resources Division. Petrobangla explores and develops domestic natural gas, and produces and sells compressed gas and coal. Bangladesh Petroleum Corporation (BPC) manages petroleum (crude oil and petroleum products), and imports, refines and sells these products. These two groups have many subsidiaries. (Please refer to Figure 3.1-1)

(1) Petrobangla (Bangladesh Oil, Gas & Mineral Corporation)

Petrobangla is a public company which is operated as statutory authority based on the Bangladesh Oil, Gas and Mineral Corporation Ordinance, 1985, and Bangladesh Oil, Gas and Mineral Corporation (Amendment) Act, 1989. There are 13 public company affiliates related to natural gas and CNG & LPG and coal under Petrobangla, and Petrobangla holds 100% of the share of stocks of these companies, except TGTDCL (Titas Gas Transmission and Distribution Company limited).The holding rate of TGTDCL's share by Petrobangla is 75%, and the detail is shown in Table 3.1-1. The breakdown of 13 public companies is three exploration and production companies, one transmission company, six distribution (ten gas-related companies in total) companies, and one CNG & LPG company, and two mining (coal and granite) companies (Figure 3.1-2). Although these companies are making profit, they pay a part of profit for exchequer. Petrobangla is entrusted with management function related to gas and petroleum business from the government, and responsible for management not only for the own business but also for the affiliated business.

The board of Petrobangla as of March 2021 consists of one chairman and eight Directors.



Source: Petrobangla Annual Report 2019-20

Figure 3.1-2 Energy-related utilities under Petrobangla

Table 3.1-1 Shareholders of TGTDCL

SI.No.	Share Percentage	Category Holding	No. of Shareholders	Total Share Holding	% of Holding
1	Government (75%)	Petrobangla	1	741,916,371	75.00
2	Public (25%)	Foreign	20	17,469,215	1.77
		Institutions	346	142,858,709	14.44
		Individual & Joint	14,637	86,977,536	8.79
		Total	15,004	989,221,831	100.00

Source: TGTDCL website

In terms of domestic gas production, Bangladesh Petroleum Exploration and Production Company Limited (BAPEX), and Bangladesh Gas Fields Company Limited (BGLCL), and Sylhet Gas Fields Limited (SGFL) produce gas, and ChevronTullow which are International Oil Company (IOC)[1] sells produced gas in Bangladesh to Petrobangla through PSC (Product Sharing Contract).

In terms of LNG, Rupantarita Prakritik Gas Company Limited (RPGCL) is entrusted with the management and operation work from Petrobangla. Petrobangla made the Sales Purchase Agreement (SPA) for long-term procurement with gas companies in Qatar and Oman, and LNG acceptance and LNG supply to the gas system had started through two floating storage and re-gasification units (FSRU) established in August 2018 and April 2019. In addition to SPA, Petrobangla is implementing use of spot market, and Petrobangla entered into Master Sales Purchase Agreement (MSPA) with 14 short listed utilities or traders. In September 2019, the first LNG through the spot market for the country had been accepted. The use of the spot market is to secure cheaper price LNG. However, after the acceptance of the first spot LNG, the spot LNG was canceled in November because spot LNG price has been increasing and reached the price same as SPA.

Next LNG development plans are onshore LNG terminal in Matarbari and, pipeline from India in 2022. No additional FSRU is planned to be built.

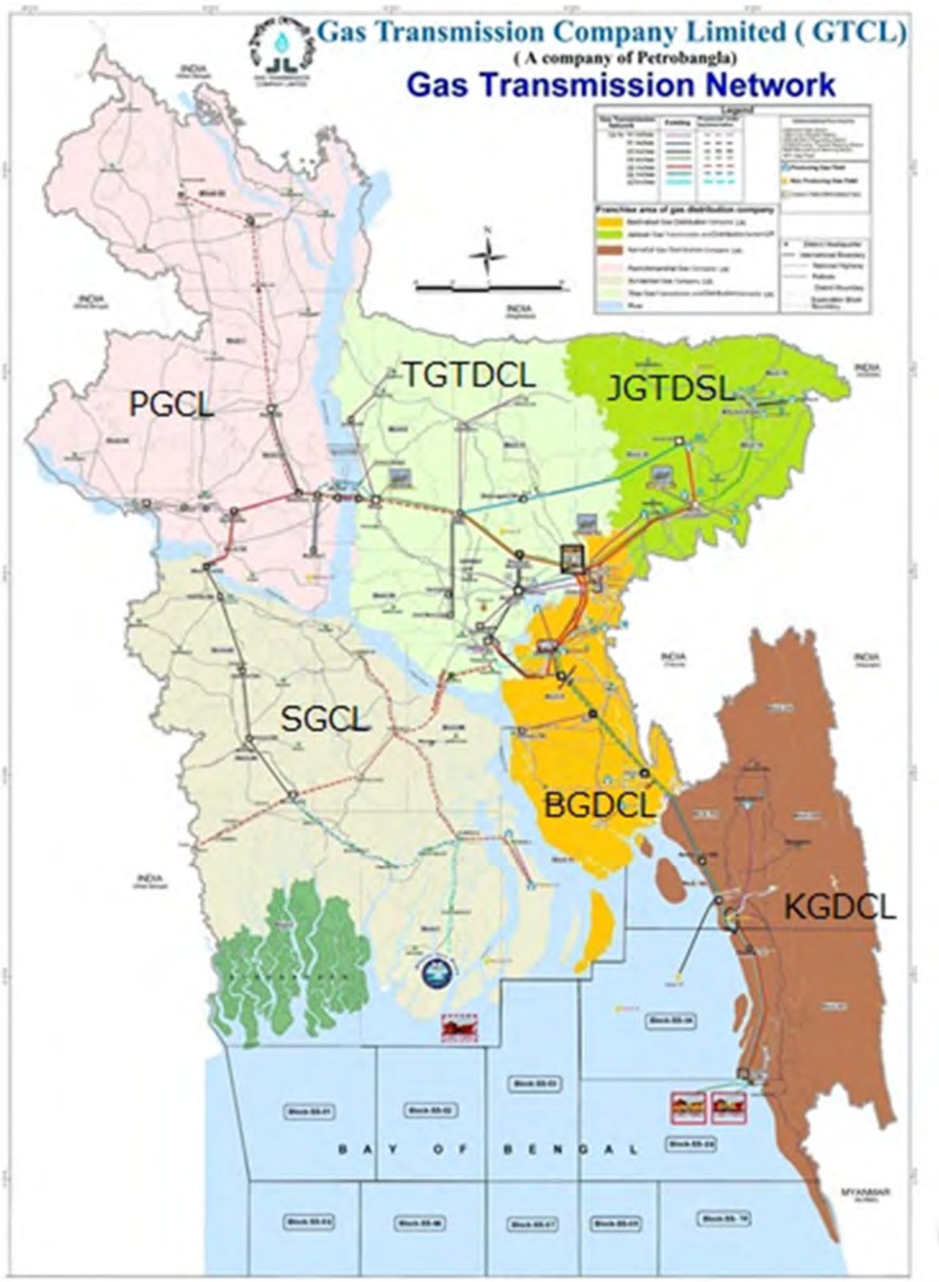
In terms of gas transmission from gas field to gas distribution companies, Gas Transmission Company Limited (GTCL) is responsible for it. GTCL is also responsible for transmission of regasified LNG.

In terms of gas distribution business, following 6 companies are responsible for it.

1) TGTDCL (Titas Gas Transmission and Distribution Company limited)
2) BGDCL (Bakhrabad Gas Distribution Company Limited)
3) JGTDSL (Jalalabad Gas Transmission and Distribution System Limited)
4) KGDCL (Karnaphuli Gas Distribution Company Limited)
5) PGCL (Pashchimanchal Gas Company Limited)
6) SGCL (Sundarban Gas Company Limited)

Figure 3.1-3 shows the gas transmission system and the distribution areas.

[1] The international 4 majors of Chevron, Cairn, Niko, Tullow



Source: GTCL website
Figure 3.1-3 Gas transmission system and the distribution areas

In terms of coal, Barapukuria Coal Mine Company Limited (BCMCL) is the only mine in operation in Bangladesh. BCMCL enters into "Management, Production, Maintenance & Provisioning Services (MPM&P)" with XMC-CMC which is joint venture company of Xuzhou Coal Mining Group and China National Machinery Import and Export Corporation (CMC). BCMCL had offered competitive bidding two times in the past, and XMC-CMC won both of the competitions.

The coal sales price for BPDB is shown in Table 3.1-2, and the price had been increasing due to increase in production cost and management cost. The coal price is calculated from the production cost and management cost, and decides by the board of BCMCL. The person from the power division and BPDB is included in the board members, and the price decision means the approval of the government.

Table 3.1-2 Coal sales price for BPDB

S.N.	DATES ON WHICH PRICES FIXED	PRICE OF COAL INCLUDING VAT/TON (US$)
1	01 July 2017	130.00 (VAT Exempted)
2	01 May 2015	131.50
3	01 February 2012	106.50
4	July 2010	85.50
5	July 2008	71.50
6	29 May 2001	61.50

Source: BCMCL website

(2) Geological Survey of Bangladesh (GSB)

The source is the "Geological Survey of India" established in 1851 by the government of the Indian Empire. In 1947 when Pakistan was divided from India, Geological Survey of India was changed into Geological Survey of Pakistan, and the regional office was established in Dhaka. After that, in 1971 when the country became independent, it became Geological Survey of Bangladesh (GSB), and GSB became the permanent organization properly in 1980. The responsibilities of this organization are the explorations of the mineral resources except gas and petroleum, and the researches in various fields of geoscience.

(3) Bureau of Mineral Development (BMD)

Established in 1962 as the organization of the state government under the Industries and Minerals Division of the government of Pakistan. The organization is responsible for the granting exploring license and mining lease, quarry lease except gas and petroleum, and the makes profit from them.

(4) Department of Explosive (DE)

The department is responsible for the management of the explosive materials, petroleum, flammable materials, high pressure gas pipelines, cylinders, and the prevention of the gas leakages. Concretely speaking, the department secures the safety and manages the licenses for the production, process, refine, import, storage, transportation/storage of the explosive materials, compressed natural gas (CNG), liquefied petroleum gas (LPG), the flammable liquids including petroleum, flammable solids including calcium carbide, harmful substances such as oxidants.

(5) Bangladesh Petroleum Institute (BPI)

The institute provides the training for the experts and the engineers engaged in the oil sector, and implements the research on the development of hydrocarbons (gas). The training courses such as the geology, geophysics, geochemistry, petroleum engineering, drilling engineering, logging, pipeline engineering, oil management, gas transmission and distribution, accounting, and finance are prepared. Established in 1981.

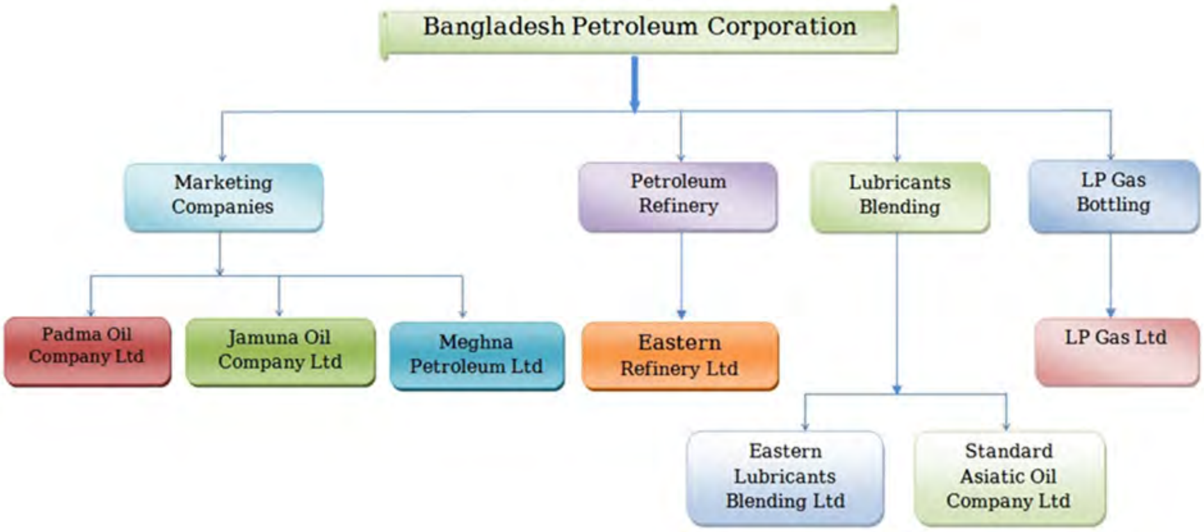
(6) Hydro Carbon Unit (HCU)

HCU collects analyses the data related to the stable supply of the primary energy, and provides technical recommendation to energy and mineral resource sector regarding development of gas and petroleum and mineral resources sector and products related to them. And the unit is making opinions and comments to international and local organizations regarding various issues related to energy sector. The unit is technical organization which was established in 1999 with the support from the government of Norway.

(7) Bangladesh Petroleum Corporation (BPC)

BPC is a public entity which manages the import of crude oil and petroleum products almost exclusively.

BPC has 7 public corporation affiliates; one refining, three sales, one LPG bottling (sales are private) and two petroleum products blending corporations (Figure 3.1-4). The shareholders of each company are shown in Table 3.1-3. BPC has 100% shares of Eastern Refinery Ltd and LP Gas Ltd, and around 50% shares of remainders. BPC is entrusted with agreement and making contract related to the import and storage and sales, and responsible for the work and the management of utilities under BPC. The board consists of one chairman and two directors and two joint secretaries (Energy & Mineral Resources Division and Finance Division, Ministry of Finance).



Source: BPC website

Figure 3.1-4 Petroleum related utilities under BPC

Table 3.1-3 Shareholders of utilities under BPC (As of September 2019)

SL NO	Subsidiary Company Name	Capital (Crore TK)		Ownership	Main Responsibility
		Approved	Paid up		
1.	Padma Oil Company Limited	100.00	98.23	BPC 50.35% Government finance companies and Private organizations 45.65%	Storage, supply and marketing of petroleum products
2.	Meghna Petroleum Limited	400.00	108.22	BPC 58.67% Private persons / organizations 41.33%	Do
3.	Jamuna Oil Company Limited	300.00	110.42	BPC 60.08% Private persons / organizations 39.92%	Do
4.	Eastern Refinery Limited	500.00	33.00	BPC 100%	Crude oil refining and production bitumen
5.	LP Gas Limited	50.00	10.00	BPC 100%	LP Gas Bottling & Distribution
6.	Eastern Lubricants Blending	5.00	0.994	BPC 51.00% Government finance companies and Private organizations 49.00%	Production Lubricating Oil
7	Standard Asiatic Oil Company Limited	0.50	0.1976	BPC 51.00%, Private 50%	Production Lubricating Oil

Source: BPC website

BPC has large deficit because formerly, petroleum products had been sold in cheaper price than import price. Although the deficit as of June 2015 was 468.9 billion Tk, the deficit as of June 2019 decreased to 144.9 billion Tk, because BPC has been made around 50 billion operating profit in recent years. And apart from the profit, BPC has been paying the exchequer every year.

3.1.4 Overview of Power Sector

The power sector is managed and supervised by the Power Division. The structure of power sector (on grid) is shown in Figure 3.1-5. Formerly, BPDB had managed and operated all electricity business form generation business to distribution business as a monopoly utility. In 1978, Bangladesh Rural Electrification Board (BREB) was established with being separated from BPDB. And then power sector reforms have been implemented since the 1990's.

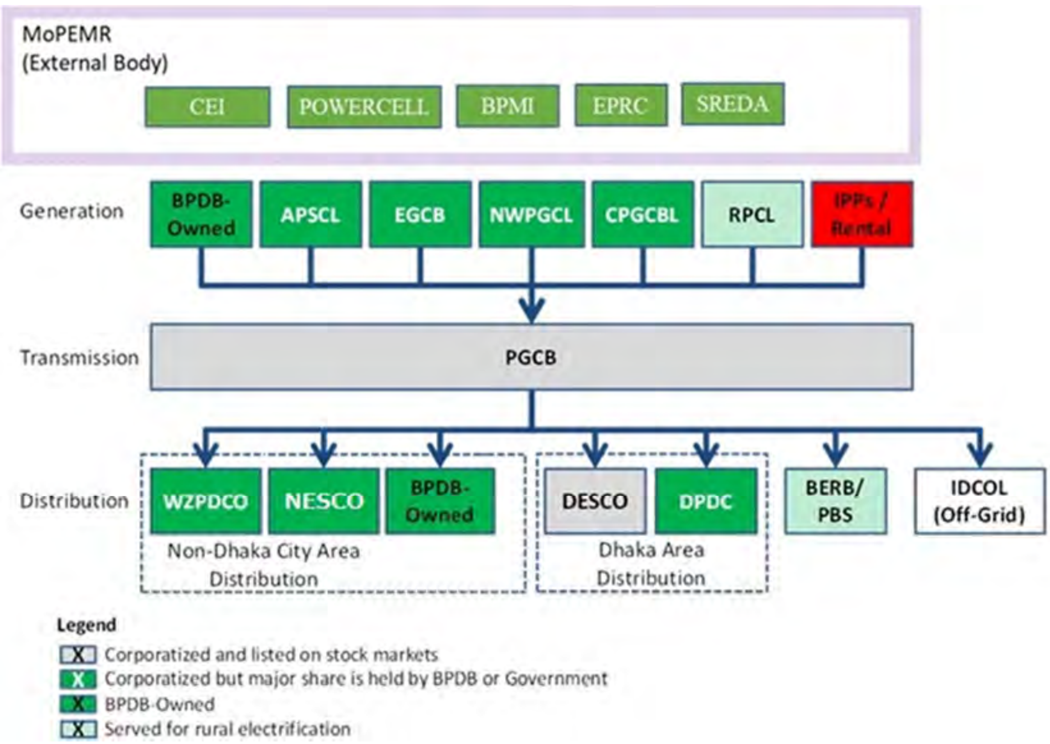
In terms of the distribution sector, Dhaka Electric Supply Authority (DESA) was established in 1991 as public distribution agency in Dhaka area. And Dhaka Electric Supply Company Limited (DESCO) became independent in 1997 with taking over parts of assets from DESA. In 2005, Dhaka Power Distribution Company Limited (DPDC) was established with taking over DESA's all assets and deficit. After that, West Zone Power Distribution Company Limited (WZPDCL) which is responsible for the cities in west area and Northern Electricity Supply Company Limited (NESCO) which is responsible for the cities in north-west area were established. Still BPDB is conducting the distribution business in some cities.

In terms of transmission sector, Power Grid Company of Bangladesh Limited (PGCB) was established in 1996. However, reforming is on the process of implementation. The National Load Dispatch Center (NLDC) which is control the demand- supply balance is placed in PGCB.

In terms of generation sector, Meghnaghat Power Company Limited (MPC) was formed by BPDB in 1996, and the MPC was renamed to Electricity Generation Company of Bangladesh (EGCB) in 2004 and EGCB continues up to today. In 2000, Ashuganj Power Station Company Limited (APSCL) was established with taking over a part of power plant from BPDB. And North West Power Generation Company Limited (NWPGCL) was established in 2007.

In Power Division, the PowerCell was established in 1995 in order to promote power sector reforms and monitor the performances of power sector reforms.

Although corporatizations have been implemented from BPDB which was monopoly national utility, the government and BPDB Officials holds positions on Board of Directors of each corporation, and the government and BPDB hold stocks in these corporations (Figure 3.1-5). PGCB and DESCO participate in the stock market, but the government stock share of PGCB as of 30th June 2020 was 84.64%, and as a result of increase in stock issue in FY2019, the share of BPDB increased than previous fiscal year (Table 3.1-4). As other shareholders of PGCB, RARE Infrastructure Ltd. (Investment Management) and MCB-Arif Habib Savings & Investments Ltd. (Invt Mgmt) and Eurizon Capital SA are named. In terms of DESCO, the government stock share as of 30th June 2020 was 67.63% (Table 3.1-5). As other shareholders of DESCO, Investment Corporation of Bangladesh and Shanta Holdings Ltd. are named. Demerged public corporations are generally performing well.



Source: Study Team from PSMP2016

Figure 3.1-5 Power Sector Structure under MoPEMR

Table 3.1-4 Shareholders of PGCB

Particulars	30-Jun-20		30-Jun-19	
	No. of shares	%	No. of shares	%
Sponsors (BPDB)	603,260,348	84.64	351,446,348	76.25
Institutions (financial & others)	88,060,109	12.36	86,755,354	18.82
Individual	21,406,534	3.00	22,711,289	4.93
Total	**712,726,991**	**100**	**460,912,991**	**100**

Source: PGCB Annual Report 2019-20

Table 3.1-5 Shareholders of DESCO

Category	Number of Shareholder	Number of Shares	% of Total Shares
Government	1	268,866,788	67.63
Institute	274	94,434,297	23.75
Public	5,401	33,505,853	8.43
Foreign (NRB)	41	762,866	0.19
Total	5,718	397,569,804	100.00

Source: DESCO Annual Report 2019-20

In terms of nuclear power development, it is implemented by Ministry of Science and Technology and Bangladesh Atomic Energy Commission, not by MoPEMR, is developing the first nuclear power plant for Bangladesh.

Rooppur nuclear power plant is under construction with support from Russia, and the net capacity is two units of 1,116MW. In the power development plan as of June 2021, the unit 1 is to be started operation in February 2024, and the unit 2 is to be started operation in October 2024.

In 2015, Nuclear Power Plant Company Bangladesh Limited (NPCBL) was established as an operating company.

(1) Chief Electric Inspector (CEI)

In accordance with Electricity Act (1910) article 37, the government established the office of Electric Inspector or other officer. Its purpose is to ensure safety in generation, transmission, distribution, supply, and utilization. In the safety field, the main responsibilities are the approval of connections to the power system at the high and middle voltage levels for big consumers such as factory, and the issuance of certifications for electrical engineers and supervisors, and contract licenses. The office engages in the collection of annual government revenue by collecting license fee which the government has prescribed.

(2) Power Cell

Power Cell is a leading organization in sector reforms, and its activities are widespread. They include creating reform programs, reviewing and revising masterplans, improving desired performance in the sector, institutional design related to the sector to realize optimal development and achieve consumer satisfaction, providing business plans for power companies (including public companies) and advising on the development of human resources, and the development and installation of Management Information Systems (MIS) and IT systems in the sector, and development of telecommunication systems among power companies in the sector, which contributes to the development of the power sector. Power Cell plays the role of in-house consultant for Power Division.

Source: www.powercell.gov.bd

(3) Bangladesh Power Management Institute (BPMI)

BPMI was established in 2017 to develop high-level human resources to promote power system reliability by providing appropriate training. Their target is to be an international standards organization, although the required training facilities are still inadequate due to it being a relatively new institute. The training covers basic training to enhance operational skills and management skills for engineers and executive officers of power sector organizations/corporations, technical/managerial training to develop theorical knowledge and

power system analysis skills for engineers and executive officers of power sector organizations/corporations, and efficiency implementation training for engineers and executive officers of private companies. BPMI aims to expand its responsibilities, in areas such as the provision of advice to Power Division on training and skill development for human resources, convening domestic and international workshops, seminars and symposiums, and building relationships through these meetings, and strengthening networks with similar international institutes.
Source: www.bpmi.gov.bd

(4) Energy and Power Research Council (EPRC)

EPRC provides support for studies regarding energy and power technology, capability development of researchers, motivating parties to start new challenges, publication of research activities and their results through seminars and symposiums and workshops etc., and promotes the creation of innovative technologies regarding energy and power. In order to provide intelligent leadership to seek innovative solutions for the efficient and environmentally sustainable development of energy and power infrastructure, EPRC aims to develop an international online information center to satisfy needs regarding studies on the power sector.
Source: www.eprc.gov.bd

(5) Sustainable and Renewable Energy Development Authority (SREDA)

SREDA was established on the 10th December 2012 in accordance with the SREDA Act. The purpose of the authority is to ensure Bangladesh’s energy security by promoting the installation of renewable energy and energy efficiency. The SREDA Act defines the responsibilities of SREDA, covers the design of energy conservation standards and energy efficiency studies, and the assistance for energy conservation rules and regulations, renewable energy policy, and the acceptance of loans from international finance organizations and has the function of developing energy audit and energy management system as well.

(6) Bangladesh Power Development Board (BPDB)

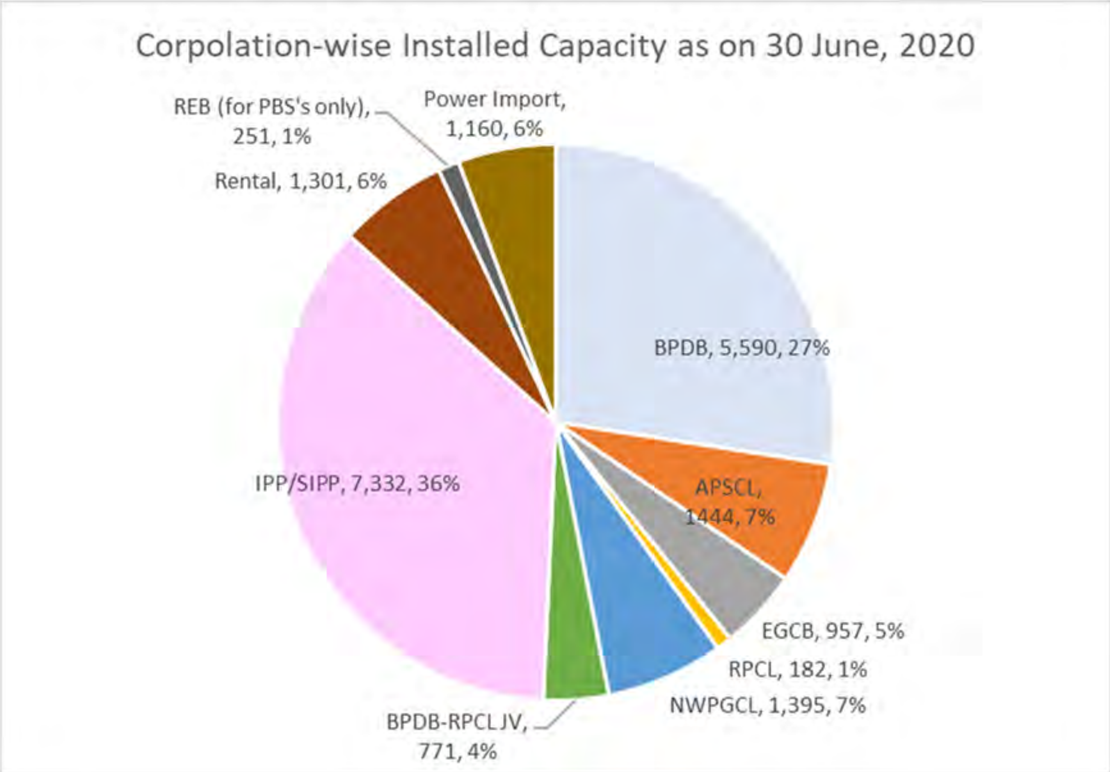
BPDB was initially established as the Water and Power Development Authority in the East Pakistan era, and it became BPDB in 1972, the year following Bangladesh’s independence. At that time, the generation capacity was only 200MW. Sector reform started in full swing in the 1990s, but BPDB was a monopoly power utility until reforming and independence in generation, transmission, and, distribution was implemented. As of 2020, BPDB has a generation capacity of 5,590MW which is 27% of the total, and distribution facilities in some areas whose demand is 15% of total distribution demand. The Board consists of a chairperson and six members, appointed by the government.

BPDB assumes an operating deficit as a single buyer due to below cost electricity tariffs. The volume of this was 4,350 crore BDT as of 30th June 2020. The details are to be described in “3.3.2 Financial Situation”.

BPDB’s distribution networks were reformed and corporatized into public distribution companies in the 1990s to the early 2000s as part of power sector reforms. Two companies in the Dhaka area, and one company in the western region (including Khulna and Barisal), and one company in the northwestern region (including Rangpur and Rajshahi) were established. In the remainder of the regions (north-eastern region including Mymensingh and Sylhet, southern region including Comilla and Chittagong), BPDB continues its ownership ongoingly. BPDB has a plan to establish new distribution companies in their distribution area, but the plan is not implemented due to those who resist corporatization into public distribution companies, mainly workers of BPDB.

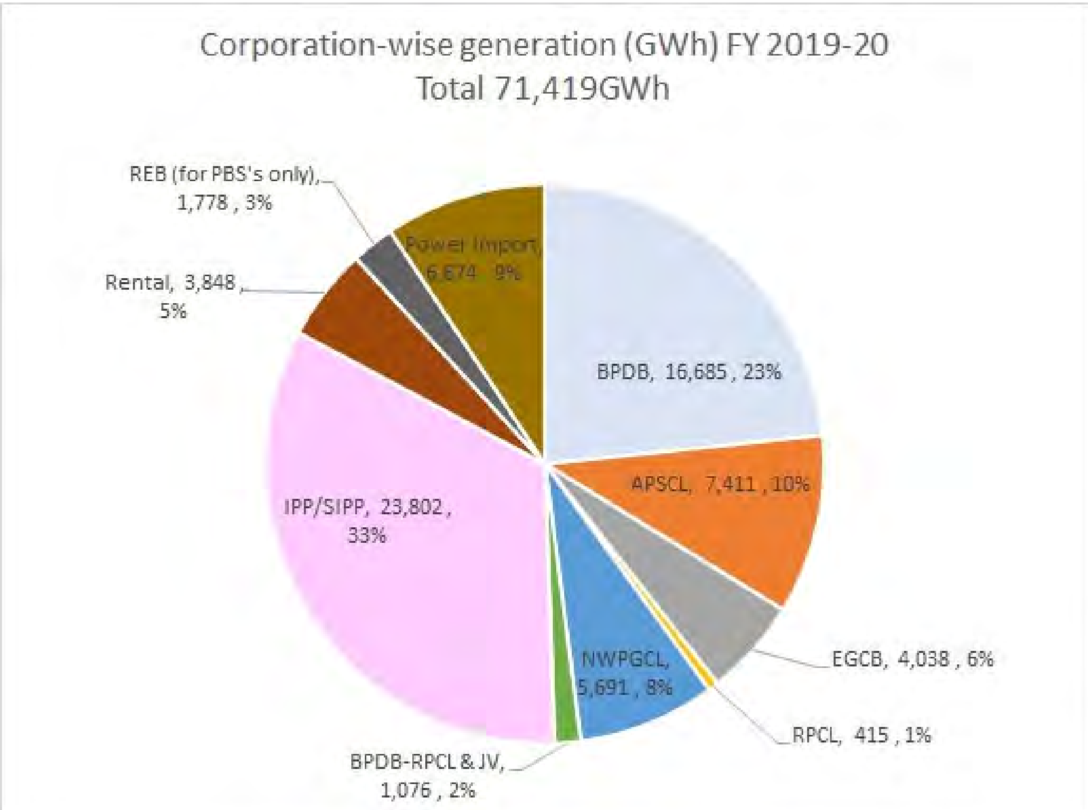
(7) Power Generation Entities

The power generation in Bangladesh apart from BPDB is to be secured by affiliated companies of BPDB and the Independent Power Producers (IPPs), Small Independent Power Producers (SIPPs), Quick Rentals, and the import from India. Figure 3.1-6 shows the utility-wise installed capacity and the ratio as of 30th June 2020, and Figure 3.1-7 shows the utility-wise generation and the ratio in FY 2019-20, and the explanations of each utility are as follows.



Source: BPDB Annual Report 2019-20

Figure 3.1-6 Utility-wise installed capacity and ratio (As of 30th June 2020)



Source: BPDB Annual Report 2019-20

Figure 3.1-7 Utility-wise generation (GWh) and the ratio (FY 2019-20)

(a) Ashuganj Power Station Company Limited (APSCL)

Established in 2000 as a private company. In 2003, APSCL had been reorganized into a public company, and took over assets from BPDB of that year. APSCL is expanding their business and its installed capacity as of 30th June 2020 is 1,444MW. BPDB holds 99.99% stocks, and the remainder of the stocks are held by the government.

(b) Electricity Generation Company of Bangladesh Limited (EGCB)

BPDB established Meghnaghat Power Company Limited (MPC) in 1996, and in 2004, the company name was changed to Electricity Generation Company of Bangladesh Limited, and it continues up to today. The installed capacity as of 30th June 2020 is 957MW. BPDB holds 99.99% stocks, and the remainder of the stocks are held by the government.

(c) North West Power Generation Company Limited (NWPGCL)

Established in 2007. NWPGCL have developed gas combined cycle thermal power stations in Khulna and northwestern region, and challenges to develop renewable energy stations in addition to thermal power stations in response to the increase in power demand. The installed capacity as of 30th June 2020 is 1,395MW. BPDB holds 100% stocks.

(d) Coal Power Generation Company of Bangladesh Limited (CPGCBL)

Established in 2011 as a company which develops and operates mainly coal based power plant. CPGCBL is an executing agency of the JICA-supported Matarbari ultra super critical (USC) coal fired power plant. The board consists of chairman (Secretary of Power Division) and ten directors, and Managing Director of CPGCBL. The board members are selected from various fields such as Power Division, BPDB, Ministry of Finance, NWPGCL, Ministry of Shipping, Federation of Bangladesh Chambers of Commerce and Industry (FBCCI), Bangladesh Supreme Court, PGCB, University of Dhaka.

CPGCBL is operated by the fund and equity from the government and JICA loan, because CPGCBL doesn't have any power station in operation, and no income from power sales. Financial is healthy and the remaining account is about 260 million Tk as of 30th June 2020. BPDB and the government holds 100% stocks of CPGCBL.

The power generation capacity of five power plants including Matarbari coal-fired power plant (Unit 1/2) is 4,900MW in total. But the 1,900MW of coal-fired thermal power plant has been cancelled in accordance with the coal power development policy announced by the government on 27th June 2021. The CPGCBL plans to develop not only coal-fired power plants, but also an LNG fired combined cycle power plant. The power development plan formulated by the CPGCBL is listed in Table 3.1-6. The coal-fired thermal power plant has been decided to be developed for the project (The second row of the Table 3.1-6).

Table 3.1-6 CPGCBL's power development plan

Name of the Power Plant	Developed as a coal power plant (MW)	Developed as an other than coal (MW)	Fuel Type	Ownership	Expected Commissioning Date	Remarks
Matarbari 1200 MW USCPP (Phase 1: Unit 1&2)	1200		I. Coal	CPGCBL	1st unit: January 2024 2nd unit June 2024	•Progress: 42 %
Matarbari 1200 MW USCPP (Phase 2: Unit 3&4)	1200		I.Coal	CPGCBL	December, 2030	• Under Feasibility study
CPGCBL-Mitsui 500-600 MW LNG based CCPP (Phase-1)	600		LNG	JV CPGCBL	2028	•Feasibility done •ESIA study On-going.
	3,000	0				

Source: Study team from BPDB power development plan as of June 2021

(e) Rural Power Company Limited (RPCL)

Established in 1993. Bangladesh Rural Electrification Board (BREB) owns 30% of equity and 13 PBSs (Palli Bidyut Samity: agricultural community electrification union) own the rest. The installed capacity as of 30th June 2020 is 392MW, and aside from this, RPCL has a power plant of 150MW as joint venture project (BPDB-RPCL Powergen) with BPDB.

(f) Independent Power Producers (IPPs), Small Independent Power Producers (SIPPs) and Quick Rentals

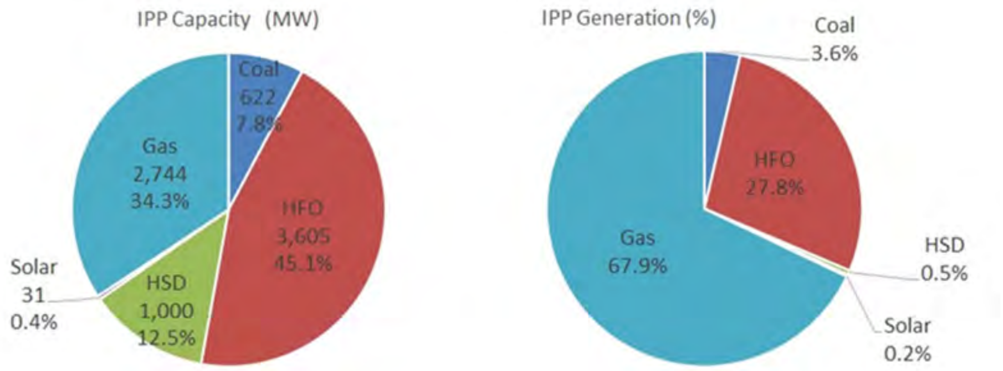
The government is promoting the participation of private sector to the generation business in order to respond to increase in power demand and implement healthy generation business. There are long-term IPP and SIPP as a private generation business, and the number of companies or groups participating as IPP or

SIPP is 39, and the number of power plants is 58, and the total capacity is 7,332MW which is 36% of the total as of 30th June 2020.

Quick rentals are the utilities which supply the power in short-term such as 3 years to 7 years contract. Quick rental power station had increased since 2009 with the government subsidies in response to rapid increase in power demand with fast-track development characteristics, but now they are decreasing due to increase in IPPs. The government declared that quick rental power plants are to be zero by 2024.

IPPs and SIPPs are selected through competitive bidding for the government's public tenders, and the power stations are to be developed and operated by private responsibilities based on Build-own-operate (BOO).

In terms of fuel-wise power plant portfolio, coal fired IPP has started the commercial operation with Chinese support in FY2019-20, and gas fired IPPs and Heavy Fuel Oil (HFO) IPPs whose unit prices are high such as at the 10Tk/kWh level to 20Tk/kWh level are increasing. High Speed Diesel (HSD) IPPs and quick rentals whose generation prices are high are decreasing. (In terms of power generation, refer to 3.3.1 Cost of power generation). Figure 3.1-8 shows fuel-wise IPP capacity and generation in FY2019-20.



Source: Study team from BPDB (Finance)

Figure 3.1-8 Fuel-wise IPP capacity and generation (FY2019-20)

(8) Power Grid Company of Bangladesh (PGCB)

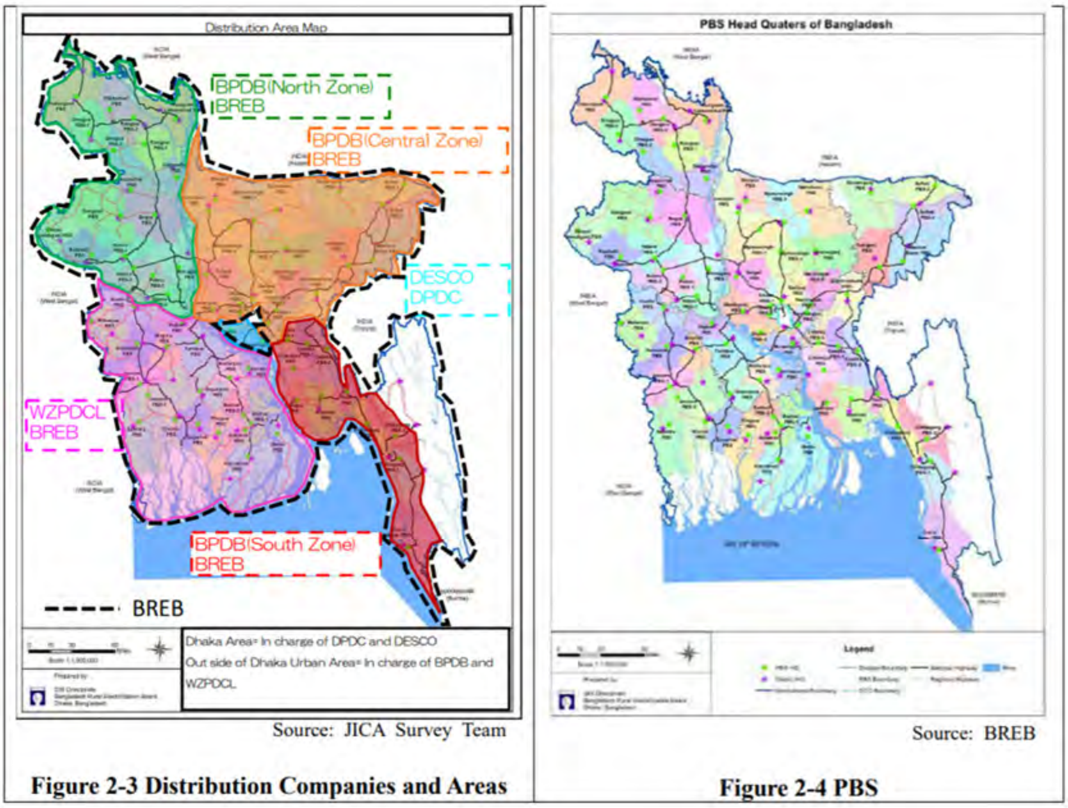
PGCB was established in 1995, as a result of the reforming the power sector. It is the sole transmission company in Bangladesh. As PGCB has the National Load Dispatch Center (NLDC) as its sub-division, PGCB has an aspect of Transmission System Operator (TSO). PGCB is listed on the stock market, but the government owns 80% or more of the shares. PGCB's main assets are 400kV, 230kV and 132kV transmission facilities, and the wheeling charges is the only revenue source.

(9) Distribution Entities and Bangladesh Rural Electrification Board: BREB

There are six urban distribution companies in Bangladesh. DESCO and DPDC are in charge of Dhaka area, WZPDCL is in charge of the western municipalities (including the Khulna and Barisal areas), and NESCO is in charge of the north-west region of Rajshahi Division and Rangpur Division. The rest of the municipal power distribution (Mymensingh, Sylhet, Comilla, and Chittagong areas) is still under BPDB (Figure 3.1-9)

DESCO and DPDC have made significant operational improvement after its corporatization. DESCO outsourced its meter-readers and introduced performance-based compensation and reduced the meter-reader's frauds. System loss of DESCO and DPDC are at the 6% levels, and both billing collection ratios are more than 98%, which is higher than other distribution utilities.

Bangladesh Rural Electrification Board (BREB) was established in 1977, with reference to the US's rural electrification cooperatives. BREB supervise and manages 72 PBS all over in Bangladesh, and monitor the electrification projects of PBSs. BREB also promotes use of electricity to facilitate socio-economic development and improve agriculture in rural areas. The number of BREB's customers (the total contracts of all sectors including industry, commercial and domestic) is more than 30 million, as of December 2020.



Source: PSMP2016

Figure 3.1-9 Distribution Companies and Areas, and PBS Areas

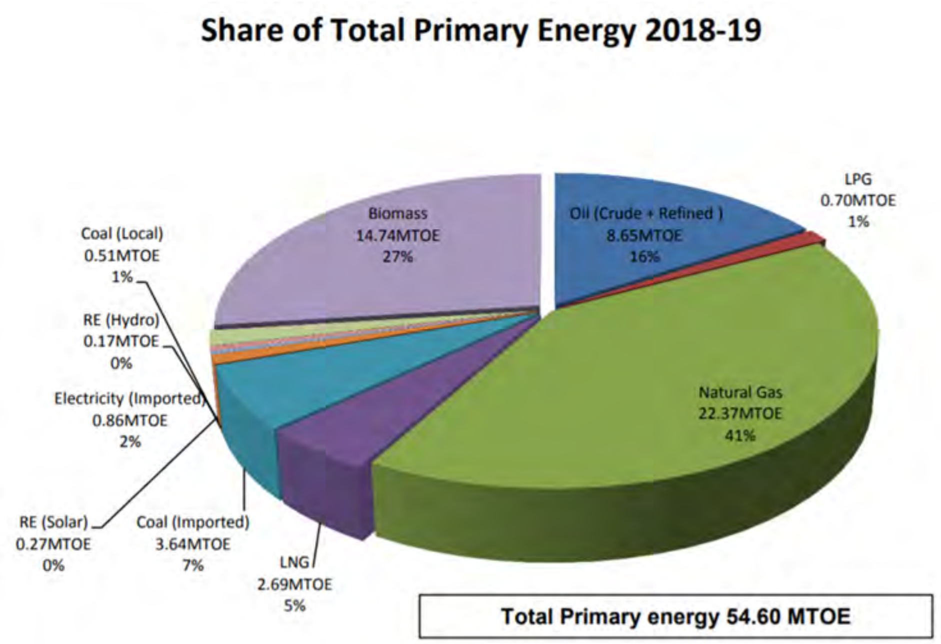
(10) Infrastructure Development Company Limited (IDCOL)

IDCOL was established in 1997 as a non-bank financial institution for infrastructure financing, 100% owned by the government. While IDCOL has financed infrastructure, such as telecommunications, ICT and ports, it has also financed millions of solar home system (SHS) and helped improve access to energy in Bangladesh. IDCOL has also financed renewable energy technologies other than SHS, such as solar irrigation, mini grids, and biogas.

IDCOL appraises projects submitted from “partner organizations (PO)”, and provides subsidy and loan to SHS users. As of 2020, 5.8 million sets of SHS have been installed, and approximately 18 million people (more than 11% of the entire population) have benefited from electricity access.

3.2 Current Status of the Energy Sector

Figure 3.2-1 shows the current state of primary energy supply in Bangladesh. Mainly, natural gas accounts for 46%, coal accounts for 7%, and oil accounts for 16%.

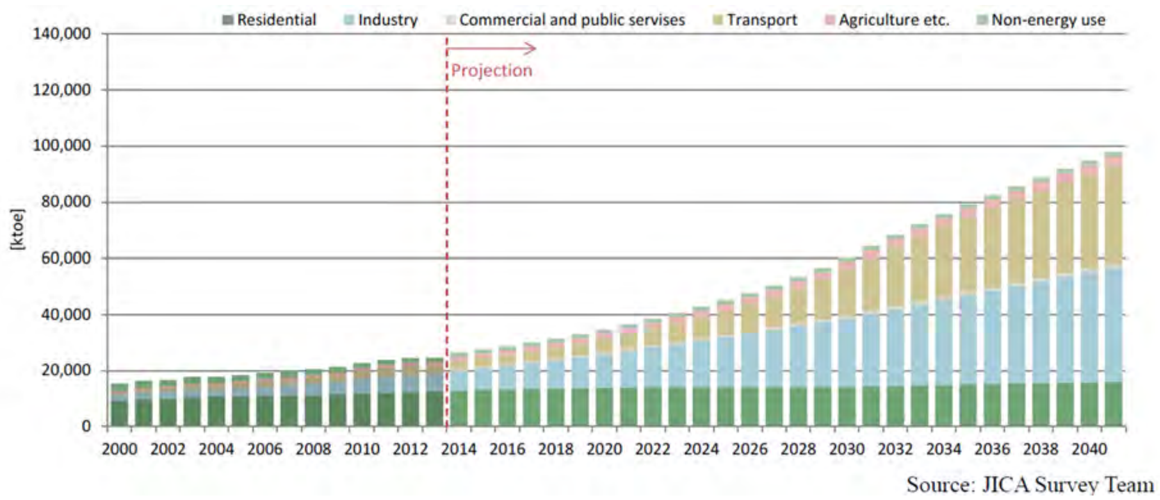


Source: MoPEMR, Energy Scenario Bangladesh 2018-19

Figure 3.2-1 Share of Total Primary Energy (2018-19)

Regarding the energy demand forecast up to 2041, the BAU (Business As Usual) case, which is expected to grow by 6.3% every year, and the energy saving case, which reflects the contents of the 2015 energy saving master plan, are shown in PSMP2016. The measures summarized in the Energy Saving Master Plan have been put into practice, and it is evaluated that the assumption of an energy saving case that energy consumption per GDP will decrease by 20% or more compared to 2014 is close to reality.

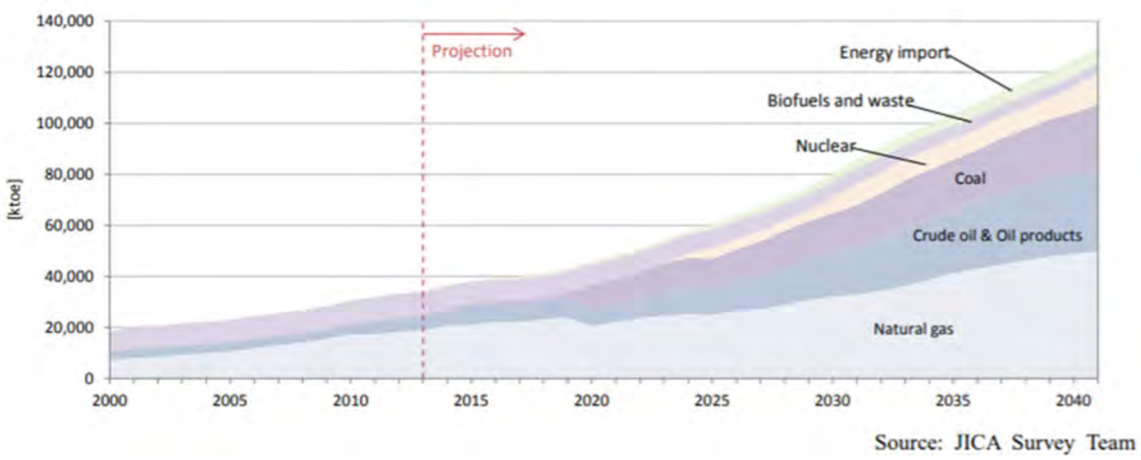
Figure 3.2-2 shows the PSMP2016 energy demand forecast (energy saving case). The economic growth rate is expected to be 4.8% by 2040, and due to the steady growth of industry and transportation, consumption will more than double the current level by 2040.



Source: PSMP 2016

Figure 3.2-2 PSMP 2016 Energy Demand Forecast (energy saving case)

To meet this demand, it is necessary to diversify the energy sources shown in Figure 3.2-3. Diversification of energy sources enables low-cost energy supply.



Source: PSMP2016

Figure 3.2-3 Primary Energy Supply Estimation (Diversification of Energy Source)

In PSMP2016, five scenarios of energy mix are set by changing the ratio of gas power generation and coal power generation as of 2041, and indicators are calculated in terms of economic efficiency, environment, and security, and a comprehensive evaluation is conducted. The results are shown in Table 3.2-1, with Scenario 3 with 35% gas, 35% coal, 15% renewable, 10% nuclear power, and 5% oil and hydropower giving the best rating at US 26 cent/kwh. In the future if the renewable price is less than half the price as of 2014, with gas 25%, coal 25%, renewable 35%, nuclear power 10%, oil / hydropower 5%,it is expected that we will get the same comprehensive evaluation as scenario 3.

Table 3.2-1 3E Evaluation Results for Five Energy Mix Scenarios

	Composition (MW base)	Economy [US cent/kWh]	Environment [US cent/kWh]	Energy Security [US cent/kWh]	Total [US cent/kWh]
Scenario 1	Gas 15%, Coal 55%	11.2	6.6	9.8	27.6
Scenario 2	Gas 25%, Coal 45%	11.6	6.2	8.9	26.7
Scenario 3	Gas 35%, Coal 35%	12.1	5.7	8.2	26.0
Scenario 4	Gas 45%, Coal 25%	12.9	5.0	9.0	26.9
Scenario 5	Gas 55%, Coal 15%	13.7	4.4	10.2	28.2

Source: JICA Survey Team

Source: PSMP2016

Proper low-cost energy supply is essential for fostering a competitive and sustainable industry and for cheap electricity supply. Under the declining domestic gas supply, the introduction of coal-fired power is indispensable in order to achieve an energy mix with the aim of achieving a stable energy supply. Ensuring energy security is also an important goal of a proper energy mix.

This chapter summarizes the current status, challenges and solutions to natural gas, oil and coal, which will play an important role in the future energy mix.

3.2.1 Natural Gas

(1) Current Situation and Issues

Natural gas accounts for 46% of the country's energy, including electricity, fertilizer, industry, commerce and domestic consumption. So far, 27 gas fields have been discovered in the country. Domestic gas production is by the public corporation Petro Bangla and the private producer INPEX Oil Company. Table 3.2-2 shows the amount of gas produced by producer and the breakdown of gas fields owned. Major gas fields are BGFCL's Titas, Habiganj, and IOCs Chevron’s Jalalabad and Bibiyana, with a total of 2,174.9 MMscfd at four locations in December 2019, account for 84.3% of national natural gas production of 2,581.0 MMscfd and 68.3% of total natural gas.

In particular, the production of Bibiyana is 1,301.7 MMscfd, which accounts for more than half of the national production. LNG is 602.4 MMscfd, which accounts for 18.9% of all natural gas.

Table 3.2-2 Gas Production Status

(As in December, 2019) Gas in MMscfd, Condensate in BBL

Company	Gas Field	Total Wells (No.)	No of Producing Wells	Production Capacity (MMscfd)	Production	
					Gas	Condensate
1. BGFCL	Titas	27	26	542	443.9	416.0
	Bakhrabad	10	7	43	42.1	40.0
	Habiganj	11	8	225	188.9	15.7
	Narsingdi	2	2	30	26.7	39.9
	Meghna	1	1	11	8.1	19.9
	Sub-Total	**51**	**44**	**851**	**709.8**	**531.5**
2. SGFL	Sylhet	8	1	6	3.6	26.9
	Kailashtila #1 (Silicagel)	4	1	13	6.0	37.1
	Kailashtila #2 (MSTE)	3	3	55	50.4	366.1
	Rashidpur	11	5	60	47.6	47.0
	Beanibazar	2	1	15	8.6	137.3
	Sub-Total	**28**	**11**	**149**	**116.2**	**614.5**
3. BAPEX	Saldanodi	4	2	3	4.6	0.7
	Fenchuganj	5	2	26	3.3	1.0
	Shahbazpur	5	4	50	34.4	3.4
	Semutung	6	2	3	0.9	0.0
	Sundalpur	2	1	5	7.2	0.4
	Srikail	4	3	40	32.0	81.1
	Begumganj	3	1	10	5.3	2.8
	Rupganj	1	0	8	0.0	00.0
4. IOCs						
CHEVRON	Jalalabad	9	7	270	240.4	1277.8
	Moulvibazar	9	5	42	21.6	4.4
	Bibiyana	26	26	1200	1301.7	8371.5
TULLOW	Bangora	6	5	103	103.2	305.0
	Sub-Total	50	43	1615	1666.9	9958.8
	Indigenous	159	113	2760	2581.0	11194.0
5. RPGCL	R-LNG	0	0	1000	602.4	0.0
	Sub-Total	**0**	**0**	**1000**	**602.4**	**0.0**
	Grand Total (1+2+3+4+5):	**159**	**113**	**3760**	**3183.0**	**11194.0**

Source : Production & Marketing Division, Petrobangla.

Source: Petrobangla Annual Report 2019

Table 3.2-3 shows the amount of natural gas reserve. Out of the 27 gas fields, there are 7 gas fields with reserve capacity of 1,000 BCF or more, led by Titas and Bibiyana, but only 4 gas fields with reserve capacity of 1,000 BCF or more are left. There is not a bright future for the domestic production of natural gas.

Table 3.2-3 Natural Gas Reserve

(As of 31 December, 2019) Figure in BCF

SL No	Fields	Year of Discovery	Reserve Estimated By		GIIP	Recoverable Reserve			Cumulative Production (Dec, 2019)	Remaining Reserve w.r.t 2P (1st Jan, 2020)
			Company	Year		Proved (1P)	Proved + Probable (2P)	Proved + Probable +Possible (3P)		
A. Producing										
1	Titas	1962	RPS Energy	2009	8148.9	5384.0	6367.0	6517.0	4786.50	1580.50
2	Habiganj	1963	RPS Energy	2009	3684.0	2647.0	2647.0	3096.0	2506.84	140.16
3	Bakhrabad	1969	RPS Energy	2009	1701.0	1052.9	1231.5	1339.0	840.48	391.04
4	Kailashtilla	1962	RPS Energy	2009	3610.0	2390.0	2760.0	2760.0	715.73	2044.27
5	Rashidpur	1960	RPS Energy	2009	3650.0	1060.0	2433.0	3113.0	642.63	1790.37
6	Sylhet/Haripur	1955	RPS Energy	2009	370.0	256.5	318.9	332.0	216.57	102.33
7	Meghna*	1990	RPS Energy	2009	122.1	73.95	73.95	101.0	73.95	-
8	Narshingdi	1990	RPS Energy	2009	369.0	218.0	276.8	299.0	210.44	66.36
9	Beani Bazar	1981	RPS Energy	2009	230.7	150.0	203.0	203.0	105.38	97.62
10	Fenchuganj	1988	RPS Energy	2009	553.0	229.0	381.0	498.0	161.15	219.85
11	Shaldanadi	1996	RPS Energy	2009	379.9	79.0	279.0	327.0	92.20	186.80
12	Shahbazpur**	1995	Petrobangla	2011	918.1	-	642.7	-	77.37	565.31
13	Semutang	1969	RPS Energy	2009	653.8	151.0	317.7	375.1	13.31	304.39
14	Sundalpur Shahzadpur	2011	BAPEX	2012	62.2	25.0	35.1	43.5	14.73	20.37
15	Srikail	2012	BAPEX	2012	240.0	96.0	161.0	161.0	92.73	68.27
16	Begumganj	1977	BAPEX	2014	100.0	14.0	70.0	-	3.62	66.38
17	Jalalabad*	1989	D & M	1999	1491.0	1356.71	1356.71	1185.0	1356.71	-
18	Moulavi Bazar	1997	Unocal	2003	1053.0	405.0	428.0	812.0	327.09	100.91
19	Bibiyana	1998	D & M	2008	8350.0	4415.0	5755.4	7084.0	4075.02	1680.41
20	Bangura	2004	Tullow	2011	1198.0	379.0	522.0	941.0	456.99	65.01
	Sub-total A:				**36884.7**	**20382.1**	**26259.8**	**29186.6**	**16769.45**	**9490.34**
B. Non-Producing										
21	Kutubdia	1977	HCU	2003	65.0	45.5	45.50	45.5	0.00	45.50
22	Bhola North1	2018	BAPEX	2018	621.9	-	435.32	-	-	435.32
	Sub-total B:				**686.9**	**45.5**	**480.8**	**45.5**	**0.00**	**480.82**
C. Production Suspended										
23	Rupganj	2014	BAPEX	2014	48.0	-	33.60	-	0.68	32.92
24	Chattak***	1959	HCU	2000	1039.0	265.0	474.0	727.0	26.46	447.54
25	Kamta	1981	Niko/Bapex	2000	71.8	50.3	50.3	50.3	21.1	29.20
26	Feni	1981	Niko/Bapex	2000	185.2	125.0	125.0	175.0	62.4	62.60
27	Sangu****	1996	Cairn/Shell	2010	899.6	544.4	577.8	638.7	487.91	89.85
	Sub-total C:				**2243.6**	**984.7**	**1260.7**	**1591.0**	**598.5**	**662.11**
Grand Total (A+B+C) in BCF					**39815.2**	**21412.3**	**28001.27**	**30823.1**	**17368.00**	**10633.27**
Grand Total (A+B+C) in TCF					**39.8**	**21.4**	**28.00**	**30.82**	**17.37**	**10.63**

Note: * The cumulative production of Meghna and Jalalabad gas field have been shown as 1P (and 2P) reserve. Reserve re-evaluation is under way.
** 2P Reserve of Shabazpur gas field including Shabazpur East-1 re-estimated by BAPEX as 642.7 Bcf.
*** Reserve of Chattak Gas Field is under re-evaluation due to excessive seepage caused by the two consecutive blowouts in 2005.
**** Production from Sangu gas field suspended since 1st October, 2013

Source: Petrobangla Annual Report 2019

According to the latest data, Petro Bangla's initial total gas volume (GIIP) estimate is 39.82 trillion cubic feet (TCF), of which 28.23 TCF is recoverable. From 1960 to June 2020, a total of 17.79 TCF of gas was produced cumulatively, leaving a recoverable 10.43 TCF. The status of gas production and reserves in 2020 is shown in Table 3.2-4.

Table 3.2-4 The Status of Gas Production and Reserve 2020

Sl. No.	Items	Quantity
1.	Total Number of Gas Fields (June 2020)	27
2.	Number of Gas Fields under Production (June 2020)	20
3.	Total Number of producing Wells (June 2020)	113
4.	Total initial gas in place (GIIP)	39.8 TCF
5.	Total Reserve of Extractable Gas (Proven + Probable)	28.23 TCF
6.	Total Consumption of Gas (up to June 2020)	17.79 TCF
7.	Total Reserve Remaining (Proven + Probable) (June 2020)	10.43 TCF
8.	Daily Gas Production (as of June 2020) including RLNG	3038.9 MMCFD
9.	Production by Petrobangla Companies	880.6 MMCFD
10.	Production by International Oil Companies (IOCs)	1644.5 MMCFD
11.	R-LNG	513.9 MMCFD
12.	Present Daily Gas Demand	About 3700 MMCFD
13.	Gas Production increased from 2009 to 2019 including R-LNG	About 1294.9 MMCFD

Source: Energy and Mineral Resources Division

Source: 8th 5-year plan

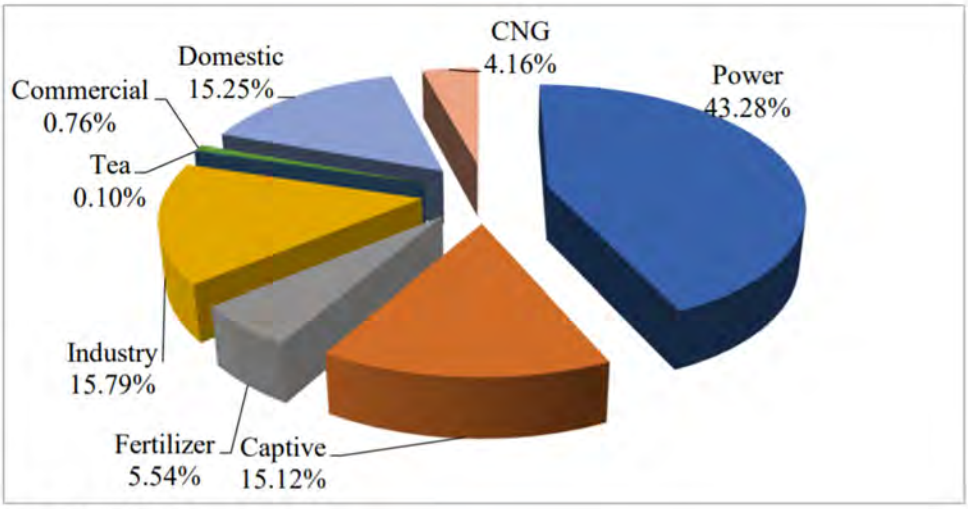
As is clear from Table 3.2-5 and Figure 3.2-4, the electricity sector is the major consumer of gas, followed by the industrial sector (both industrial and captive). Other major domestic users will be fertilizer and compressed natural gas (CNG) stations.

Table 3.2-5 Natural gas production and consumption by sector (in BCF)

FY	Production	Consumption									
		R-LNG	Power	Captive Power	Fertilizer	Industry	Tea Estate	Com.	Dom.	CNG	Total
2009-10	703.6		283.3	112.6	64.7	118.8	0.8	8.1	82.2	37.2	707.6
2010-11	708.9		275.8	121.6	58.9	122.1	0.8	8.5	87.4	38.5	713.6
2011-12	743.7		302.3	124.2	58.5	128.3	0.8	8.6	89.2	38.3	750.4
2012-13	800.6		328.8	134.1	60.0	135.7	0.8	8.8	89.7	40.2	798.1
2013-14	820.4		337.4	143.8	53.8	141.9	0.8	8.9	101.5	40.1	828.1
2014-15	892.2		354.8	150.0	53.8	147.7	0.8	9.1	118.2	42.9	877.3
2015-16	973.2		399.6	160.8	52.6	156.0	0.9	9.0	141.5	46.5	966.9
2016-17	969.2		403.6	160.5	49.1	163.1	1.0	8.7	154.4	47.0	987.3
2017-18	968.7		398.6	160.5	43.0	166.6	0.9	8.2	158.0	46.2	982.0
2018-19	961.7	116.0	450.9	157.5	57.7	164.5	1.0	7.9	158.9	43.4	1157.8

Source: BER 2019 & Petrobangla, Energy and Mineral Resources Division

Source: 8th 5-year plan



Source: Petrobangla

Source: 8th 5-year plan

Figure 3.2-4 Gas Consumption Ratio by Category (FY 2018-19)

Regarding the future demand forecast for natural gas, the "Bangladesh Gas Sector Master Plan" (GSMP2017) was published as an updated version of the 2006 plan in 2017, and the forecast up to 2041 is specified. The main purpose of GSMP2017 is to update GSMP2006 to align with the country's current infrastructure development priorities and lead to sector development.

In GSMP2017, the following three gas demand scenarios are analyzed, taking into account different GDP growth rates.

Scenario A: PSMP2016 revised case
GDP growth will gradually decrease from 8% in 2020 to 4.3% in 2041
Scenario B: High growth case
GDP growth rate will be maintained at 7% from 2021 to 2041
Scenario C: Climate change case
Due to climate change considerations, coal-fired development is limited and will be covered by renewable energy, gas-fired and hydropower imports. GDP growth rate is equivalent to scenario A

The 8th Five-Year Plan, formulated in December 2020, provides further analysis based on "Scenario C," which indicates that the Government of Bangladesh places a high priority for climate change in future energy policies. Table 3.2-6 shows the gas demand forecast by sector in the case of scenario C. Total gas demand is projected to be 4,520mmcfd between 2020 and 2021, 5,257mmcfd between 2025 and 2026, 6,228mmcfd between 2030 and 2031, 7,532mmcfd between 2035 and 2036, and 8,346mmcfd between 2040 and 2041.

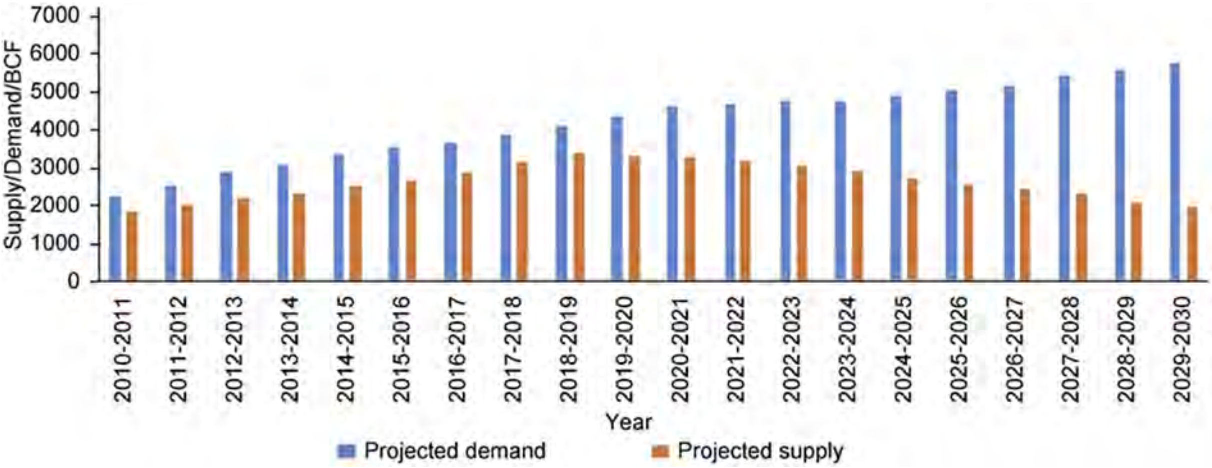
Table 3.2-6 Forecast of Gas Demand by Sector (in mmcfd)

Sector	2020-21	2025-26	2030-31	2035-36	2040-41
Power	2197	2315	2468	2950	2991
Cap. Power	480	283	167	99	58
Fertilizer	316	316	316	316	316
Industry	925	1575	2302	2994	3613
Domestic	425	557	721	867	994
Commercial & Tea	38	38	38	38	38
CNG	139	173	216	269	335
Total	**4520**	**5257**	**6228**	**7532**	**8346**

Source: Gas Sector Master Plan Bangladesh 2017 (Scenario C)

Source: 8th 5-year plan

Figure 3.2-5 shows the supply and demand forecast for natural gas by 2030. The decline in supply capacity to demand is expected to be significant after 2020, because the supply from old gas fields will gradually decline, while the development of new gas fields will not be able to keep up. It will be necessary to improve the recovery capacity from existing gas fields, and we will have to rely on LNG imports from overseas.



Source: Journal of Natural Gas Geoscience

Figure 3.2-5 Supply and Demand Forecast for Natural Gas by 2030

(2) Problem-solving measures

Since it is predicted that the supply of domestically produced natural gas alone will not meet future demand, it is necessary to promote further development of domestic gas resources and imports from overseas in order to meet this shortfall. In addition, in order to make up for the shortage of gas and promote an appropriate energy mix, it is necessary to introduce coal that is inexpensive and can be expected to provide a stable supply.

(a) Efficient and economical development of domestic gas resources

Domestic natural gas has great value to the country's economic development, and maximizing its recovery is important.

Significant technological advances have been made in the areas of gas and oil field development since 1990, with significant improvements in gas and oil recovery rates. Bangladesh gas development needs to take advantage of such advanced technologies. The country should invite highly skilled and financially sound IOCs (International Petroleum Companies) to offshore gas development and implement them together, thereby maximizing gas recovery from offshore fields and making it more efficient. It will be possible to develop. The existing PSC (Production Sharing Contract) needs to be modified to be attractive to the IOC.

Under the revised PSC, an international bid should be held in which domestic manufacturers (BAPEX, BGFCL, SGFL) and the IOC collaborate.

(b) Imported gas development

The Government of Bangladesh has already taken steps to import natural gas in order to respond to the supply-demand gap of natural gas and future energy growth.

1) Introduction of FSRU (Floating Storage and Regasification Unit)

The country's first FSRU was installed by Excelerate Energy Bangladesh Limited (EEBL) and has been in operation since August 2018. The capacity of the FSRU is 500mmcfd.

The second FSRU was installed by Summit LNG Terminal Co Ltd. and has been in operation since April 2019, and the capacity of the FSRU is 500mmcfd, which is the same as the first FSRU.

The two FSRUs are located in the Bay of Bengal near Maheshkhali in Cox's Bazar.

Regarding FSRU, a proposal to install a 500 mmcfd capacity at Kutubdia by Reliance Power Ltd. of India is under negotiation, and research activities are underway to install an FSRU with a capacity of 500 mmcfd and a fixed pier at Kutubdia by Hong Kong Shanghai Manjala Power Ltd.

2) Introduction of onshore LNG terminal

The government is also planning to introduce an onshore LNG terminal.

A consortium of Huanqui Contracting & Engineering Corp. (HQC) in China and CAMC Engineering

Co. Ltd. in China is conducting an FS on the introduction of an onshore LNG terminal with a capacity of 1,000mmcfd in Maheshkhali. If the project has been judged to be feasible. Project will enter the next stage of negotiations.

Petronet India Ltd's FS to introduce an onshore LNG terminal with a capacity of 1,000mmcfd in Kutubdia has been completed, the terms and conditions have already been signed, and negotiations have begun for a contract agreement.

Tokyo Gas of Japan has been appointed as a consultant to the FS to set up onshore LNG terminal in the Port of Payra or in the rest of the Kutubdia and Maheshkhali areas with Petrobangla fund. The FS is in the final stages and it is expected that onshore LNG bases will be installed in one or two of these locations if the results are feasible.

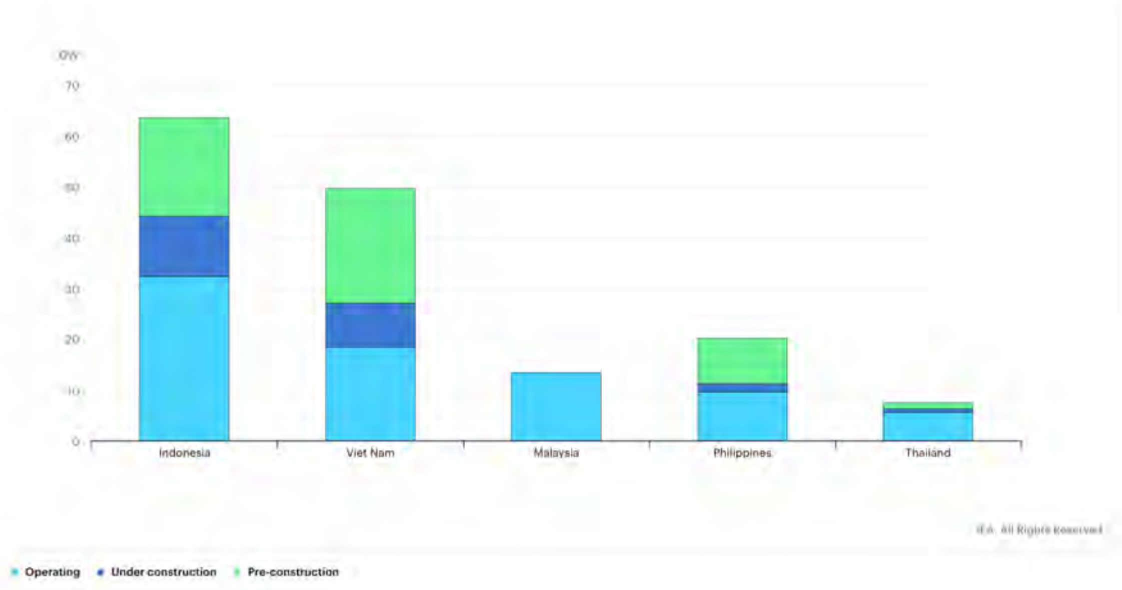
3) LNG procurement contract

The LNG market is oversupplied due to the development of shale gas and the switch from fossil fuels to renewable energy to reduce CO2 as a measure against global warming. Until now, long-term procurement contracts have been the mainstream, but now it is possible to procure cheap LNG with spot contracts. Therefore, in the short term, the introduction of FSRU (floating storage and regasification unit), which has a short construction period was a good idea to start importing LNG as soon as possible. However, on the other hand, like this winter due to the global cold wave and troubles in the supply areas, the spot market may temporarily soar. Therefore in the medium to long term we aim to achieve a stable supply of natural gas and a low procurement price looking at the market situation. The best mix of long-term contracts and spot contracts should be used.

To date, the country has already signed a long-term (15-year) LNG sales and purchase agreement (SPA) with Ras Laffan Natural Gas Company Limited (3) in Qatar to supply 1.8-2.5 MTPA LNG. Another long-term (10-year) SPA signed an LNG purchase agreement for 1.0 MTPA with Oman Trading International (OTI) in Oman. In addition, the Master Sales Purchase Agreement (MSPA) has signed 14 shortlist LNG suppliers / traders that supply LNG on a spot basis.

3.2.2 Coal

Cheap and high quality electricity is indispensable for economic development. Figure 3.2-6 shows the operation and development status of coal-fired power plants in Asian countries . In order to achieve cheap electricity by the best mix of fuels, Indonesia and Vietnam are planning to construct coal-fired power plants of 30GW or more, which is the same amount as under operation.



Source: IEA, Electricity Market Report (December 2020)

Figure 3.2-6 Development Status of Coal-fired Power Plant in Asian Countries

Table 3.2-7 shows the current unit price of power generation by fuel in Bangladesh.

Compared to LNG and oil power generation, coal power generation is far cheaper. In order to achieve an energy mix that maximizes the evaluation in terms of economy, environment, and energy security, coal power generation should be expanded.

Table 3.2-7 Power Generation Unit Price by Fuel

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

Source: Power Division

Source: 8th 5-year plan

(1) Current Situation and Issues

(a) Domestic Coal

Five coal mines have been discovered in the country so far: Barapukuria, Khalaspir, Phulbari, Jamalganj and Dighipara. The total reserves of these five coal mines are approximately 7,962 million tons, and as of June 2020, a total of 11.78 million tons of coal have been mined. The coal is used to generate 525MW of electricity for supply to the National Grid. Currently, about 1 million metric tons of coal are produced each year from the coal mine in Barapukuria, Dinajpur.

As part of its strategy, Perspective Plan of Bangladesh (PP 2041) emphasized the need to find more domestic coal for long-term energy security. Regarding the development of already discovered coal mines, all coal mines have a depth of 100m or more, which requires a large initial investment, but will generate high returns in the future. On the other hand, the use of imported coal requires a large investment in ports, storage and transportation infrastructure.

Coal can be an alternative fuel to natural gas, and these coals meet Bangladesh's energy needs for 50 years. It is worth noting that Bangladeshi coal is superior in quality to imported coal, has a high calorific value and is low in sulfur. Source: Petrobangla 2019 Annual Report

Table 3.2-8 Quality of Bangladesh Coal

No.	Item	Percentage
1	Calorific Value	25.68 MJ/kg or 11,040 Btu/lb or 6,072 kcal/kg
2	Ash	12.4%
3	Moisture	10.00%
4	Fixed Carbon	48.40%
5	Volatile Matter	29.20%
6	Sulphur	0.53%

Source: Barapukuria Coal Mining Company Limited (BCMCL) website

(b) Coal Consumption

Table 3.2-9 shows the coal production results for the last five years, including imported coal.

The amount of coal imported for consumer use was more than three times that of domestic coal for public use.

Table 3.2-9 Coal Production Results (Metric ton)

Year	Public Sector Production	Import (Private)	Total
2014-15	675,775.50	1,812,030	2,487,806
2015-16	1,021,638	3,812,060	4,833,698
2016-17	1,160,657.81	2,801,407	3,962,065
2017-18	923,276.00	3,394,534.24	4,317,810
2018-19	803,315.00	5,754,025	65,57,339

Source: MoPEMR, Energy Scenario Bangladesh 2018-19

Table 3.2-10 and Figure 3.2-7 shows the future supply and demand forecast for coal.

The movement toward CO_2 emission reduction is strengthened as a measure against global warming. The coal power development plan has been revised. As the result, coal supply forecast was drastically reduced comparing PSMP2016.

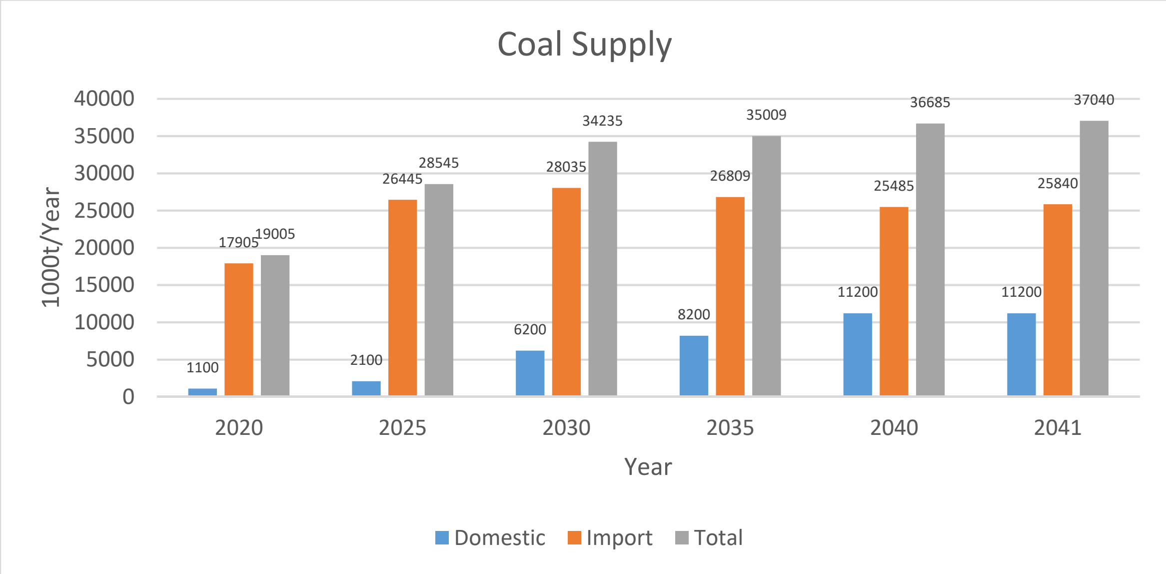
Table 3.2-10 Supply and Demand Forecast for Coal

(Unit: 1000 ton)

	Year	2020	2025	2030	2035	2040	2041
Supply	Domestic	1100	2100	6200	8200	11200	11200
	Import	17905	26445	28035	26809	25485	25840
	Total	19005	28545	34235	35009	36685	37040
Demand	Power	16339	24601	28806	27930	27930	27930
	Non-power	2000	3944	5429	7079	8755	9110
	Total	19005	28545	34235	35009	36685	37040

Remarks: Coal demand for Power was calculated under the assumption of coal calorific value 5,000kcal/kg, plant efficiency 40%, plant factor 80%.

Source: Study Team from power generation plan by BPDB on June 2021, coal power plan by GoB June 27, 2021, Revisiting PSMP2016



Source: Study Team

Figure 3.2-7 Coal Supply Forecast

(2) Problem-solving measures

The introduction of ultra-supercritical coal-fired power is the key to achieving low-cost electricity for economic development, environmentally friendly high-efficiency power generation, and energy security, but infrastructure development to secure coal as fuel is indispensable.

(a) Infrastructure development for imported coal

Domestic coal has excellent quality, but the required excavation depth is as deep as 100m or more, and development requires time and money. For this reason, it is necessary to develop infrastructure for accepting overseas coal.

In the future, with the increase in the development of new coal-fired power plants, it will be necessary to implement FS for further infrastructure development and plan efficient coal transportation. In the near future, it will be necessary to carry out an FS that includes an actual record analysis of loading and unloading at offshore in the Bay of Bengal.

(b) Domestic coal development

It will take about 10 years to develop and start production of a new mine, so production will start in 2025 at the earliest, even if it is ready now. Therefore, in order to utilize the best domestic resources as much as possible, it is necessary to start from the preparations that can be made now.

Currently, about 1 million metric tons of coal are produced each year from the only coal mine in Barapukuria, Dinajpur. In March 2020, an FS was implemented in Dighipara, Dinajpur, to develop an underground coal mine with an average annual coal production target of 2.8 million tons. To meet coal demand for power generation from domestic coal sources, Petrobangla plans to develop two other coal fields in Jamalganj and Khalaspir by 2041.

The Dinajpur, Khalaspir and Phulbari coalfields have high development potential, with total production of 1.1 million tons by 2020, 5.7 million tons by 2030 and 11.2 million by 2041 under expected production scenarios.

By 2020, at the Barapukuria coal mine, a system has been established that allows the country to learn technologies such as mining, ventilation, and mine safety technology, so we believe that Bangladesh will be able to respond to the development of new coal mines without problems.

Establishing an institution to train mining engineers and third parties, as well as organization for technology transfer such as mining colleges where workers in the country can learn and assess the outcome of the program. It is necessary to expand the use of transferred technology to other coal mines in the medium to long term.

3.2.3 Oil

Until 1997, when a private company dealing with gas condensate extracted from gas fields entered the market, the oil business was a complete government-only business by the Bangladesh Oil Corporation (BPC).

(1) Current situation and issues

80% of petroleum products are imported by BPC (Bangladesh Petroleum Corporation).

Petroleum products, such as diesel oil, gasoline and octane furnace oil, account for 16% of the country's primary energy supply.

As shown in Table 3.2-11, the liquid fuel used in the country is mainly imported, and locally produced gas condensate accounts for only 6% of the total consumption of liquid fuel. The country imports about 1.36 million metric tons of crude oil and about 6.7 million metric tons of refined petroleum products annually. Approximately 4,118,000 barrels a year locally produced gas condensate is the only source of domestic liquid fuel in the country, which is mainly divided into gasoline, diesel and kerosene. The main consumption sector of liquid fuel is the transportation sector, followed by the electricity, agriculture, industry and commerce sectors. The consumption of petroleum products by sector is shown in Table 3.2-12 and Figure 3.2-8. Transportation-50.26%, electricity-24.36%, agriculture 16.37%, industry 5.32%, domestic-3.21%, and others 0.48%.

Table 3.2-12 shows the product sales performance of BPC of Petroleum Corporation for the past eight years. Diesel fuel accounts for half of the total.

Table 3.2-11 Overview of Oil Sector (2018-2019)

Product	2018-19 (in Ton)
Import of Refined Oil by BPC	4,863,711
Import of Furnace Oil by BPC	318,634
Import of Crude Oil by BPC	1,361,877
Total import by BPC	**6,544,222**
Import of Furnace (Private)	1,614,310
Production of Condensate	523,123
Total Sale	**8,658,532**
Export of Naptha	36,513
Storage Capacity of BPC	1,300,000
Refining Capacity of ERL	1,250,000
LPG Production from ERL	12,832
LPG Production from Kailashtila Frac. Plant	5321
LPG import (private)	681,036

Source: MoPEMR, Energy Scenario Bangladesh 2018-19

Table 3.2-12 Sales Record of BPC past 8 years

Quantity in MT

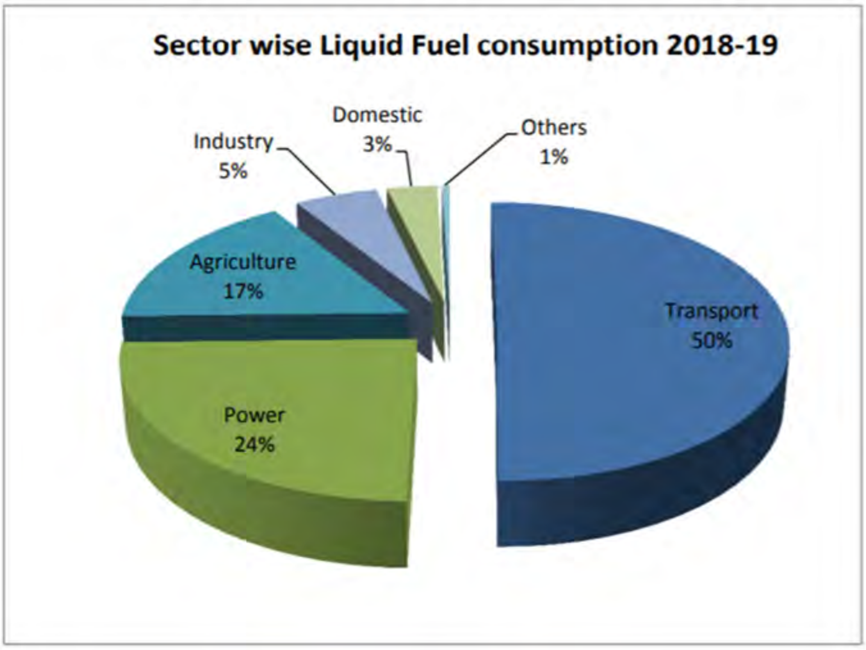
Products	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19
Octane	107150	110850	117452	126114	147557	186911	230280	266988
Petrol	158707	169710	178674	166823	137360	232359	284668	318593
Diesel	3240349	2962872	3242554	3396061	3606404	4000044	4835712	4593486
Kerosene	358436	314450	289871	263029	213685	170993	138403	121497
Furnace Oil	883735	1070096	1202505	906771	711889	806440	925150	683725
Jet A-1	311890	318423	323327	338829	347323	376700	408272	429951
Others	153379	131591	130583	123796	91802	115283	125851	129982
Total	**5213646**	**5077992**	**5484966**	**5321423**	**5256020**	**5888730**	**6948336**	**6544222**

Source: MoPEMR, Energy Scenario Bangladesh 2018-19

Table 3.2-13 Oil Consumption by Sector (2018-2019)

Sector	Uses amount in M.T.	%
Transport	3289126	50.26
Power	1594172	24.36
Agriculture	1071289	16.37
Industry	348153	5.32
Domestic	210070	3.21
Others	31412	0.48
Total	**6544222**	**100**

Source: MoPEMR, Energy Scenario Bangladesh 2018-19



Source: MoPEMR, Energy Scenario Bangladesh 2018-19

Figure 3.2-8 Sector wise Liquid Fuel Consumption (2018-2019)

(2) Problem-solving measures

The highest priority issue for the oil market is how to privatize the market and introduce competition to make petroleum products available at low prices.

It is necessary to reduce the consumption of liquid fuel in the electric power sector to make cheaper the electricity rate. Liquid fuel consumption will be reduced in transportation sector also. Coal-fired power generation is responsible for this reduction, and the introduction of environmentally friendly ultra-supercritical coal-fired power generation is required.

(a) Demand for petroleum products

Demand for petroleum products is growing at an annual rate of 2-4%. If this trend continues, oil demand is expected to increase to about 15 million tons by 2030. The country has decided to make road connections with neighboring countries such as India, Nepal and Bhutan. Since neighboring countries can also use the port facilities of Chittagong Port and Mongla Port, it is expected that transportation movements will increase significantly within the territory of the country. Along with this, demand for petroleum liquid fuel products is expected to increase in the future. In the future energy mix of our country, it will be necessary to transfer the generated power to other fuels, specifically cheap coal.

(b) Supply country of imported oil

ADNOC in the United Arab Emirates and Saudi Aramco in Saudi Arabia are suppliers of crude oil imported by BPC, and petroleum products are imported from 13 national oil companies (NOCs).

The government is actively considering a project to import diesel oil produced by Numaligarh Refinery Ltd (NRL) in Assam from the marketing terminal in Shiliguri to the Parbatipur Depot in the Dinajipur district via a pipeline.

(c) Capacity expansion project

The Eastern Refinery Ltd (ERL), which was installed in Chittagong in 1968, has an annual processing capacity of 1.5 million tons, and the current annual processing amount has reached about 1.25 million tons. A project to install an annual refining capacity of 3 million tons is being implemented as the second unit of an existing refinery. The government has allowed private entrepreneurs to set up condensate sorting plants to split the natural gas condensate (NGC) received from various gas fields and imported LNG in the country.

The total storage capacity of various petroleum products is about 1.3 million metric tons nationwide. According to the country's energy policy, 60 days' worth of petroleum product stock will be maintained for energy security, but BPC only maintains the stock of petroleum products for 35 to 40 days in shortage due to the insufficient storage capacity and huge funds for oil procurement.

As the second major storage facility, BPC is implementing a project to build the Mongla oil facility, with 14 oil storage tanks and an increase of 100,000 metric tons. A single point mooring (SPM) project is currently underway. BPC is currently required 9 to 10 days for unloading from a large vessel with a capacity of 120,000 tons through an undersea pipeline from near Kutubdia in the Bay of Bengal. BPC plans to shorten it within 48 hours to receive crude oil and diesel. The SPM project plans to build a storage facility with a capacity of 240,000 metric tons to facilitate the receipt of 150,000 metric tons of crude oil and 90,000 metric tons of diesel in Moheshkhali. It can be assumed that operational flexibility will be improved after the completion of the SPM project.

The major BPC projects planned in the future are as follows.

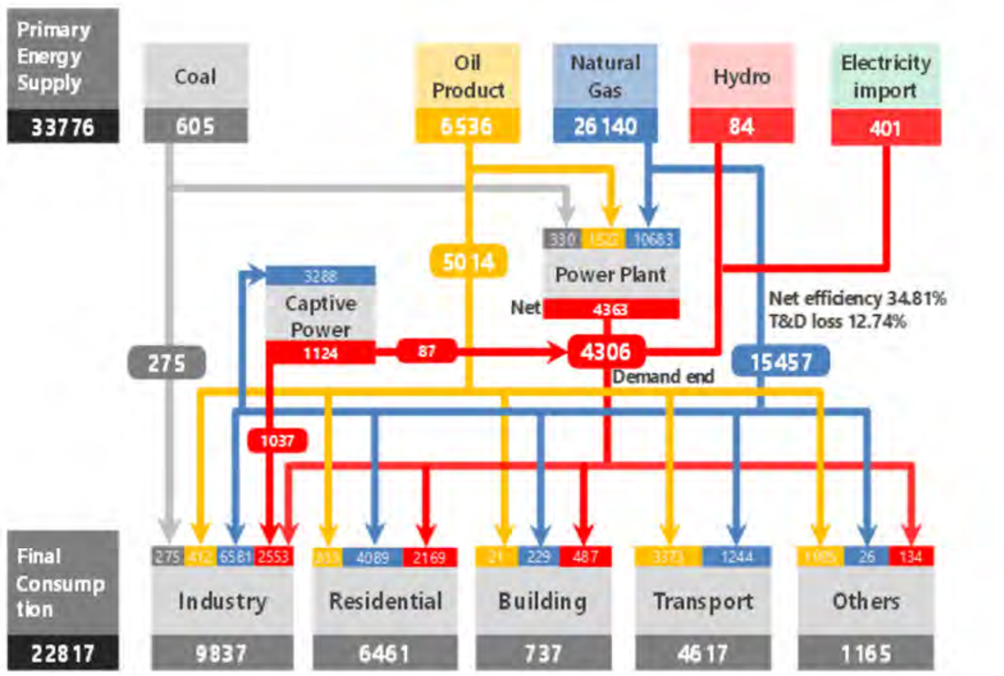
- India-Bangladesh Friendship Pipeline (IBFPL)
- Installation of storage transfer flowmeter at ERL tank company
- Terminal automation of BPC marketing company

3.2.4 Energy saving promotion policy and implementation status

Bangladesh's energy demand continues to grow rapidly against the backdrop of stable economic growth.

The country relies on domestically produced natural gas as its main energy source. According to the latest data (based on analysis of 2016 data collected from multiple government agencies), 26,140 ktoe, or 77% of the country's primary energy supply (33,766 ktoe), is covered by domestic natural gas. It became clear that. The industrial sector is the largest energy consuming sector, consuming 26 million toes, or about 50% of total energy consumption. The next largest is the household sector. There is a lot of room for improvement in energy saving in both sectors.

According to the energy balance, which analyzes the energy supply and demand of the whole country, about half of the primary energy supply is supplied as electricity. This includes electricity generated at power plants and electricity supplied by private power generation installed on-site in the industrial sector. Electricity is consumed in the order of industrial sector, household sector, and business sector. Natural gas is used to produce electricity and used as heat source in the industrial and household sectors. Petroleum products are characterized by the fact that more than half are used in the transportation sector.



Note: Unit = ktoe

Excluding biomass & solar

Rectangles in Energy Balance Chart show: Upper - Total Primary Energy Supply (TPES), Middle - Energy Conversion, Bottom - Total Final Energy Consumption (TFEC) by Sector

Source: SREDA compilation from Power Division Hydrocarbon Unit, BPC, LPG association

Figure 3.2-9 Energy Balance (FY 2016)

Bangladesh Energy Conservation Master Plan sets the goal of reducing the national energy consumption intensity (primary energy consumption / GDP) by 15% by 2021 and 20% by 2030 compared to 2013. The energy consumption intensity in 2016 was 3.56 ktoe / billion taka, which has already achieved a 4% reduction from the baseline (3.72 ktoe / billion taka). One of the factors behind the reduction in energy consumption intensity is that the service sector, which consumes less energy, has increased its share of GDP. In 2017, 52% of GDP was in the service sector, 34% was in the industrial sector, and 14% was in the agricultural sector. However, considering the growth rate of each sector, the growth of the industrial sector is remarkable, and in FY2017, the industrial sector grew by 12% and the service sector by 6% compared to the previous year. Therefore, it is expected that energy demand in the industrial sector, which consumes more energy, will continue to grow, and energy saving efforts in the industrial sector are becoming more important.

3.3 Current status of Power Sector

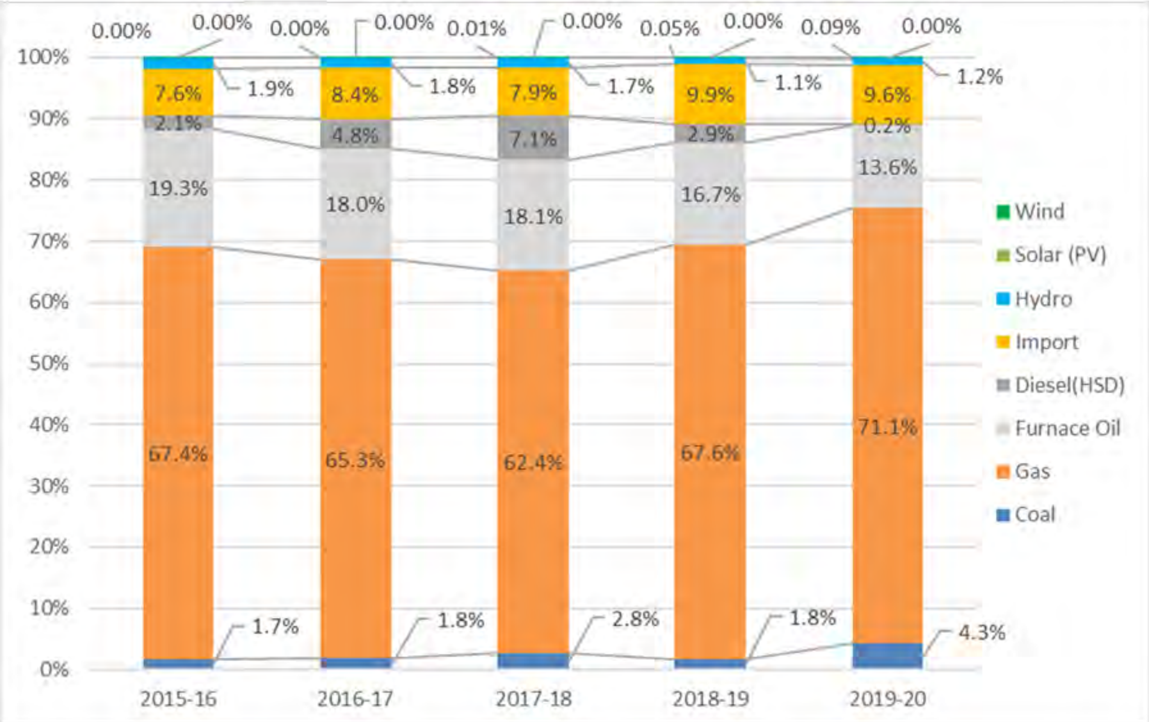
3.3.1 Cost of power generation

According to the data from BPDB, the cost of power generation calculated from the actual generation records of all in Bangladesh including fixed costs (annual average) from FY2016 to FY2020 is surprisingly cheap of 6Tk/kWh level (Figure 3.3-1) comparing to 10Tk/kWh to 12Tk/kWh of the LNG combined cycle generation unit price in Japan. Since total cost of power generation includes The Interest on Budgetary Support and The Maintenance & Development Fund, it is 0.33Tk to 0.46Tk higher than the value calculated by Variable Cost and Fixed Cost. Gas-fired power, which accounts for a large amount of electricity generated, is pushing down the average cost of power generation. Fuel costs for gas power plants are roughly 1Tk/kWh to 1.8Tk/kWh, which is extremely cheap considering that the Japanese LNG combined cycle generation unit price (variable cost) is inferred from 6.5Tk/kWh to 7.5Tk/kWh. According to the graph, the total unit price of power generation (Total) was 6.35 Tk/kWh in FY2018, but the cause is furnace oil fuel and HSD fuel such as rental power plants with high fuel costs, and since FY2019, the cost of power generation has decreased due to a decrease in power generation derived from these Oil fuels (see Figure 3.3-2).

Regarding wind power, there are variations in the amount of electricity generated depending on the fiscal year, partly due to poor wind conditions, especially in FY 2017-18, the wind condition was so bad and the range of power generation costs is large. The cost of solar power generation has remained relatively low.

Source: Study Team from BPDB (Finance)

Figure 3.3-1 Trends in generation cost from 2016 to 2020 (Tk/kWh)



Source: Study Team from BPDB (Finance)

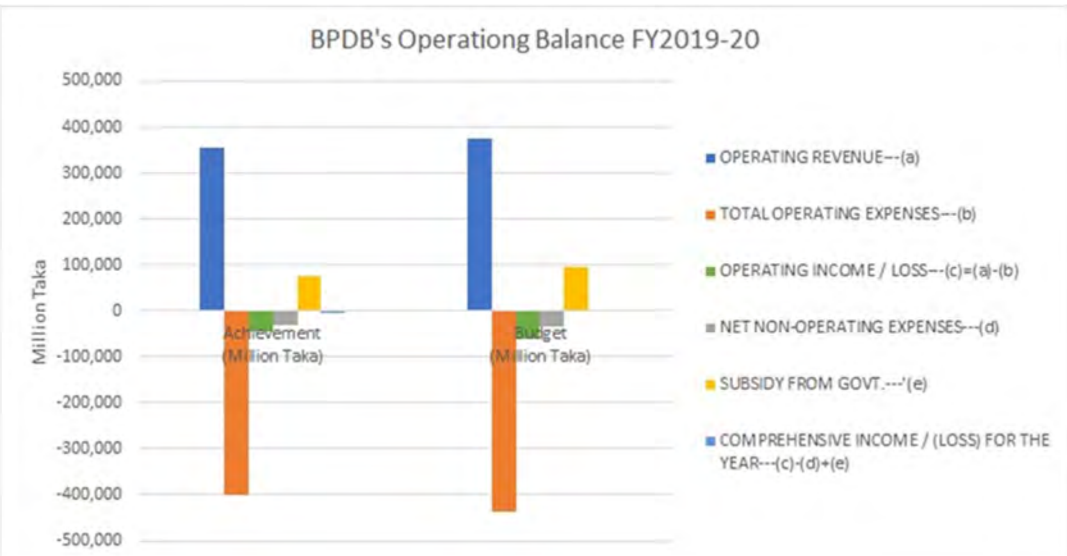
Figure 3.3-2 Trend in power generation rate from 2016 to 2020 (%)

3.3.2 Financial Situation

As a single buyer, BPDB buys electricity from all power generation utilities and wholesales it to distribution companies. The wheeling charge to PGCB, the transmission company, is paid from distribution companies. Here, BPDB's operating balance and others are checked as a single buyer. Figure 3.3-3 and Table 3.3-1 shows BPDB's operating and other balances. The operating balance is a loss of 43.5 billion taka, and the total balance becomes almost zero with the injection of about 74.4 billion Taka in government subsidies.

With the increase in imported coal and LNG expected to increase spending on power generators, it is essential to raise wholesale prices for distribution companies.

Financial situation of power generation companies, transmission company, and distribution companies is mentioned in the draft final report.



Source: Study Team from BPDB Annual Report 2019-20

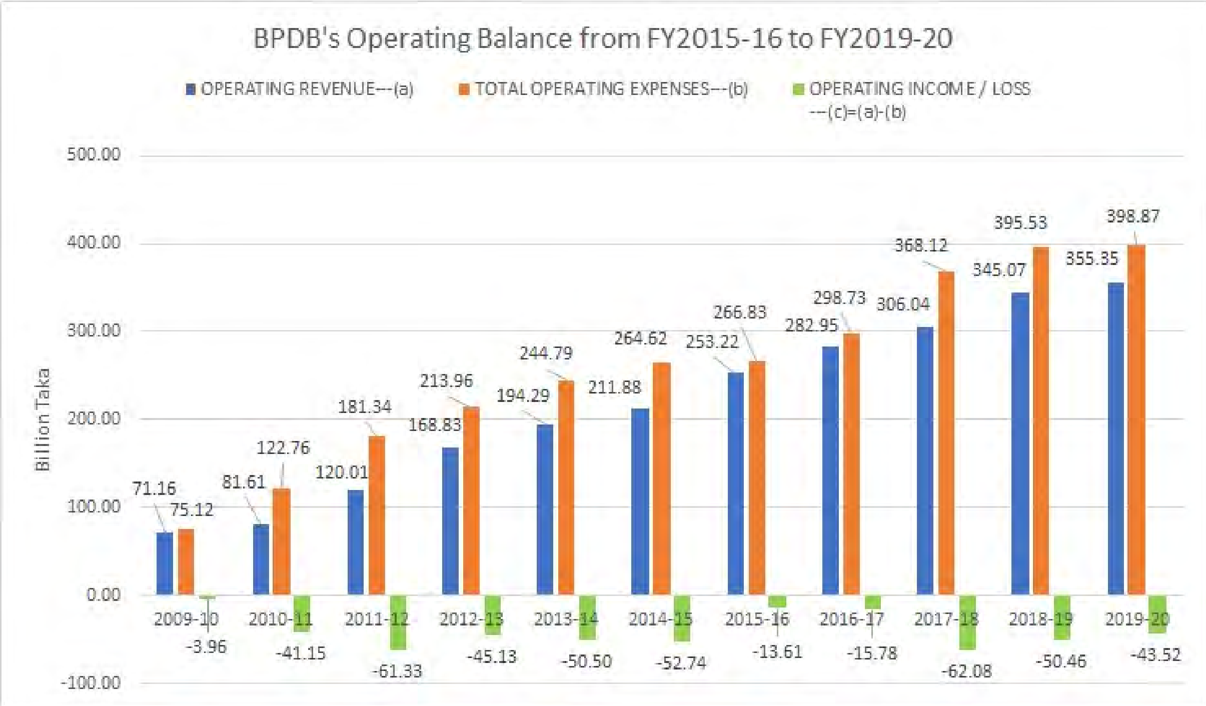
Figure 3.3-3 BPDB's operating balances in FY 2019-20

Table 3.3-1 BPDB's operating and other balances

Particulars	Achievement (Million Taka)	Budget (Million Taka)
OPERATING REVENUE		
ENERGY SALES	340,116	364,042
OTHER OPERATING INCOME	15,239	10,820
OPERATING REVENUE---(a)	355,354	374,861
FUEL COST - GAS	17,462	21,391
DIESEL/FURNACE OIL USED FOR ELECTRICITY GENERATION	6,547	9,690
COAL USED FOR ELECTRICITY GENERATION	10,142	11,832
ELECTRICITY PURCHASE FROM IPP	175,190	173,533
ELECTRICITY PURCHASE FROM RENTAL	32,164	35,320
ELECTRICITY PURCHASE FROM INDIA	40,171	46,935
ELECTRICITY PURCHASE FROM PUBLIC PLANT	66,717	86,777
DEPRECIATION	23,078	18,856
REPAIR & MAINTENANCE EXPENSES	9,698	9,340
PERSONNEL EXPENSES	14,206	15,331
OFFICE & ADMINISTRATIVE EXPENSES	1,176	3,225
TRANSMISSION EXPENSES FOR WHEELING CHARGE	2,320	2,995
TOTAL OPERATING EXPENSES---(b)	398,872	435,224
OPERATING INCOME / (LOSS)---(c)=(a)-(b)	-43,518	-60,363
NON - OPERATING EXPENSES:	0	0
ASSETS INSURANCE FUND	70	70
INTEREST ON LOANS	20,264	23,428
PROVISION FOR MAINTANANCE & DEVELOPMENT FUND	10,150	11,022
GAIN / (LOSS) DUE TO EXCHANGE RATE FLUCTUATION	485	1,300
NET NON-OPERATING EXPENSES---(d)	30,969	35,820
SUBSIDY FROM GOVT.---'(e)	74,394	96,759
COMPREHENSIVE INCOME / (LOSS) FOR THE YEAR---(c)-(d)+(e)	-91.9	576

Source: Study Team from BPDB Annual Report 2019-20)

Figure 3.3-4 shows the BPDB's operating balances from FY 2015-16 to FY2019-20, and it indicates that BPDB has made deficits every year.

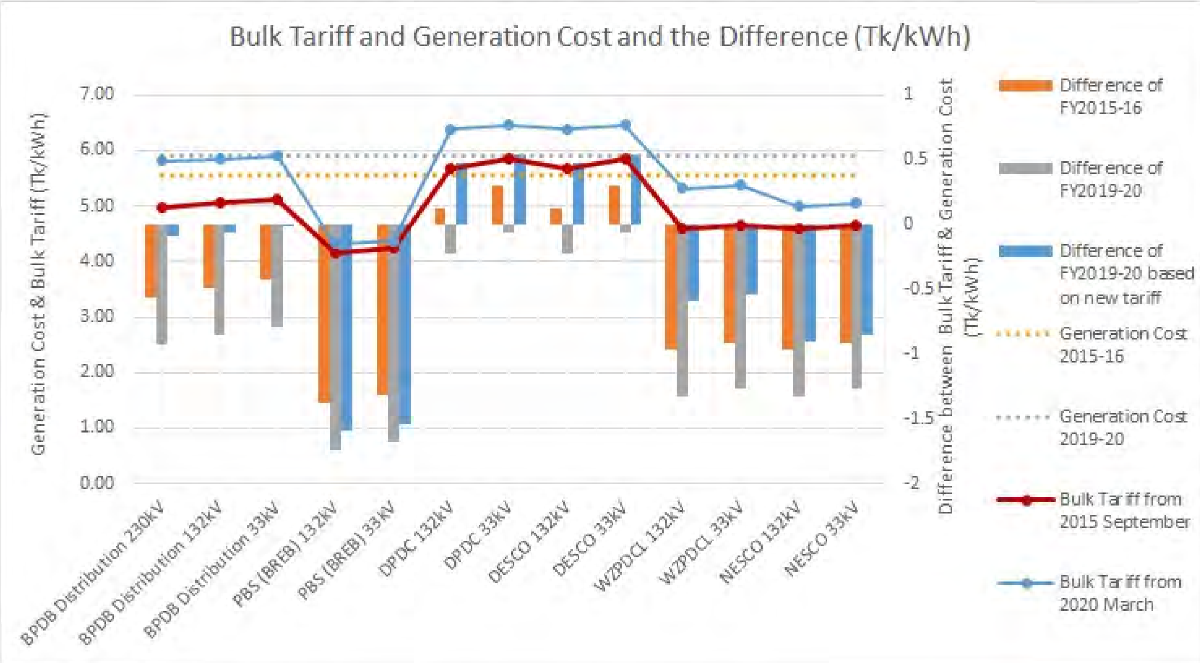


Source: Study Team from BPDB Annual Report 2019-20

Figure 3.3-4 BPDB's operating balances from FY 2015-16 to FY2019-20

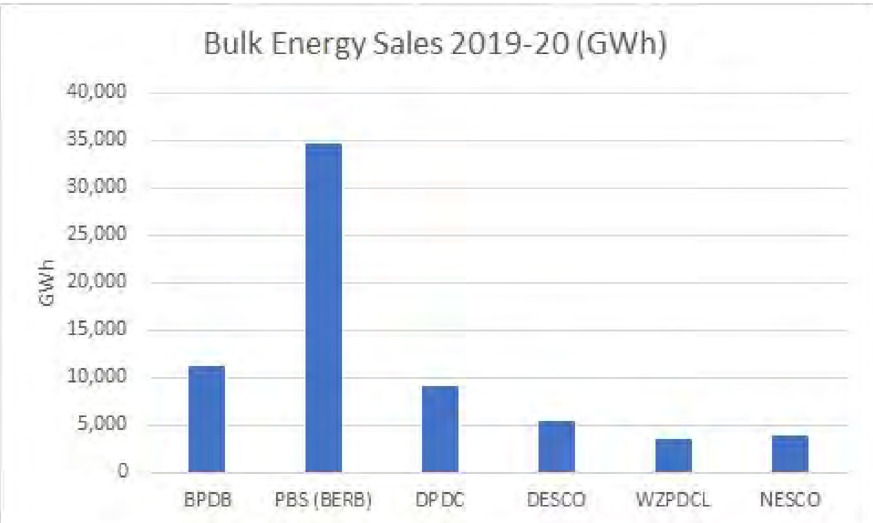
In order to identify the cause of the BPDB's deficit, the average generation price at FY 2015-16 and FY 2019-20 (the figures in Figure 3.3-1), and the bulk tariffs for distribution utilities. Then, it is identified that the cause of the deficit is to sell power in cheaper price to distribution utilities except DPDC and DESCO which distribute power in Dhaka area than purchasing price from generation utilities (Figure 3.3-5). Although the bulk tariff raise for distribution utilities was approved by BERC in March 2020, still generation price is higher than the bulk tariffs except the bulk tariffs of DPDC and DESCO. Therefore, the situation that does not make an operating profit is expected to be continued, because the impact of making profit by DPDC and DESCO is smaller than the deficit of other distribution utilities considering the power sales shown in Figure 3.3-6.

The bulk tariffs had been revised in March and September in 2012, September in 2015, and March in 2020, and the operating balances were slightly improved accordingly. However, the deficit caused by the price gap between generation cost and bulk tariff has increased with increase in power sales and generation cost. Figure 3.3-7 shows the trends in the voltage wise bulk tariffs of each distribution utility.



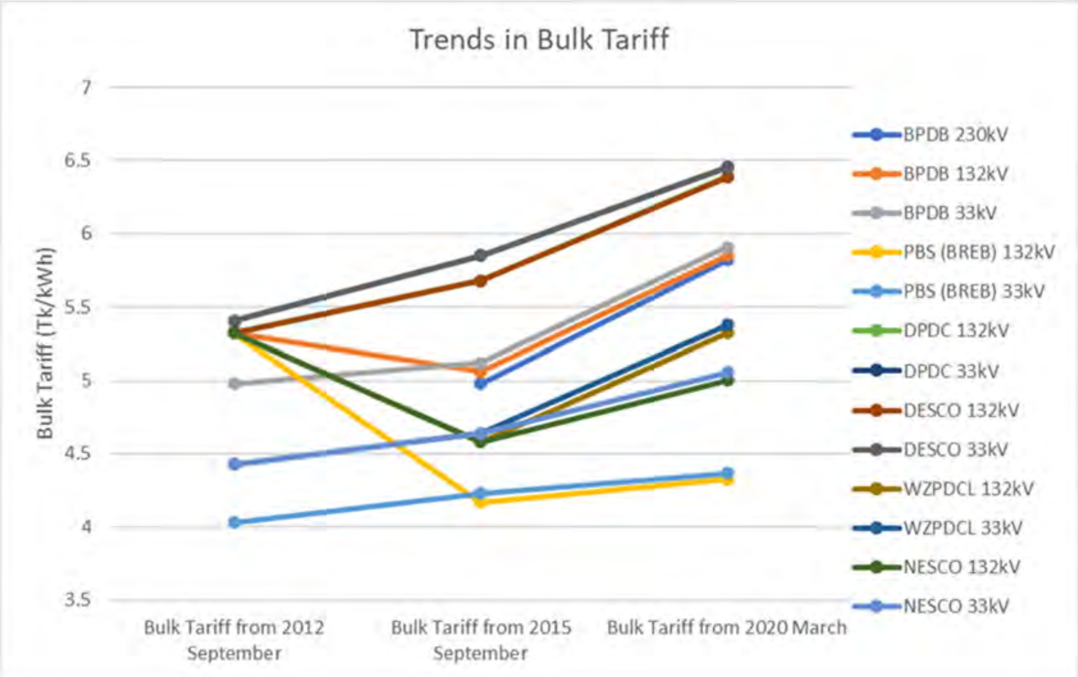
Source: Study Team from BPDB (Finance) materials and BERC, BPDB website

Figure 3.3-5 Generation prices and Bulk tariffs, and the differences



Source: Study Team from BPDB Annual Report

Figure 3.3-6 Power sales (GWh) of each distribution utility



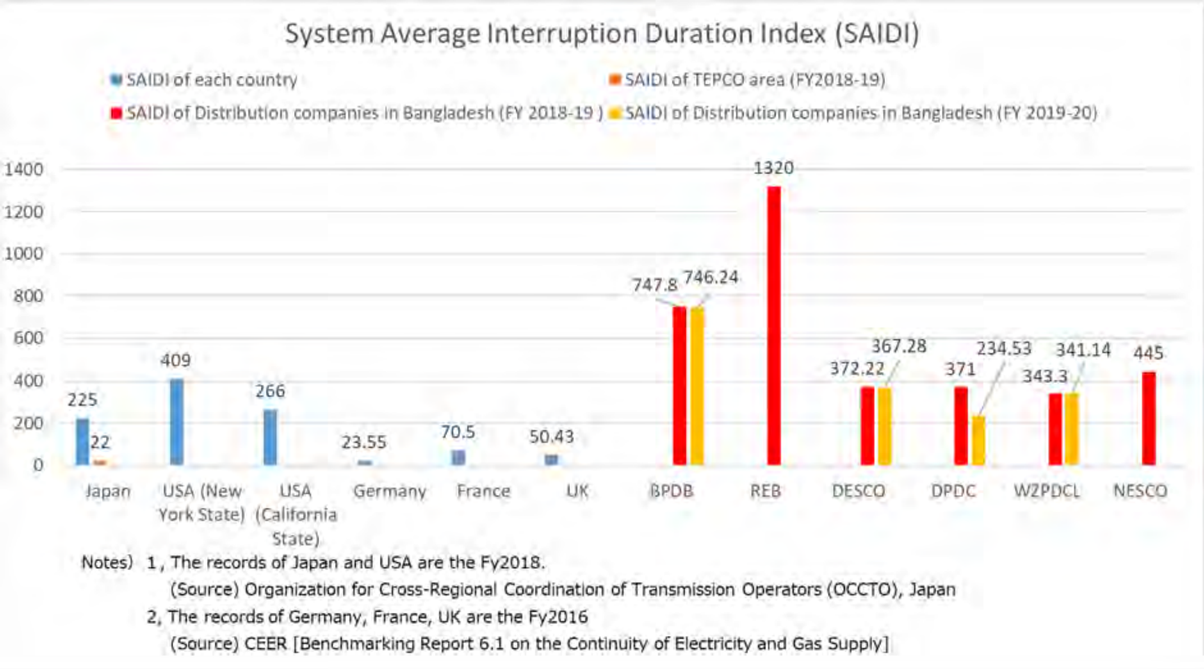
Source: Study Team from BERC, BPDB website

Figure 3.3-7 Trends in the voltage wise bulk tariffs of each distribution utility

In future, the bulk tariff raise is required along with the increase in the import of the coal and LNG because the increase in the expenses to generation utilities is anticipated.

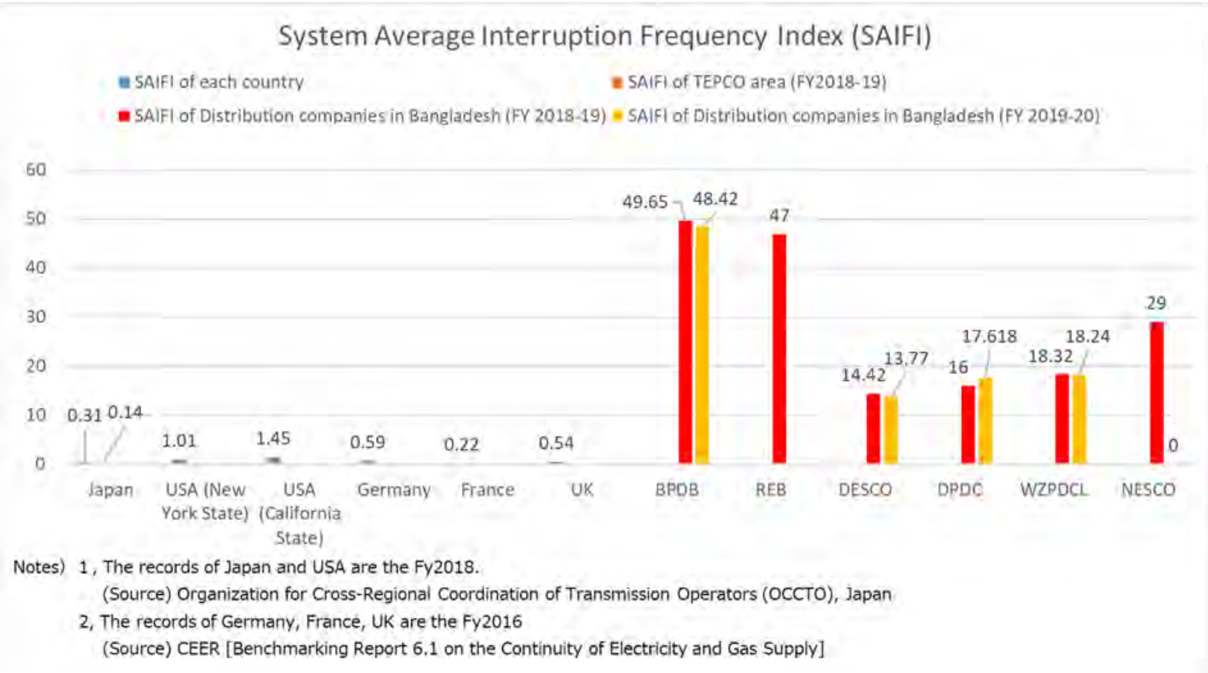
3.3.3 Power outages

Planned load shedding due to power supply shortage has not been implemented since around 2017.However the power outage occurs frequently due to a failure of transmission and distribution facilities. Figure 3.3-8 shows System Average Interruption Duration Index (SAIDI) that is the average outage duration for each customer served. Figure 3.3-9 shows System Average Interruption Frequency Index (SAIFI) that is the average number of interruptions that customer would experience. The SAIDI and SAIFI values in the country are bigger than those in Japan, USA and European countries. It means that the power outage in the country occurs frequently and lasts for a long time. The SAIDI and SAIFI values of split-up companies such as DESCO, DPDC, WZPDCL and NESCO, are smaller than those in BPDB and REB. It is assumed that the facility management has been improved due to the company split-up. Since the PSMP2016 suggests to monitor the SAIDI and SAIFI values as KPI, each distribution company implements the suggestion.



Source: Study Team from TEPCO investigation materials and Annual reports of distribution companies in the country

Figure 3.3-8 Comparison of the system average interruption duration index (SAIDI)



Source: Study Team from TEPCO investigation materials and Annual reports of distribution companies in the country

Figure 3.3-9 Comparison of the system average interruption frequency index (SAIFI)

3.4 Support status of other donors

3.4.1 Major supporting countries and organizations

As of 2019, the main support countries for Bangladesh are Japan, Russia, China, India, and the main support organizations are the World Bank's International Development Association (I.D.A) and ADB.
Table 3.4-1 shows the external debts from each country and institution to Bangladesh as of June 2019.

Table 3.4-1 External debts from each country and institution to Bangladesh (June 2019)

Country and Institution	External debt (in million USD)
Japan	5,922
Russia	2,012
China	1,380
India	462
WB (IDA)	15,649
ADB	9,597

Source: ERD website

Table 3.4-2 shows the support records from major agencies over past five years.
Support from JICA, ADB, and WB accounts for more than 60% of the total. In recent years, support from AIIB（Asian Infrastructure Investment Bank）has been increased.

Table 3.4-2 Support records from major agencies over past 5 years

SL	Name of the Donor Agency	2015	2016	2017	2018	2019	Total (Figure in US $)
1	ADB	13,233,059	26,111,307	25,395,281	27,009,166	51,784,576	**143,533,390**
2	KFW	175,488	302,451	19,125,866	26,208,354	32,850,476	**78,662,634**
3	WB	63,651,402	145,453,451	201,600,744	137,258,939	134,299,561	**682,264,098**
4	JICA	191,646,451	132,943,159	51,769,049	71,258,598	533,485,976	**981,103,232**
5	IDB	–	–	18,429,124	7,877,311	40,312,010	**66,618,445**
6	AIIB	–	–	89,544,939	34,767,720	10,647,622	**134,960,280**
7	UNDP	–	–	–	–	662,329	**662,329**
8	EIB	548,780	2,191,463	3,414,634	–	–	**6,154,878**
9	AFD	11,733,074	12,103,957	42,384,233	37,466,804	28,768,662	**132,456,730**
	Total	**280,988,255**	**319,105,788**	**451,663,870**	**341,846,891**	**832,811,212**	**2,226,416,016**

Source: Study Team from Power Division Website

3.4.2 Supports from each institution

(1) World Bank: WB

Bangladesh has made considerable progress in increasing its generation capacity and access to electricity. Access to electricity has reached 97% (grid and off-the-grid), and the installed capacity of power generation has increased to 22,692MW, including private and renewable energy. However, this sector still faces challenges in ensuring a reliable power supply, primarily due to distribution failures, inefficiencies associated with aging systems, and inadequate transmission and distribution networks. Over the last decade, Bangladesh's energy demand has increased at an average annual rate of 10 percent.

With ongoing support of $ 1.83 billion in the energy sector, the World Bank has increased capacity, generated clean energy, improved the efficiency of power generation and transmission and system operation, reduce technical losses, improved local transmission and distribute network and introduced renewable power. With IDA support, 2,652MW of electricity has been added to the national grid, 181MW of electricity has been added to the off-grid area, solar home systems, solar irrigation pumps and solar mini-grids have been installed, and more than 1 million improved cooking stoves have been installed. An additional 310MW of capacity has been added by an ongoing grid-connected solar project.

The World Bank has been working on the promotion of power sector policy and institutional capacity building within governments, electricity and gas companies, and the Bangladesh Energy Regulatory

Commission (BERC) with the aim of improving financial soundness, investment and quality of service.

Under the COVID-19 pandemic electricity demand declined in the first few months and is slowly recovering, but has fallen below its peak in 2019 and the projected demand has not been met. The pandemic reduced sales, and the slump in utility finances required government support to cover operating costs. Lower levels of employment and household income are undermining the affordability of electricity consumers.

Main supports to power sector from WB are shown in Table 3.4-3.

Table 3.4-3 Main Supports to Power Sector from WB

Calendar Year	Project	Type	Amount (US$ Million)	Executing Agency	Project Description Progress
2019/3～ 2024/1	Bangladesh Scaling-up Renewable Energy Project	Loan	156	Infrastructure Development Company Limited (IDCOL), Sustainable and Renewable Energy Development Authority (SREDA), Electricity Generation Company of Bangladesh (EGCB)	The Project objective is to increase installed generation capacity of, and mobilize financing for, renewable energy in Bangladesh.
2018/4～	Additional Financing II for Rural Electrification and Renewable Energy Development II	Loan	55	Power Cell, Infrastructure Development Company Limited (IDCOL)	The development objective of the Second Rural Electrification and Renewable Energy Development Project for Bangladesh is to increase access to clean energy through renewable energy in rural areas.
2018/3～ 2023/12	Enhancement and Strengthening of Power Transmission Network in Eastern Region	Loan	450	Power Grid Company of Bangladesh Limited (PGCB)	The proposed project aims to increase the transmission capacity and reliability of the electricity network in the eastern region and strengthen the institutional capacity of the Power Grid Company of Bangladesh Limited (PGCB)
2017/4～ 2021/12	Power System Reliability and Efficiency Improvement Project	Loan	59	Power Grid Company of Bangladesh (PGCB) Ltd.	The Project is to improve the reliability and efficiency of the power system in Bangladesh through optimization of dispatch operation.
2014/2～ 2021/6	Bangladesh: Rural Electricity Transmission and Distribution Project	Loan	600	Power Grid Company of Bangladesh (PGCB) Ltd.	The objectives of the Rural Electricity Transmission and Distribution Project for Bangladesh are to reduce system losses and enhance capacity in the rural distribution network of primarily the eastern part of the country.
2012/9～ 2021/12	Rural Electrification and Renewable Energy Development II (RERED II) Project	Loan	155	Power Grid Company of Bangladesh, Ltd. (PGCB)	The development objective of the Second Rural Electrification and Renewable Energy development Project is to increase access to clean energy in rural areas through renewable energy and promote more efficient energy consumption.
2015/2～ 2018/6	GPOBA (the Global Partnership on Output-Based Aid) Scale-up for Bangladesh RERED II	Grant	15	IDCOL	Increase access to clean energy through renewable energy in rural areas.
2014/6～	RERED II Additional Financing	Loan	78.4	IDCOL	The objectives of the Second Rural Electrification and Renewable Energy Development Project for Bangladesh are to increase access to clean energy in rural areas through renewable energy and to promote more efficient energy consumption. This project

Calendar Year	Project	Type	Amount (US$ Million)	Executing Agency	Project Description Progress
					paper seeks the approval of the Executive Directors to provide an additional credit to the Bangladesh Rural Electrification and Renewable Energy Development II (RERED II) Project.

Source: WB Website

(2) Asian Development Bank: ADB

ADB has supported $ 300 million in Dhaka and Western Zone grid expansion projects. The project includes expanding transmission lines and building substations, establishing core information systems, building drone inspection centers to improve operational efficiency, and introducing advanced conductor that transmit more power with lower energy losses.

The additional funding will bring about the expansion of the outcome of the former project, which has improved the distribution network in rural Bangladesh. More than 46,000 km (previously improved: 38,000 km) of 33kV and 11kV distribution lines and related facilities will be restored, and more than 16,000 km (previously constructed: 12,000 km) of 33kV and 11kV distribution lines and related facilities will be constructed.

An additional loan to the Bangladesh Rural Electrification Board (BREB) has been proposed to further improve access to an efficient and reliable electricity supply in the rural areas of the Khulna Division (western Bangladesh). ADB assists BREB to enhance the primary distribution network capacity of local electrified networks and to repair and improve sections of networks with low capacity conductors over 20 years old using wooden distribution poles. These investments are needed to supply reliably power for growing demand and meet customer demand in an efficient and reliable way. The proposed additional scopes are strongly linked to the scopes of ongoing projects and can be implemented efficiently under the same equipment installation arrangements. The overall scope of the project is consistent with the government's Bangladesh Outlook Plan, 2010- 2021: Making Vision 2021 a Reality, and the 7th Plan.

Main supports to power sector from ADB are shown in Table 3.4-4.

Table 3.4-4 Main Supports to Power Sector from ADB

Calendar Year	Project	Type	Amount (US$ Million)	Executing Agency	Project Description Progress
2021/1 ～ 2026/7	Bangladesh Power System Enhancement and Efficiency Improvement Project -Additional Financing	Loan	200	Bangladesh Rural Electrification Board (BREB) Ministry of Power, Energy and Mineral Resources (MoPEMR)	46,000 km (Original: 38,000 km) of 33 kV and 11 kV distribution lines and associated facilities rehabilitated, and over 16,000 km (Original: 12,000 km) of 33 kV and 11 kV distribution lines and associated facilities
2020/11～ 2023/12	Sustainable and Resilient Energy Sector Facility in Bangladesh	Technical Assistance Special Fund	1	MoPEMR	technical assistance (TA) facility
2020/7～ 2024/12	Dhaka and Western Zone Transmission Grid Expansion Project	Grant Loan co-financed with AIIB	300	Power Grid Company of Bangladesh, Ltd. (PGCB)	Complementing the investment in the recently-approved Southwest Transmission Grid Expansion Project and Rupsha 800-Megawatt Combined Cycle Power Plant in the southwest region
2019/7～	Spectra Solar Power Project	Loan	15	Shunfeng Investments Limited Spectra Engineers Limited	The project consists of a 35-megawatt (net) grid connected solar power plant in Paturia, Shibaloy, Manikgonj, located approximately 85 kilometers west of Dhaka. The project site includes 141 acres of land, an approximately 7 km interconnection transmission line
2018/12～ 2021/11	Capacity Development for	TA	1.9	Ministry of Power, Energy and Mineral	The knowledge and support technical assistance (TA) to

Calendar Year	Project	Type	Amount (US$ Million)	Executing Agency	Project Description Progress
	Renewable Energy Investment Programming and Implementation			Resources	Bangladesh's' energy agencies will help strengthen their planning and technical skills in preparing a renewable energy investment plan
2018/9～2023/12	Southwest Transmission Grid Expansion Project	Grant Loan	350	Power Grid Company of Bangladesh, Ltd. (PGCB)	The project will improve the operational performance of the power sector and contribute to the Government of Bangladesh's target to achieve electricity for all by 2021 through (i) constructing (a) a 400/132-kilovolt (kV) substation at Gopalganj; (b) a 230 kV transmission line in the southern zone, from Barisal to Faridpur; and (c) a 400 kV transmission line in the western zone, from Bogra to Rohanpur; and (ii) implementing a capacity development program in the electric utility industry to promote socially and gender inclusive growth . The project will use state-of-the-art conductors with higher power transmission capacity and lower energy loss in both the 230 kV and 400 kV transmission lines
2018/8～2022/12	Rupsha 800-Megawatt Combined Cycle Power Plant Project	Loan	500 Islamic Development Bank 300	North-West Power Generation Co. Ltd.(NWPGCL)	Project implementation ongoing although facing some delay due to COVID-19 pandemic.
2017/12～2019/12	SASEC Bangladesh-India Electrical Grid Interconnection Project	Technical Assistance Special Fund	US$ 225,000	PGCB	Output 1 Roadmap for cross border power trading for Bangladesh finalized. Output 2 Technical and sector studies for potential interconnection projects prepared
2017/9～2019/12	Southwest Transmission Grid Expansion Project	Technical Assistance Special Fund	1.25	PGCB	prepare an investment project for developing and expanding the transmission network in southern and western zones of the country
2017/6～2021/12	Bangladesh Power System Enhancement and Efficiency Improvement Project	Grant Loan	600	Bangladesh Rural Electrification Board Dhaka Electric Supply Company Ltd. (DESCO) Power Div-Min of Power, Energy & Mineral Resources Power Grid Company of Bangladesh, Ltd. (PGCB)	The project will build a 174 km transmission line linking Dhaka to the southwest of the country, and introduce new control systems and other improvements to distribution networks in Dhaka and rural areas.

Source: ADB Website

(3) Islamic Development Bank: IDB

The Islamic Development Bank created a new regional hub in Dhaka in September 2018. The purpose is to support the sustainable social and economic development of the region through this hub. Bangladesh is the bank's largest beneficiary and will carry out more projects through this hub.

Table 3.4-5 shows the projects underway or planned in power sector, which include new development and renovation of power plants and strengthening of the power grid.

Main supports to power sector from IDB are shown in Table 3.4-5.

Table 3.4-5 Main Supports to Power Sector from IDB

Calendar Year	Project	Type	Amount (US$ Million)	Executing Agency	Project Description Progress
2018/5～	Bhola 220 MW Dual Fuel Combined Cycle Power Plant Project	Loan joint with AIIB	60	SP Group	The project involves the construction and operation of a 225 MW dual fuel Combined Cycle power plant at Bhola, an island situated 250 km south of Dhaka in Bangladesh.
2015/4～	Power Grid Expansion Project	Loan	220	Power Grid Company of Bangladesh, Ltd. (PGCB)	The project includes the construction of new 400kV, 230kV and 132kV transmission lines and substations as well as strengthening of the distribution network in Dhaka.
2017/10～	400 MW Ashuganj East Power Plant Efficiency Improvement	Loan joint with ADB	327.57	Ashuganj Power Station Company Ltd (APSCL)	The project aims at satisfying the increasing demand of electricity through improving the efficiency of the generation system by replacing old and inefficient power plant units at Ashuganj power plant complex by a modern and efficient 400 MW CCPP.

Source: IDB Website

(4) Asian Infrastructure Investment Bank: AIIB

Bangladesh was one of the first countries to receive support from the Asian Infrastructure Investment Bank in 2016. Four projects are underway in the power sector. The power sector includes strengthening power generation (IPP business) and transmission and distribution.

Main supports to power sector from AIIB are shown in Table 3.4-6.

Table 3.4-6 Main Supports to Power Sector from AIIB

Calendar Year	Project	Type	Amount (US$ Million)	Executing Agency	Project Description Progress
2018/2～	Bhola 220 MW Dual Fuel Combined Cycle Power Plant Project	Loan joint with IDB	60	SP Group	The project involves the construction and operation of a 225 MW dual fuel Combined Cycle power plant at Bhola, an island situated 250 km south of Dhaka in Bangladesh.
2016/6～	Bangladesh Distribution System Upgrade and Expansion Project	Loan	165	The Bangladesh Rural Electrification Board (BREB) Dhaka Electric Supply Company Limited (DESCO)	The Project will enhance power distribution capacity and increase the number of rural and urban electricity consumers in Bangladesh, and is comprised of two components: (1) provision of about 2.5 million service connections to rural consumers; (2) upgrading two grid substations and conversion of 85 km overhead distribution lines into underground cables in north Dhaka.
2019/4～ 2022/12	Bangladesh Power System Upgrade and Expansion Project	Loan	120	Power Grid Company of Bangladesh, Ltd. (PGCB)	The objective is to upgrade and expand the power transmission system in the Chittagong region to ensure adequate and reliable power supply in the southeastern region of Bangladesh. Upon completion, the capacity of the transmission network in the Chittagong region will be enhanced, load shedding will be reduced, and new consumers will be

Calendar Year	Project	Type	Amount (US$ Million)	Executing Agency	Project Description Progress
					connected to the grid. This will further create some cascading benefits to the 132 kilovolts (kV) and 33 kV secondary networks with respect to the quality of power supply in the region, such as improved voltage stability and reduced voltage fluctuation.
2020/1～	Dhaka and West Zone Transmission Grid Expansion Project	Loan co-financed with ADB	200	Power Grid Company of Bangladesh, Ltd. (PGCB)	The proposed Project will include three components. • Component 1: construction of substations with a total capacity of 4,450 megavolt-ampere (MVA) and transmission lines of 40 km in Greater Dhaka. • Component 2: construction of substations with a total capacity of 2,990 MVA and transmission lines of 368 km and 20 bay extensions in Western Zone. • Component 3: strengthening of institutional capacity of Power Grid Company of Bangladesh (PGCB).

Source: AIIB Website

3.4.3 Supports from each country

(1) Germany

Bangladesh development cooperation by Germany focuses on relatively abundant renewable energy and reduction of electricity loss. For this purpose the German Reconstruction Finance Corporation (Kreditanstalt für Wiederaufbau: KfW) has funded the construction of energy-efficient transmission and distribution networks and supported the installation of prepaid electricity meters to promote energy-saving behavior. KfW is promoting domestic biogas plants to increase energy supply in rural areas, supporting solar pumps for irrigation and solar home systems that supply energy to local residents. These technologies enable electrification in areas far from the country's power grid and are an alternative to traditional energy sources such as cow dung, firewood and kerosene.

Since 2007, the loan to Infrastructure Development Company Ltd (IDCOL) has reached 16.5 million EUR, and 440,000 solar home systems have been introduced.

(2) Russia

When the nuclear power plant construction plan was resumed in the 1990s, Russia officially proposed the construction of two 1,000MW class nuclear reactors in March 2009. In November 2011, the Bangladesh Atomic Energy Commission and Rosatom of Russia signed an intergovernmental agreement on the construction of the Rooppur nuclear power plant, and Atomstroyexport was selected as the main contractor. 90% of the construction funds were financed by a loan from Russia, and construction of Unit 1 began on November 30, 2017.

The power plant is located in Rooppur, about 140km west of the capital Dhaka, and will be delivered with an improved Russian pressurized water reactor (Gross; 1,200MW x 2 units) manufactured by Atomstroyexport, a Russian nuclear power company. Unit 1 is scheduled to start operation in 2023, and Unit 2 is scheduled to start operation in 2024.

(3) China

In March 2014, the state-owned North-West Power Generation Company (a subsidiary of the Bangladesh Power Development Commission) and CMC (China National Machinery Import & Export (Group)

Corporation) signed a memorandum of understanding to build a 1,320MW Payra coal-fired power plant. . This project will be located on the banks of the Ramnabad Channel near Payra Bandar. The estimated cost was $ 2 billion.

According to BCPCL (Bangladesh-China Power Company Limited) in November 2019, Unit 1 has been completed, but the transmission facilities are not yet ready, so the power plant is currently scheduled to start operations in 2020. The test power generation at the power plant started on January 13, 2020.

Commercial operation started in May 2020 due to the impact of Covid-19 and delays in power transmission facilities.

Regarding funding sources, it was reported in October 2014 that BCPCL would provide 30% of the $ 2 billion project funding and mobilize the remaining 70% from international funding sources.

In April 2016, BCPCL announced that it would invest $ 1.56 billion in the Payra coal-fired power plant. 80% of the investment will be funded by a loan from the Bank of China.

In October 2016, the government approved a US $ 1.9 billion loan from Exim Bank of China for this project, maintaining its debt-to-capital ratio at 70:30. Investment from BCPCL at this ratio was $ 815 million.

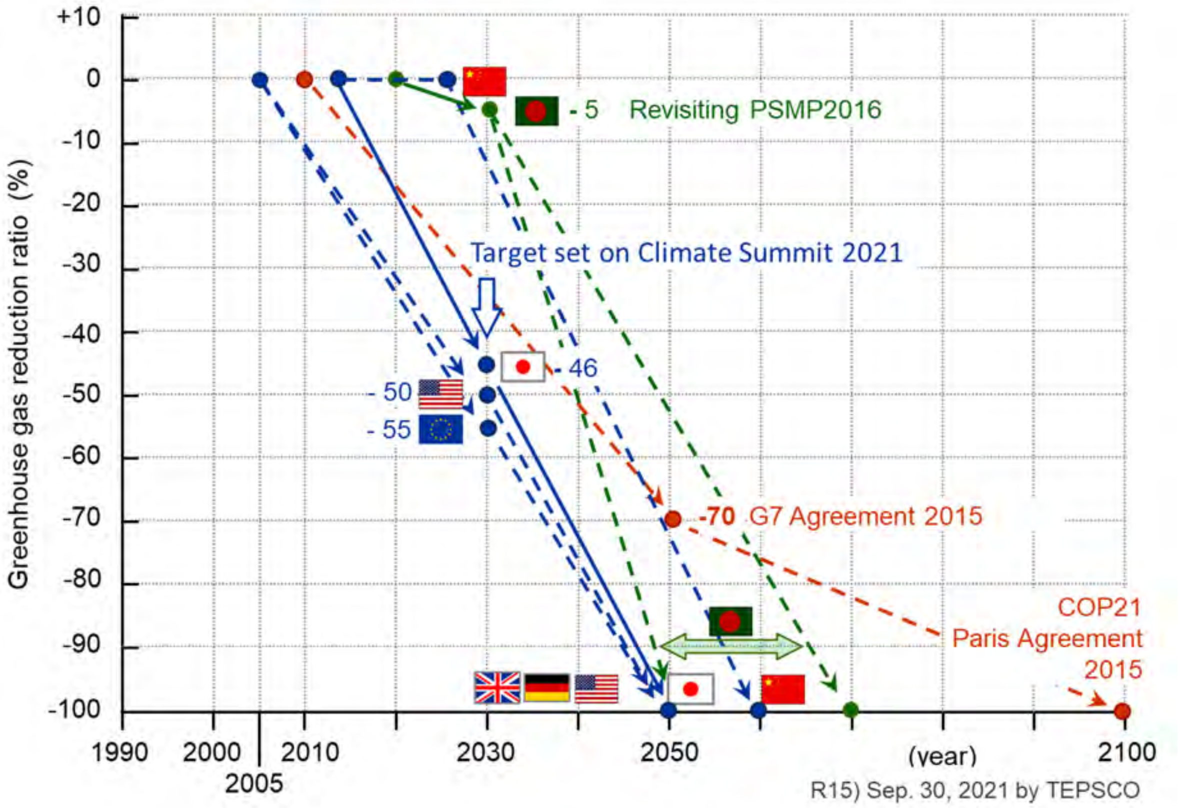
(4) India

Based on a memorandum of understanding (MoU) signed between Bangladesh Power Development Board (BPDB) and National Thermal Power Corporation (NTPC) in August 2010. 2000 acres of land for the Rampal power plant was acquired. On January 29, 2012, BPDB and NTPC agreed to establish a joint venture, Bangladesh-India Friendship Power Company (BIFPC), to carry out the project on a 50:50 equity basis to build the plant. NTPC will build and operate the plant. Bangladesh and India share up to 30 percent of the project's capital equally. The remaining capital, worth US $ 1.5 billion, was made into a bank loan with the support of NTPC.

Construction has been significantly delayed due to the opposition movement, which is concerned about the impact on the adjacent Sundarbans and the response to Covid-19. The progress rate is 50% as of July 2020.

Chapter 4 Technical Study for Balancing the Introduction of Coal-Fired Thermal Power with Low-Carbonization and De-Carbonization

4.1 Changes surrounding coal-fired power generation in the world



Source: Study Team

Figure 4.1-1 GHG Reduction Targets of Major Countries and the Paris Agreement

Figure 4.1-1 shows the GHG reduction targets of major countries and the Paris Agreement.

The Paris Agreement, presented in 2015, aims to achieve zero greenhouse gas emissions by the end of 21st century. In contrast, at the Climate Summit 2021 held on April 22, 2021, hosted by the U.S., all major countries presented challenging goals, as shown in the figure. Japan announced a target of -46% in 2030 compared to 2013, the US -50% in 2030 compared to 2005, and the EU -55% in 2030 compared to 2005. In addition, China aims to peak out by 2025 and achieve zero emissions by 2060.

In addition, Bangladesh has already announced its policy to achieve -15% in 2030 compared to 2020. And it is necessary to consider what kind of national energy goals Bangladesh will set in the future.

(1) Climate Changes Summit (in April 22, 2021)

U.S. President Joe Biden said at the Virtual Climate Change Summit, which opened on April 22, that this is the "Decade of Victory" in tackling climate change.

President Biden pledged that the U.S. will reduce its carbon dioxide (CO_2) emissions by 50-52% below 2005 levels by 2030. He nearly doubled the previous target of a 26-28% reduction by 2025.

Representatives from 40 countries and regions attended the climate change summit, but India and China, the world's largest CO_2 emitters, did not present any new initiatives.

In his opening remarks at the summit, President Biden said,

"Scientists are telling us that this is a critical decade in addressing climate change and that it is time to make decisions that will avoid the worst consequences of the climate crisis.

We must work to limit the rise in global temperatures to 1.5 degrees Celsius.

In a world above 1.5 degrees Celsius, severe fires, floods, droughts, heat waves and hurricanes will be more frequent than now. It will tear communities apart and kill. It will mean tearing apart communities and

destroying lives and livelihoods.
It is a moral and economic imperative that we take immediate action on climate change."

(2) G7 Summit (in June 11-13, 2021)

One of the major subjects of the G7 Summit held in Cornwall, UK from June 11-13 was climate change and environmental issues.

The UK, the presidency of the summit, is also the presidency of COP26 November 2021, and it had a clear strategy to send a positive message to COP26 at the G7 Summit.

As of May 2021, all G7 countries had announced a net zero emission target for 2050, and had also announced an increase in the 2030 target in line with this. The UK government's intention is to pin this down and send a positive message toward carbon neutrality at the G20 level, in cooperation with Italy, the chair of the G20 process.

Outline of the climate change-related part of the summit declaration

1. Commits to a net-zero target by 2050 at the latest, and to a 2030 target raised accordingly by individual countries
2. Phase out new direct government support for international fossil fuel energy, with limited exceptions, as soon as possible
3. Committing to end by the end of this year new international direct government support for coal-fired power generation for which no emission reduction measures have been taken.
4. Committing countries to increase and improve overall international public climate finance through2025 to support developing countries.
5. Decarbonize domestic power system in Japan to the maximum extent possible in the 2030s.
6. Rapid expansion of technologies and policies in Japan to further accelerate the transition away from coal-fired power generation with no emission reduction measures in place to achieve the NDC (mid-term targets for 2030) and net zero commitments.

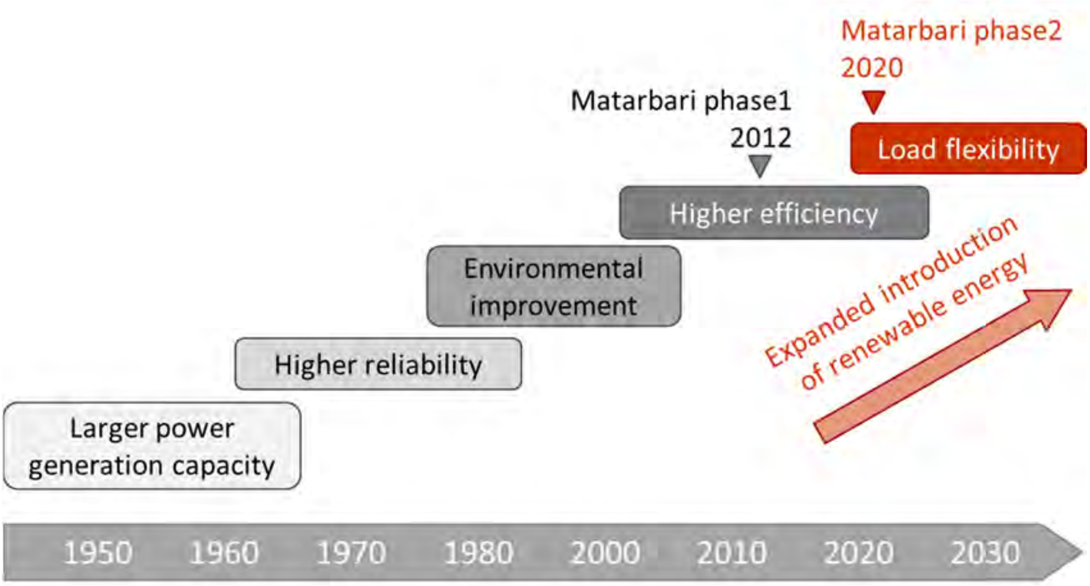
(3) Technical Study for Balancing the Introduction of Coal-Fired Thermal Power with Low-Carbonization and Decarbonization

As shown in Figure 4.1-1, the environment surrounding thermal power is rapidly changing toward low-carbonization and decarbonization in 2021. Therefore, the coal-fired power plants currently planned for Matarbari Units 3/4 will be subjected to technical studies to adapt to such changes in the environment as much as possible.

The main items for consideration are

・Coal-fired power generation that can be adapted to the renewable energy expanding era.
・Coal-fired thermal power that can be adapted to the low-carbon era.
・The possibility of realizing CCS, which is required to achieve zero emissions.
etc.

The contents of these studies are described below.



Source: Study Team

Figure 4.1-2 Transition of Needs for Thermal Power around the World

Figure 4.1-2 shows the transition of needs for thermal power around the world.

In the 1950s, when thermal power became the leading role of power generation, it responded to needs such as increasing the capacity of power generation and then improving reliability and the environment in response to changes in the times. Then, in the 2000s, high efficiency aimed at reducing fuel costs became a need for thermal power.

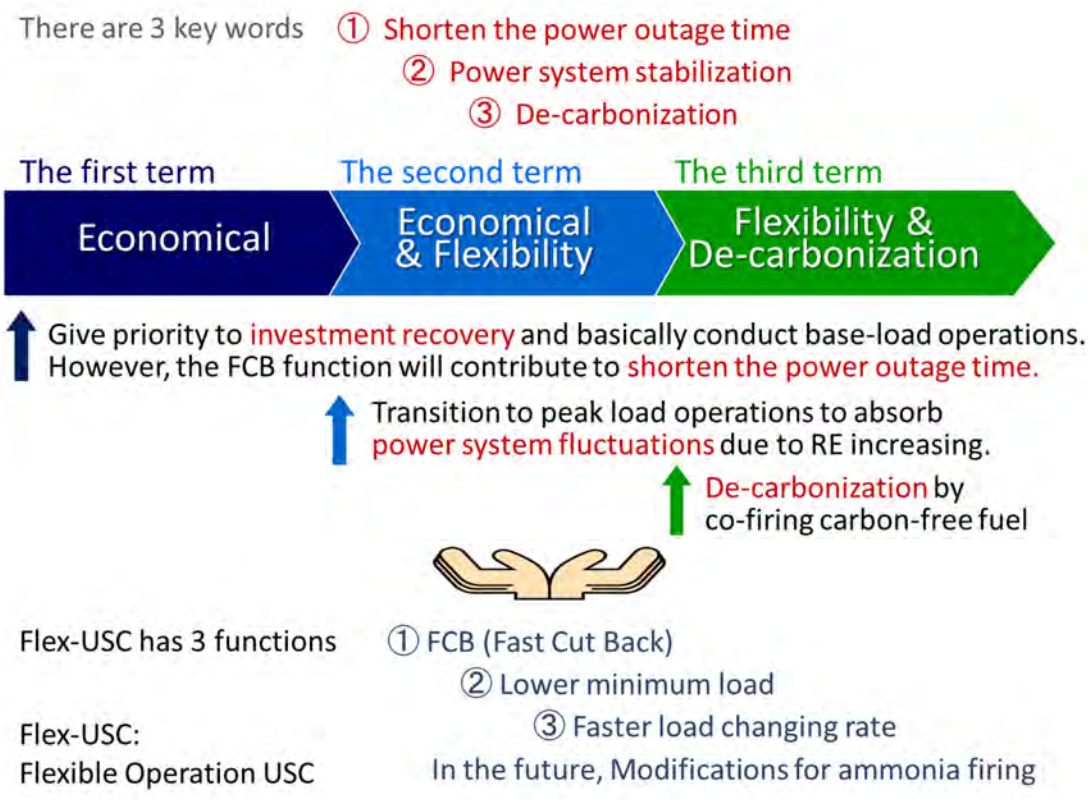
In the Units 1/2 planned in 2012, it was decided to introduce Ultra Super Critical thermal power plant (USC) in response to the needs for higher efficiency at that time.

About 10 years have passed, now we are in an era of expanding the introduction of the renewable energy in order to meet the Green House Gas reduction targets of the Paris Agreement adopted in 2015. It is said that solar power depends on the weather, wind power depends on the wind, and the renewable energy is a discontinuous power source. In such an era of expanding the introduction of the renewable energy, it is necessary to consider a system configuration that considers the stabilization of the power system more than ever.

Therefore, in this study, the Study Team will investigate the major system accidents and power outages that occurred in major countries, and evaluate the USC that has a load flexibility function.

4.2 Operation policy of Units 3/4

4.2.1 Operation policy of Unit 3/4 to meet the need of the times



Source: Study Team

Figure 4.2-1 Operation policy of Units 3/4 to meet the needs of the times

Figure 4.2-1 shows the operational policy plan for Units 3/4 to meet the needs of the times.

Up to now, coal-fired power plants have aimed for higher efficiency in order to reduce fuel costs. In addition, base-load operation has been the basic approach, taking advantage of the low cost of fuel.

However, in recent years, as a countermeasure against accelerating global warming, there has been a shift in the direction of increasing renewable energy and reducing coal-fired power generation. In order to respond to this trend, challenging greenhouse gas reduction targets are being considered in Japan, and it is desirable to make Unit 3/4 systems that take this historical background into account.

Figure 4.2-1 summarizes the operation policy of Units 3/4 in response to this historical background.

There are three key words in the operation policy.

1. Shorten the power outage time
2. Power system stabilization
3. De-carbonization

In addition, Flex-USC (Flexible Operation USC), which will be applied to Units 3/4, has three functions, and these can be adapted to the needs of each era.

- In the first step, priority will be given to investment recovery based on base load. However, by providing the FCB function (Fast Cut Back: detailed explanation is given in Section 4.3.12) from 100% load, the power outage time will be shortened.
- In the second step, the system will be shifted to peak load operation as needs to absorb load fluctuations caused by renewable energy.
- In the third step, the system will be converted to carbon-free fuels to achieve zero emissions. For

example, biomass or ammonia co-firing.

4.2.2 The function of Flex-USC

Table 4.2-1 Comparison between USC and Flex-USC

		USC		Flex-USC
		Matsuura#2	Matarbari#1,#2	Matarbari#3,#4
FCB	from x% load	Available from 30% load	Available from 100% load	Available from 100% load
	HP/LP bypass	40%MCR	70%MCR	70%MCR
Minimum Load		15%	30%	15%
Load Changing Rate		4%/min	3%/min	4%/min (Goal:5%/min)

- The Flex-USC is a combined version of the highest performance of the individual functions in the USC.
- Flex-USC has three main functions.
  - ① The first function is the FCB (Fast Cut Back) .
    It is a function to shift to island operation in the event of a power system accident, which can contribute to shortening the power outage time.
  - ② The second function is the capability of lower minimum load.
  - ③ The third function is the increasing the load changing rate.
  - ⇨ Power system stabilization

Source Study Team

Table 4.2-1 show Comparison between USC and Flex-USC.

The Flex-USC is a combined version of the highest performance of the individual functions in the USC.

Table 4.2-1 compares USC and Flex-USC with respect to the functions of Fast Cut Back (FCB), minimum load, and the rate of load change. For the USC, Kyushu Electric Power Company, Matsuura Unit 2 and Matarbari Units 1 and 2 were compared as representative plants of the USC.

As can be seen from the table, there is no significant difference in the function of USC of Matarbari Units 1 and 2 and Flex-USC of Matarbari Units 3 and 4.

FCB functions are exactly the same for both USC and Flex-USC.

Minimum load function is lower in Flex-USC (15%) compared to 30% in USC.

The load changing rate is 3%/min for USC, while it is 4%/min for Flex-USC (Goal: 5%/min), a slight functional difference.

However, by adding an inverter to the Pulverizer applied to the USC, the minimum load can be reduced from 30% to 15%.

The load changing rate can be faster from 3%/min to 4%/min and 5%/min by tuning the control parameters of the control system applied to the USC.

(1) FCB

FCB (Fast Cut Back) is a function that disconnects a power plant from the power system and shifts it to island operation in the event of a power system accident. After that, the plant continues to operate at the in-plant load, and after the power system accident is restored, the plant quickly ramps up to the original load. This type of FCB function can contribute to shortening the power outage time due to a grid accident.

Kyushu Electric Power Company, Matsuura Unit 2 is available for FCB from 30% load and below, but does not allow FCB from 100% load due to the 40% HP/LP bypass valve capacity.

The reason for this is that there are many gas-fired power plants, so the FCB function is not required for On the other hand, Matarbari Units 1 and 2 allow FCB from 100% load because the HP/LP bypass valve capacity is 70%.

(2) Minimum load operation

The figures for Kyushu Electric Power Company, Matsuura Unit 2 and Matarbari Units 1 and 2 are 15%

and 30%, respectively.

Kyushu Electric Power has already seen a significant increase in the amount of solar power generation, which has led to a strong need for load adjustment capability for thermal power generation, and a need to reduce the minimum load for coal-fired USC, which has been reduced to 15%.

On the other hand, at the time of the planning of Matarbari Units 1 and 2 in 2012, the design was carried out with a minimum load of 30% because the policy was based on base-load operation.

About 10 years have passed since then, and the expansion of RE installation has become a global trend. Therefore, it is preferable to reduce the minimum load to 15% for Units 3/4, which are currently under consideration for specification.

(3) Load changing rate

For Kyushu Electric Power Company, Matsuura Unit 2, the load change rate has been set at 4%/minute, which is faster than that of the conventional USC, in order to improve the load flexibility capability required in the era of expanding RE installation.

On the other hand, Matarbari Units 1 and 2 are being designed with a load change rate of 3%/minute, based on the idea of base-load operation.

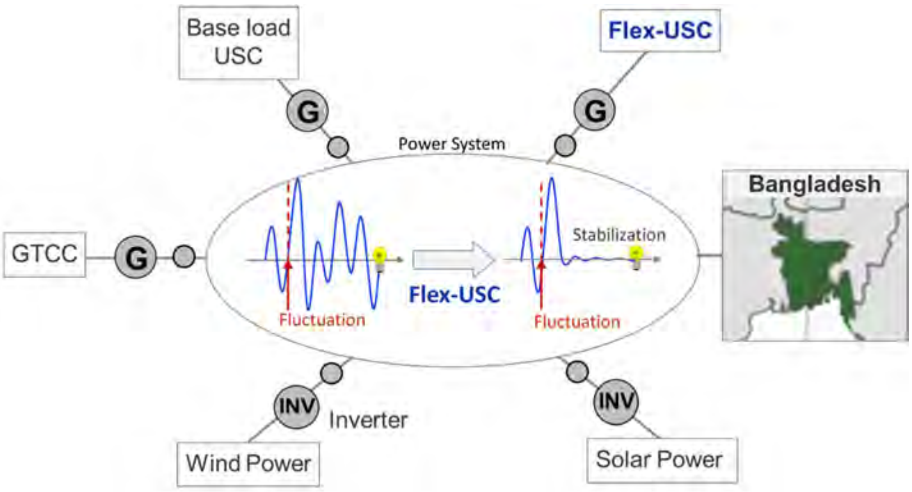
For Units 3 and 4, as well as the minimum load, the highest performance that USC has, 4%/minute, will contribute to the load regulation capability.

As mentioned so far, USC has not been designed to a unified specification because each USC is designed according to its own needs.

Flex-USC can contribute to the needs of the times for load flexible operation by combining the best performance of conventional USCs.

4.3 Approaches to power system stabilization

4.3.1 Energy best mix to achieve power system stabilization



Source: Study Team

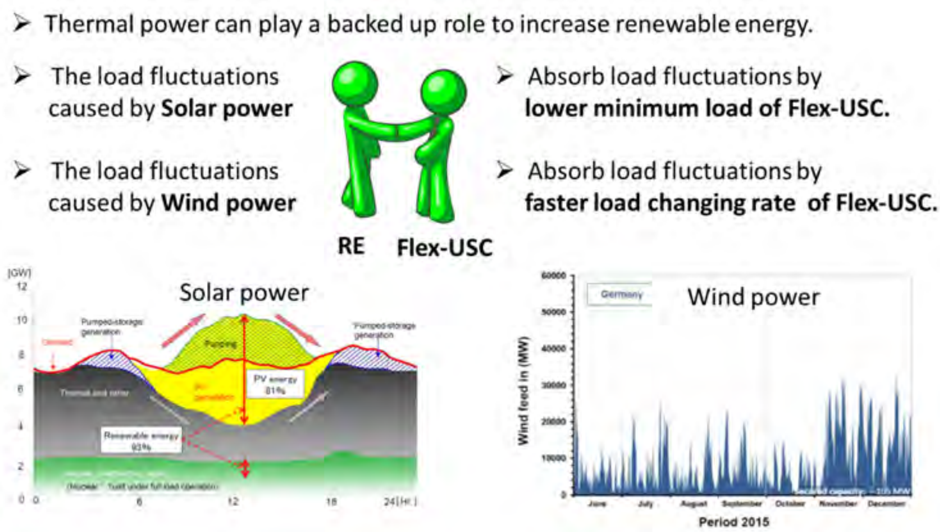
Figure 4.3-1 Energy best mix to achive power system stabilization

Figure 4.3-1 shows the energy best mix to achieve power system stabilization.

In Bangladesh, the power system is mainly composed of coal-fired thermal power based on existing baseload, and gas-fired GTCC.

On the other hand, as shown in Figure 4.1-1, the country's energy master plan is currently undergoing a challenging study to achieve zero emissions between 2050 and 2070. Looking ahead to 2050, renewable energy sources such as solar power are expected to increase further. As renewable energy is a discontinuous power source, even coal-fired power plants will be required to have Flex-USC functions with excellent load flexibility capabilities in order to maintain power system stabilization.

4.3.2 Energy best mix to achieve power system stabilization



Source: Study Team

Figure 4.3-2 Renewable energy and thermal power generation are complementary

Figure 4.3-2 shows Renewable energy and thermal power generation are complementary.

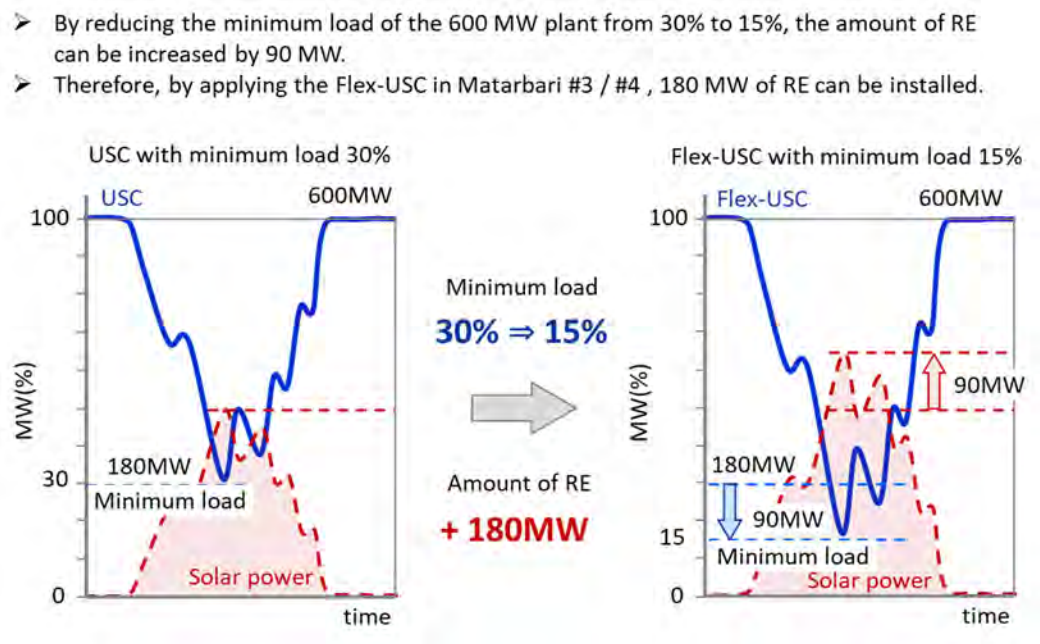
Thermal power generation with excellent load flexibility capability can absorb the fluctuation of renewable energy in the era of expanding introduction of renewable energy, which is a discontinuous power source.

Figure 4.3-2 left shows the 24-hour load curve. During the daytime when the weather is fine, the amount of solar power generation shown in yellow is large, and thermal power generation shown in gray is reduced to the minimum load, but the excess over the power demand shown in the red line is used as nighttime power by pumped storage power generation.

Such large load fluctuations caused by solar power generation can be absorbed by the minimum load of thermal power generation.

In addition, the right side of Figure 4.3-2 shows the fluctuation of wind power generation from June to December. As can be seen from the figure, the load change due to wind power is large and the load change rate is high. This rapid load change caused by wind power can be absorbed by making the load change rate of thermal power generation faster.

4.3.3 Amount of renewable energy that can be increased by applying Flex-USC



Source: Study Team

Figure 4.3-3 Amount of renewable energy that can be increased by appling Flex-USC

Figure 4.3-3 shows the amount of renewable energy that can be increased by applying Flex-USC.

Figure 4.3-3 compares a USC with an output of 600 MW and a minimum load of 30% (180 MW) and a Flex-USC with a minimum load of 15% (90 MW) to see how much renewable energy can be increased by lowering the minimum load.

Figure 4.3-3 on the left shows the case with a minimum load of 30%, and the right shows the case with a minimum load of 15%.

As can be seen in the figure on the right, by reducing the minimum load from 30% (180 MW) to 15% (90 MW) for coal-fired power (Flex-USC), we can increase the amount of renewable energy by 90 MW, which is equivalent to the difference.

This is the equivalent of one unit with an output of 600 MW, and two units of Matabari Units 3/4 would double the amount of renewable energy to 180 MW.

This is the effect of increasing renewable energy when the minimum load is lowered, which is one of the functions of Flex-USC.

Flex-USC also has the capability as the load changing rate at 4%/min.

Although it is complicated to calculate the increase in renewable energy from this feature, it can further increase the amount of renewable energy.

As shown in Figure 4.1-1, Bangladesh is expected to significantly increase the use of renewable energy in order to address to the zero emission by 2050 to 2070.

Given this background, it is an effective initiative to reduce the minimum load of Matarbari Units 3/4 and install 180 MW of renewable energy in the available space.

4.3.4 Load Adjustment by Coal-Fired Power in Germany

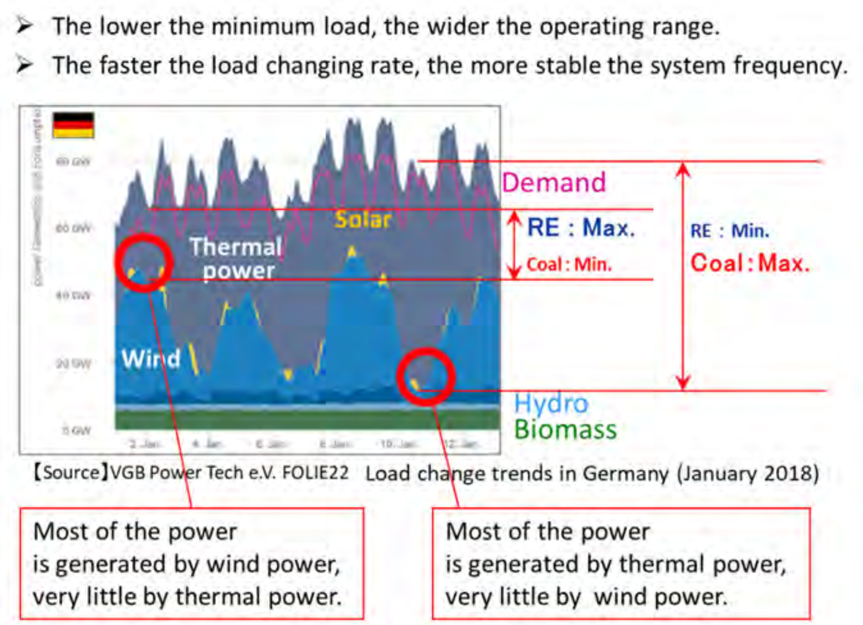


Figure 4.3-4 Actual load changes in Germany (January 2018)

Figure 4.3-4 shows Actual load changes in Germany (January 2018).

The pink line shows electricity demand, the gray area shows thermal power generation, the bright blue area shows wind power generation, and the yellow area shows solar power generation.

Here, looking at the red circled area on the left side of the figure, wind power generation is large on this day, and thermal power generation is greatly squeezed.

On the other hand, at the red circle on the left side of the figure, there is almost no wind power generation, and thermal power generation has increased significantly. Thus, we can see that the role of load regulation power from thermal power generation is significant in an era when the amount of renewable energy is expanding.

The following two points can be seen from Figure 4.3-4.

- ➢ The lower the minimum load is, the larger the operational range is.
- ➢ The faster the load change rate, the more it can contribute to stabilizing the power system.

Figure 4.3-5 shows the operational results of coal-fired power plants in Germany.

This was published by VATTENFALL in 2013, and it shows an example where the minimum load was reduced to 15% with one pulverizer in operation. The trend shows that the load change rate is about 3-4%/minute. In this way, Germany is attempting to stabilize its power system by operating coal-fired power plants, which were previously operated as baseload, as peak load.

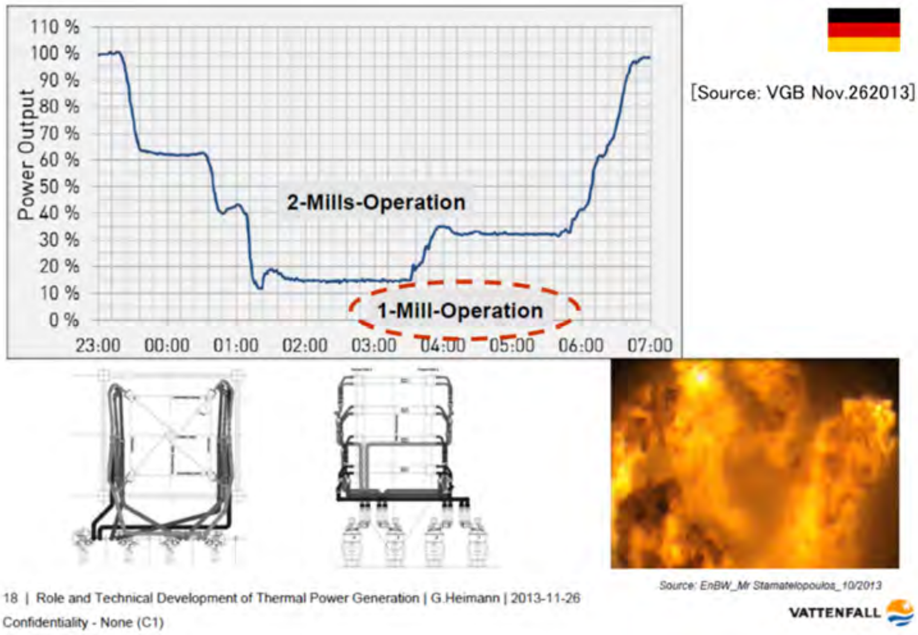


Figure 4.3-5　The operational results of coal-fired power plants in Germany

4.3.5 Load flexibility capability of Coal-Fired Power in Japan

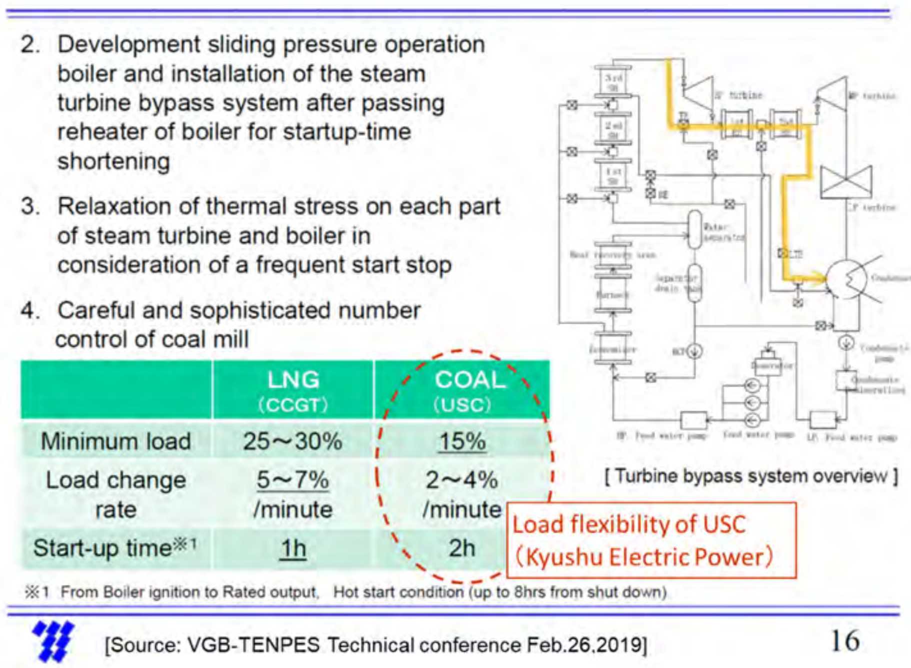
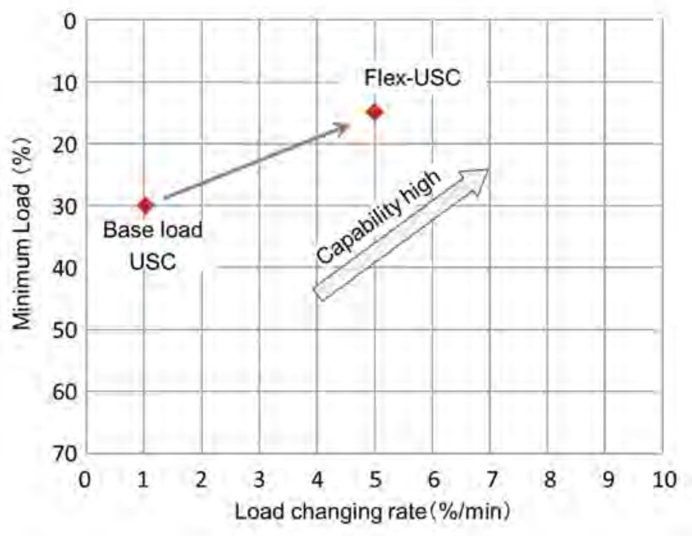


Figure 4.3-6　Operational Performance of Coal-Fired Thermal Power generation in Japan

Figure 4.3-6 shows Operational Performance of Coal-Fired Thermal Power generation in Japan.

In the Kyushu Electric Power area, the solar power generation ratio can exceed 80% during Golden Week when electricity demand is low. Kyushu Electric's Matsuura Unit 2 (600 MW, USC), which was COD in 2019 for such cases, operates with a minimum load of 15% and a load changing rate of 4%.



Source: Study Team

Figure 4.3-7 Load changing rate and minimum load for Flex-USC and Base load USC

Figure 4.3-7 shows Load changing rate and minimum load for Flex-USC and Base load USC.

The minimum load for base load USC in Japan is 30% and the load changing rate is 1%/min. Flex-USC, which requires load flexibility capability, has a minimum load of 15% and a load changing rate of 5%/min.

In 2019, Japan's energy ratio was 18% renewable energy, 76% thermal power, and 6% nuclear power.

In case of the thermal power ratio 76%, coal-fired power will not be required to have load flexibility capability.

On the other hand, the Sixth Basic Energy Plan, revealed in July 2021, plans to increase renewable energy to 38% and reduce thermal power to 41% by 2030.

In order to meet these targets, coal-fired power plants will be also required to improve their load flexibility capabilities (minimum load and load change rate), and there are plans to upgrade existing coal-fired power plants to achieve a minimum load of 15% and a load changing rate of 5% per minute.

In the Renewable Energy expanding era, the faster load changing rate, the better.

As shown in Figure 4.3-10, the variation in the amount of electricity generated by solar power differs greatly between sunny days, cloudy days, and rainy days.

The fluctuations are especially large and fast on cloudy days. This is because clouds form instantly and disappear instantly.

In the renewable energy expanding era, coal-fired thermal power plants will be required to have the load flexibility capability in order to absorb such fluctuations.

Table 4.3-1 Track records of Miminum load operation

No.	Country	Plant	MW (MW)	Press. (Mpa)	MST (dgree C)	MW (dgree C)	Minimum load (%)	COD (year)
1	Japan	A	700	25.0	566	566	15	1995
2	Japan	B	700	24.1	600	600	15	2002
3	Japan	C	1,000	24.5	600	600	15	2019

Source: Study Team

Table 4.3-1 shows the track records of minimum load operation in Japan.

As mentioned above, there has been little need for minimum load operation for coal-fired power plants so far.

However, with the recent increase in the introduction of RE, the need to reduce the minimum load for coal-fired power plants has increased, and the plant that COD in 2019 is operating with a minimum load of 15%.

4.3.6 Thermal efficiency of thermal power plant at partial load

Figure 4.3-8 shows the thermal efficiency of a thermal power plant at partial load.

The green line shows the USC and the red line shows the GTCC. As can be seen in the figure, the thermal efficiency of a thermal power decreases as the load is reduced from the rated load of 100%, but the rate of decrease in the thermal efficiency of USC is smaller than that of GTCC.

In the era of expanding the introduction of renewable energies, thermal power generations will be required to lower the minimum load to absorb large fluctuations in renewable energies, as mentioned so far, but as shown in Figure 4.3-8, USC is more advantageous for partial load operation than GTCC.

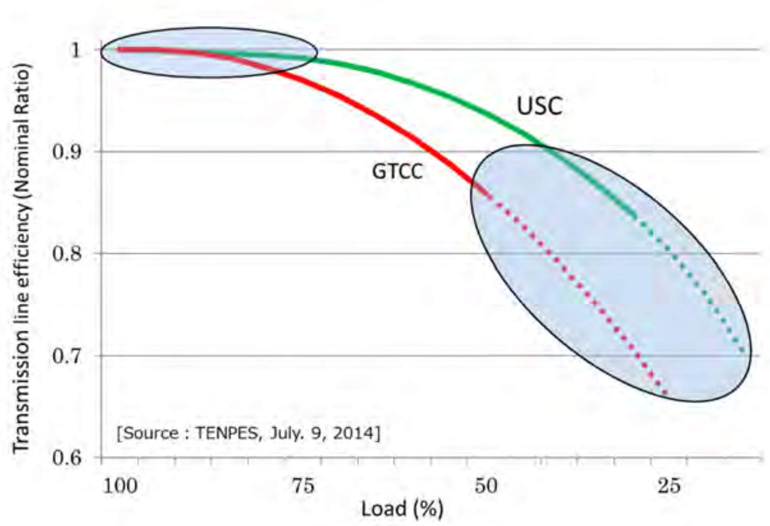
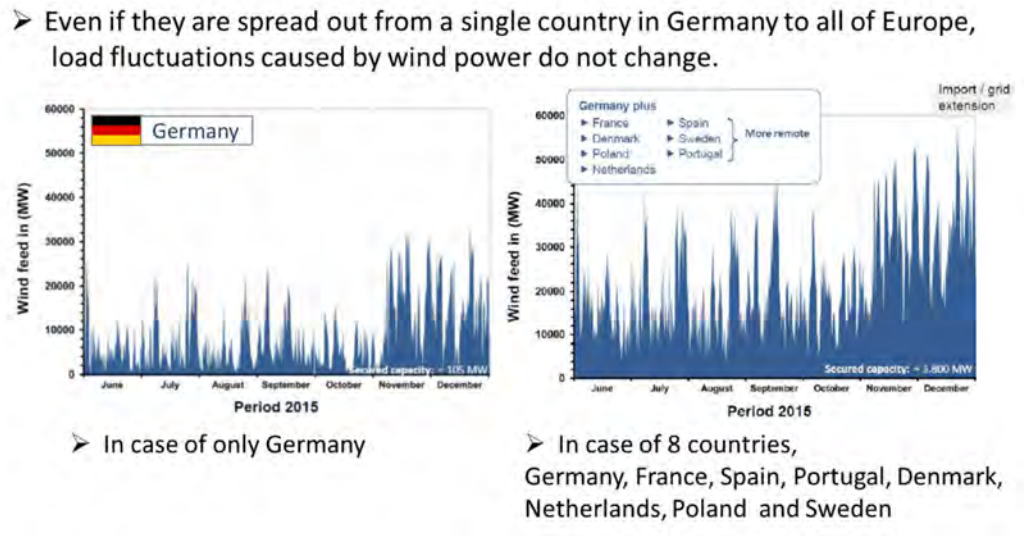


Figure 4.3-8 Thermal efficiency of thermal power plant at partial load

4.3.7 Load fluctuation caused by wind power



Source: Study Team

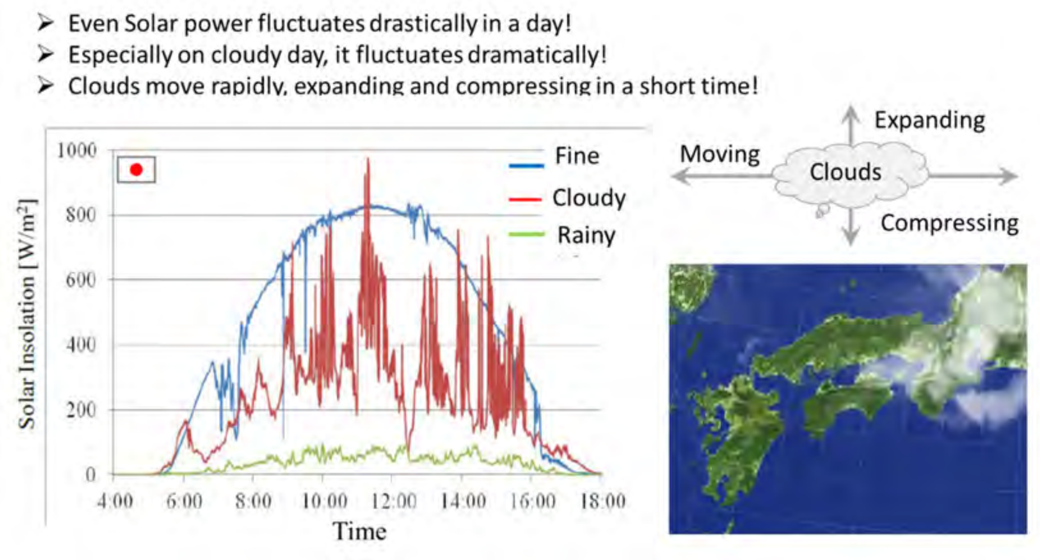
Figure 4.3-9 Load fluctuation caused by wind power

Figure 4.3-9 shows the load change due to wind power generation.

The left side of figure shows the load change due to wind power generation in Germany during the six-month period from June to December. The right side of the figure shows the load change due to wind power generation when eight European countries are interconnected.

These figures show that even if the power system area becomes larger, the load fluctuation does not slow down.

4.3.8 Load fluctuation caused by solar power



Source: Study Team

Figure 4.3-10　Load fluctuation caused by solar power

Figure 4.3-10 shows Load fluctuation caused by solar power.

The blue line shows the amount of solar power generated on a sunny day, the red line on a cloudy day, and the green line on a rainy day. What can be seen from these figures is that the changes in the amount of electricity generated in a day are quite large. Especially on cloudy days, the load fluctuation is rapid and the fluctuation range is large.

On the other hand, almost no power is generated on rainy days.

4.3.9 Load operation of coal-fired power generations in Japan

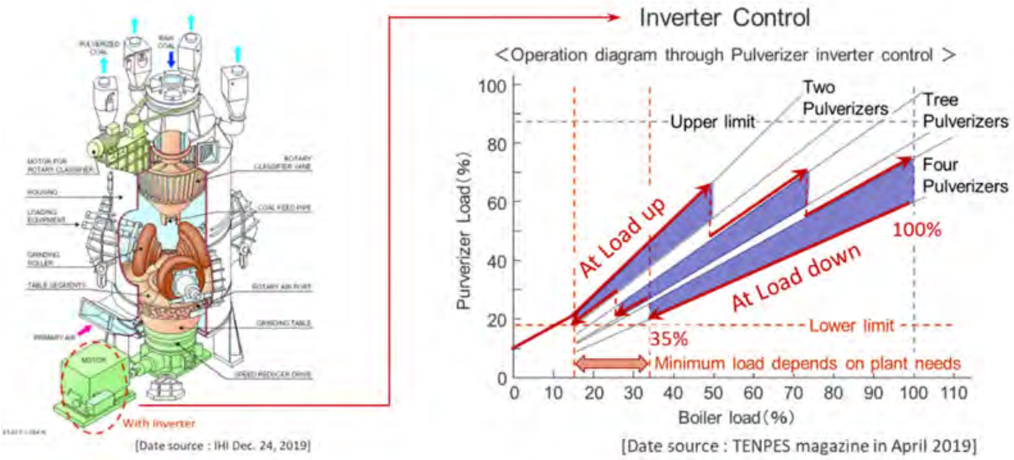


Figure 4.3-11 Load operation of coal-fired power generation in Japan

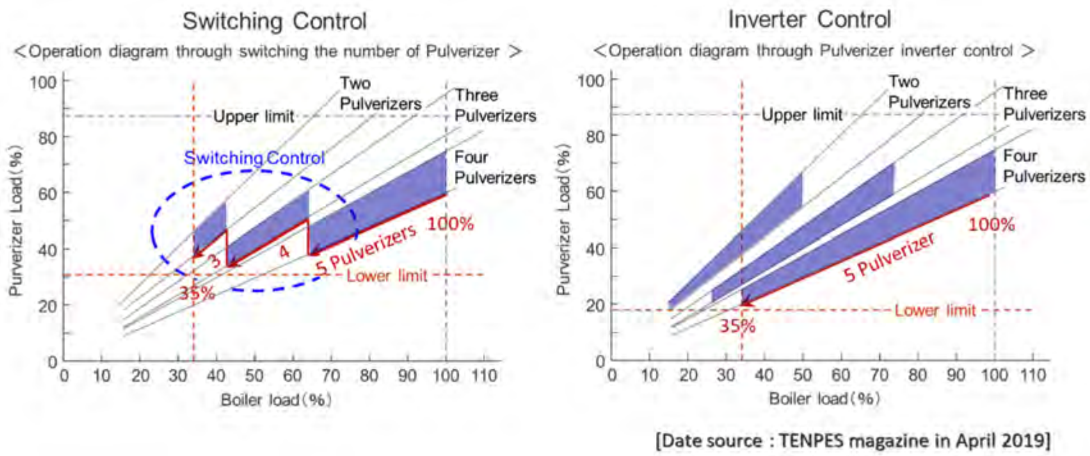


Figure 4.3-12 Comparison between the number of pulverizers control and inverter control

Figure 4.3-11 shows the load operation of coal-fired power plants in Japan, and Figure 4.3-12 shows the comparison between the number of pulverizers control and inverter control.

A pulverizer is an equipment that pulverizes coal as shown in Figure 4.3-11 right. The inverter is used to control the speed of the mill motor shown in Figure 4.3-11.

This section shows an example of operation with four pulverizers at 100% load, however it is common to install one spare pulverizer for maintenance. (Refer to Table 8.3-2)

(1) Load operation with pulverizer inverter control

Figure 4.3-11 shows an example of a load operation pattern with a pulverizer that has an inverter. The application of the inverter expands the turndown of the pulverizer. By applying the inverter, the turndown of the pulverizer is expanded. This allows the load to be changed over a wide area without switching the number of pulverizers. (The turndown of the pulverizer is the operational range of the purverizer load shown on the vertical axis in Figure 4.3-11.)

Figure 4.3-11 shows that four pulverizer can be operated continuously from 100% load to 35% load. To further reduce the load, the minimum load can be reduced to 15% by reducing the number of pulverizers.

(2) Load operation through switching control pulverizers

Figure 4.3-12 compares the comparison between the number of pulverizers control and inverter control. The turndown of the conventional pulverizer without an inverter is narrower than that with an inverter.

Therefore, it is necessary to switch the number of pulverizers when the load down from 100% load to 35% load.

As shown in the left figure of Figure 4.3-12, the load is held at 65% boiler load and the number of pulverizers are switched from 4 to 3. Also, hold the load at 40% boiler load and switch the number of pulverizers from 3 to 2.

Thus, by applying the pulverizer with inverter, the minimum load can be lowered and the load operation can be even more flexible.

Table 4.3-2 Track records of pulverizers with inverters in Japan

No.	Country	Plant	MW	Pulverizer (Numbers)	Manufacture	COD (year)
1	Japan	A plant	600	5	IHI	2002
2	Japan	B Plant	156	3	MHI	2004

Source: Study Team

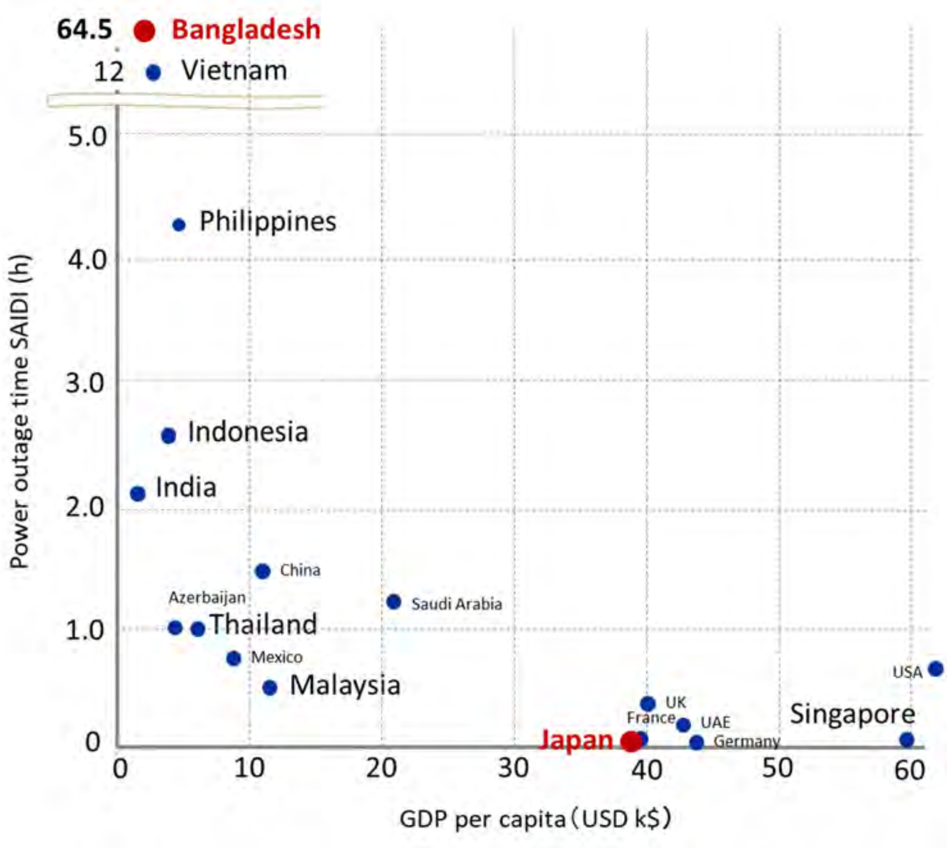
Table 4.3-2 shows Track records of pulverizers with inverters in Japan.

As can be seen in the table, the number of pulverizers with inverters delivered in Japan is a few. This is because there has not been much need for minimum load reduction in Japan.

As the need for load flexibility for coal-fired power plants increases after 2020, the number of purverizers with inverters is expected to increase, based on the delivery record of the purverizers with inverters shown here.

Refer to Appendix-14 for additional costs when applying pulverizers with inverters.

4.3.10 Comparison of power outage times in the major countries of the world



Source: Study Team

Figure 4.3-13 Comparison of power outage times in the major countries of the world

Figure 4.3-13 shows Comparison of power outage times in the major countries of the world.

The vertical axis shows the annual power outage time and the horizontal axis shows the GDP per capita, showing that the higher the GDP, the shorter the power outage time.

The vertical axis shows the annual power outage time, which is 64.5 hours in Bangladesh.

On the other hand, Japan is one of the top countries in the world, with 0.2 hours. There are various factors that cause power outages, but one of the technologies that can be applied to thermal power plants is the enhancement of the FCB function.

Therefore, it can be said that the installation of an FCB function from 100% load in Units 3/4 is an effective measure to shorten the power outage time.

4.3.11 Comparison of Frequency fluctuation between Japan and India

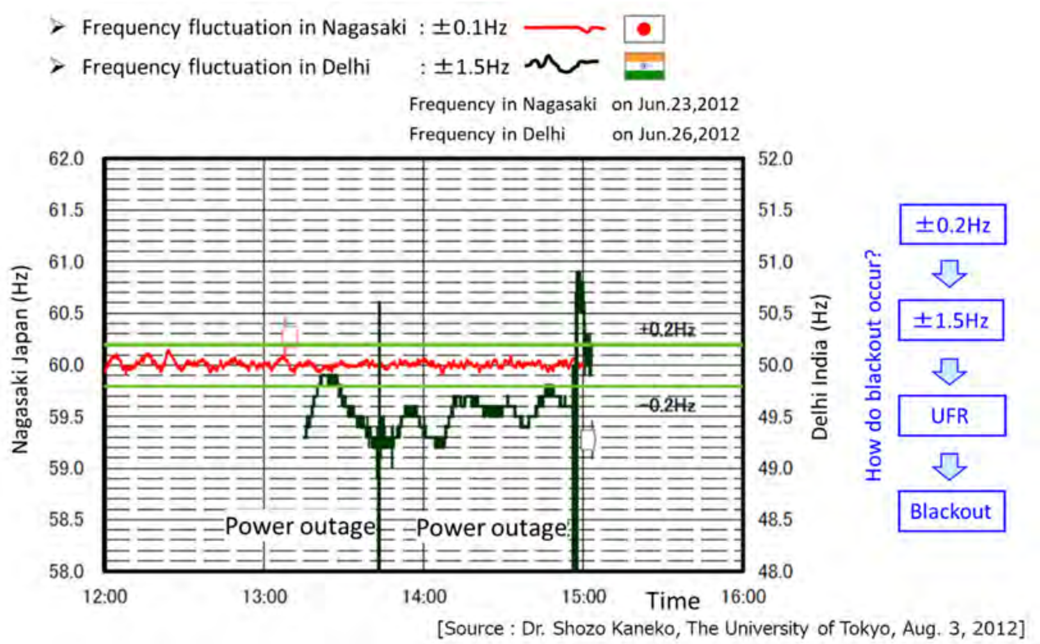


Figure 4.3-14 Comparison of Frequency fluctuation between Japan and India

Figure 4.3-14 shows Comparison of frequency fluctuation between Japan and India.

The fluctuation in red on the trend shows the frequency fluctuation in Japan, and the fluctuation in black shows the frequency fluctuation in India. The fluctuation range of Japan is ±0.1 Hz, while that of India is over ±1.5 Hz, leading to two blackouts in two hours.

Japan is one of the top countries in the world in terms of power outage time (Figure 4.3-13), with less than 0.2 hours per year. The frequency fluctuation is also controlled within ±0.1Hz, which is due to the power system operation and the detailed control function of the power generation facilities including the FCB function.

4.3.12 Island operation (FCB)

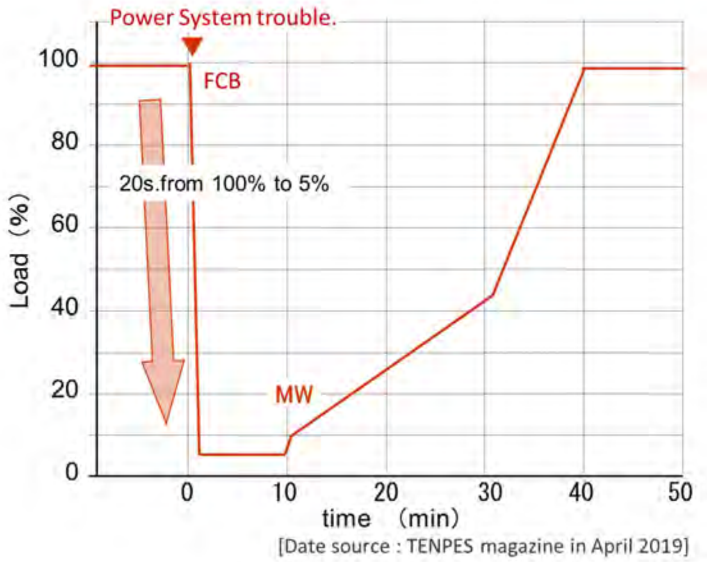
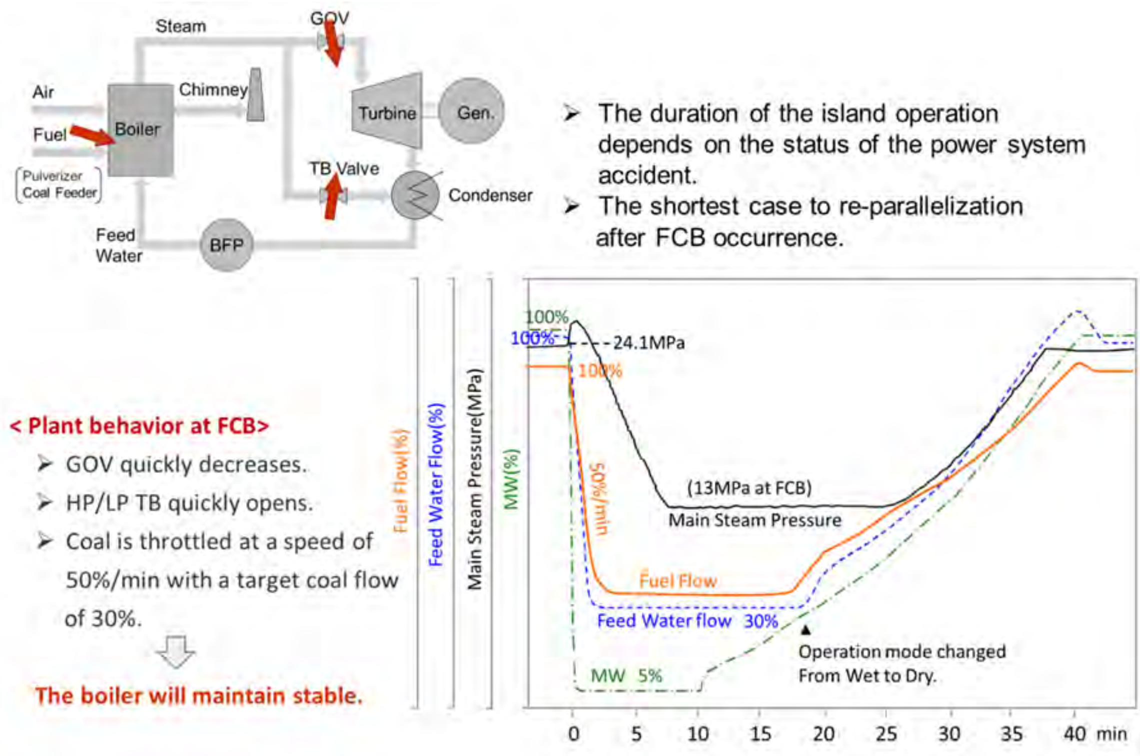


Figure 4.3-15 Island operation (FCB)

Figure 4.3-15 shows Island operation (FCB).

FCB is a function that disconnects the power plant from the grid in the event of some accident in the power system, instantly reduces the load to the on-site load to maintain island operation of the plant, and then quickly connects the plant to the grid when the power system accident is restored.

Figure 4.3-15 shows a case where an FCB occurs from 100% load. As shown in this figure, the time required for grid restoration can be significantly shortened by maintaining operation at the local load, which is expected to shorten the outage time.



Source: Study Team

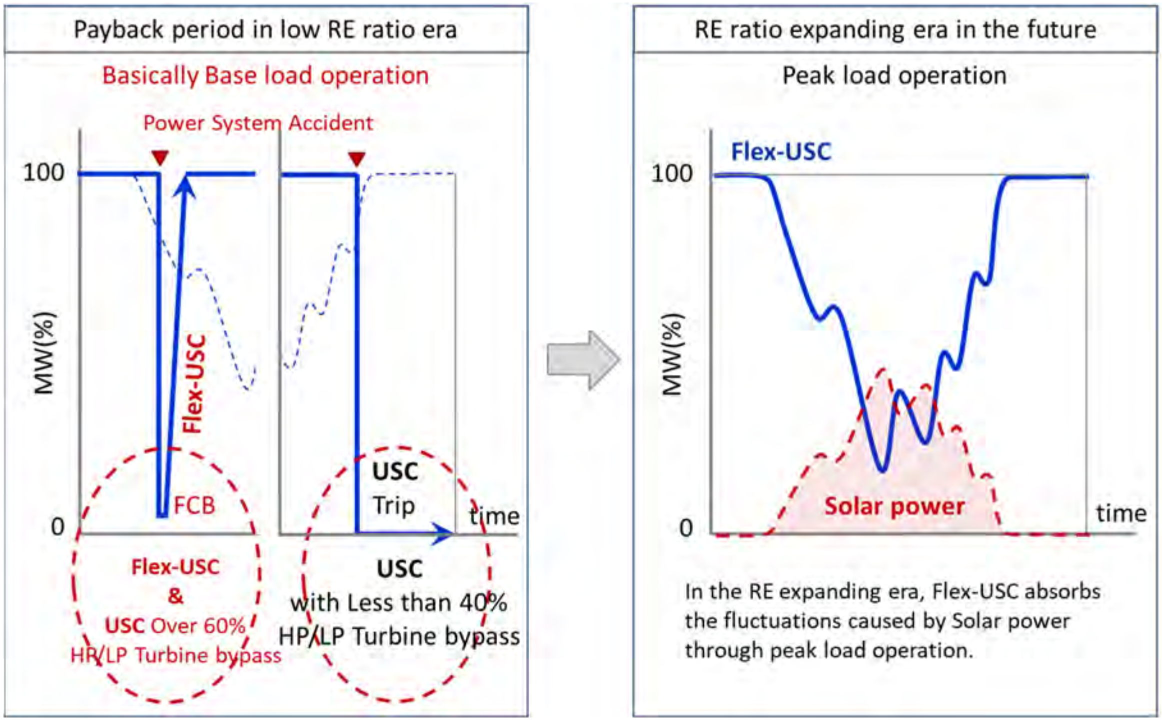
Figure 4.3-16 Plant behavior at FCB

Figure 4.3-16 shows Plant behavior at FCB.

In the lower right of the figure, the MW, feedwater flow rate, and fuel flow rate at the time of FCB occurrence are reduced at high speed to prevent the main steam pressure from rising. After that, the load is maintained, and the load is raised to the original level as soon as possible after the power system accident is restored. Such control during FCB is performed as follows.

- Upon occurrence of FCB, the turbine governor valve (GOV) is instantly throttled.
- HP/LPTB valve opens rapidly as soon as FCB occurs to prevent main steam pressure from rising.
- Fuel (coal) is throttled to 30% equivalent flow at a speed of 50%/min.
- The control condition of the boiler can be stabilized by this kind of control.

4.3.13 Adapting Flex-USC operations to the needs of the times



Source: Study Team

Figure 4.3-17 Adapting Flex-USC operations to the needs of the times

Figure 4.3-17 shows Adapting Flex-USC operations to the needs of the times.

The operational needs of coal-fired power plants are expected to change along with the national energy goals of Bangladesh. Specifically, renewable energies are expected to increase, and coal-fired power plants, which have been operated on a base-load basis, will be required to peak load operation.

(1) FCB functions to be utilized even in the era of baseload operations

The figure on the left shows an example of operation during the period when priority is given to recovering investment after Units 3/4 are operational. For the time being, baseload operation will be the basic operation after the units are COD, but in the event of a power system accident, as shown in Figure 4.3-15, the Flex-USC will be able to continue operation from 100% load using the FCB function, and after the power system accident is restored, it will be able to quickly connect to the power system.

On the other hand, in the case of conventional USC that does not have the FCB function from 100% load, it is expected to take several hours before the unit can be connected to the power system again after the unit trips due to a power system accident. Thus, the application of Flex-USC can be expected to shorten the power outage time by quickly connecting to the power system after a power system accident.

In the case of a unit trip at a USC in Japan, the minimum time required for plant inspection, re-parallelization, and restoration to the original load is about 3 hours, and depending on the situation, it may take about 6 hours. Therefore, if a unit trip can be prevented by applying Flex-USC, the generation time loss of about 3 to 6 hours can be reduced.

Matarbari Units 1/2 are USC, but which have 70% HP/LP turbine bypass capacity as shown in Table 4.2-1. Therefore, FCB function of Matarbari Units 1/2 are equivalent to Flex-USC.

(2) Load flexibility capabilities to be utilized in the renewable energy expanding era

By applying Flex-USC, the minimum load can be narrowed down to 15%, which can contribute to stabilizing the power system by absorbing the fluctuation of renewable energy.

4.3.14 Track records of FCB function from 100% load

Table 4.3-3 Track records of FCB function from 100% load

No.	Country	Plant	MW (MW)	Press. (Mpa)	MST (dgree C)	RST (dgree C)	HP/LP TB 60% or more	Fuel	FCB y/n	COD year
1	USA	A	677	25.5	566	566	y	Coal	n	2010
2	Germany	B	725	26.3	600	620	y	Coal	y	2013
3	Poland	C	1075	24.2	600	620	y	Coal	y	2017
4	Australia	D	420	25	566	566	y	Coal	y	2001
5	Australia	E	420	25	566	566	y	Coal	y	2002
6	Australia	F	420	25	566	566	y	Coal	y	2003
7	Malaysia	G	1,064	26.9	600	600	y	Coal	y	2019
8	Malaysia	H	1,064	26.9	600	600	y	Coal	y	2019

Source: Study Team

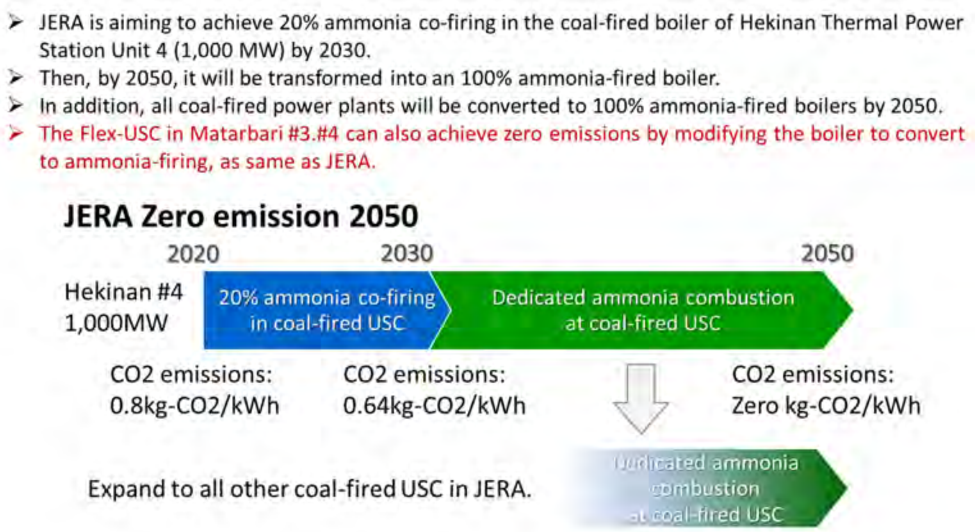
Table 4.3-3 shows Track records of FCB function from 100% load.

As shown here, there are several plants around the world that have more than 60% HP/LP bypass capacity and have FCB capability.

Therefore, it can be said that there is sufficient reliability for the application of the FCB function in Units 3/4.

4.4 Efforts to decarbonize

4.4.1 JERA Zero emission 2050



Source: Study Team from JERA data

Figure 4.4-1　JERA Zero Emission 2050

Figure 4.4-1 shows JERA Zero emission 2050.

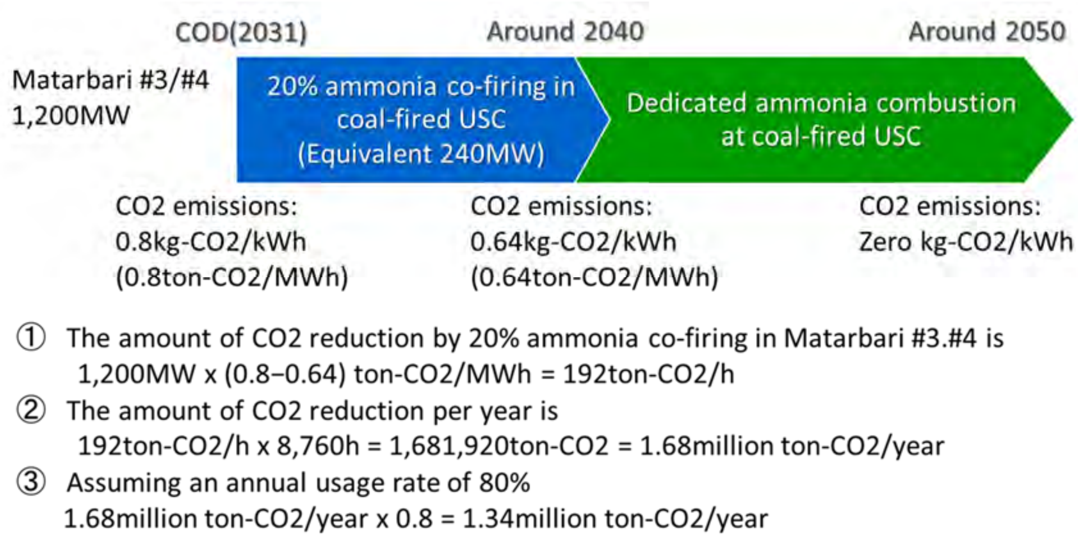
JERA's goal is to achieve 20% ammonia co-firing in the coal-fired boiler of Hekinan Thermal Power Station Unit 4 (1,000 MW) by 2030.

After that, the boiler will be 100% ammonia-fired by 2050.

Furthermore, all coal-fired power plants owned by JERA will be converted to 100% ammonia-fired boilers by 2050.

As for boiler, which will be applied to Units 3/4, zero emissions can be achieved by converting the boiler to ammonia co-firing and then to ammonia exclusive co-firing, just like JERA.

4.4.2 CO2 reduction in Matarbari Units 3/4 by ammonia co-firing



Source: Study Team

Figure 4.4-2　CO2 reduction in Matarbari Units 3/4 by anmonia co-firing

Figure 4.4-2 shows the amount of CO_2 reduction in Matarbari Units 3/4 by ammonia co-firing.

Figure 4.4-2 shows the proposed operation policy of Matarbari Units 3/4 from the COD to Bangladesh's target of zero emissions in 2050.

As of 2031, at COD, it will be exclusively coal-fired, and the CO_2 basic unit of coal at that time is 0.8 kg-CO_2/kWh.

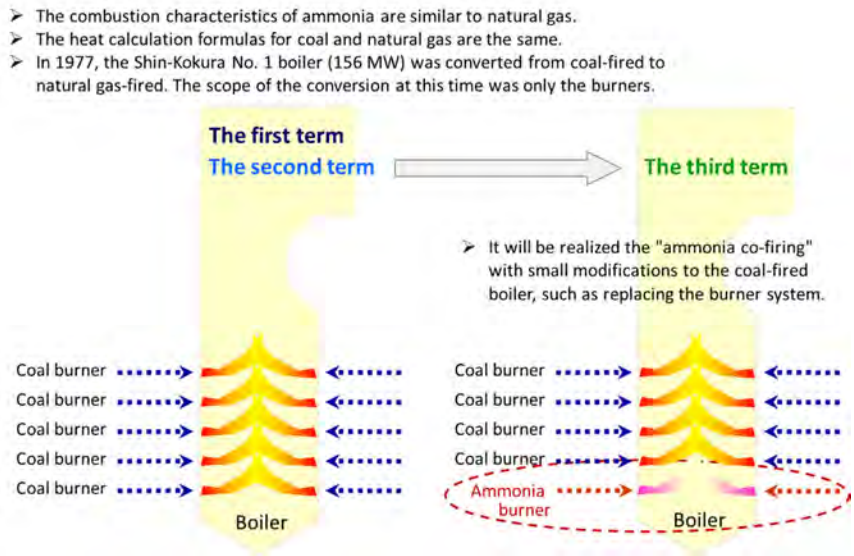
As of around 2040, CO_2 basic unit of 20% ammonia co-firing is 0.8 kg-CO_2/kWh x 0.8 = 0.64 kg-CO_2/kWh.

① in the figure, the CO_2 reduction per hour emitted from Matarbari Units 3/4 (1,200 MW) is shown. This is 192 tons-CO_2/h.

② in the figure shows the amount of CO_2 reduction per year. This is 1.68 million ton-CO_2/year.

③ in the figure shows, in easy-to-remember figures, the amount of CO_2 reduction per year when the annual average load factor of Matarbari Units 3/4 is assumed to be 80%, the annual CO_2 reduction for 240MW is 1.34 million ton-CO_2/year.

4.4.3 Scope of boiler modification to achieve ammonia co-firing



Source: Study Team

Figure 4.4-3 Scope of boiler modification to achieve ammonia co-firing

Figure 4.4-3 shows Scope of boiler modifications to achieve ammonia co-firing.

The combustion characteristics of ammonia are similar to those of natural gas.

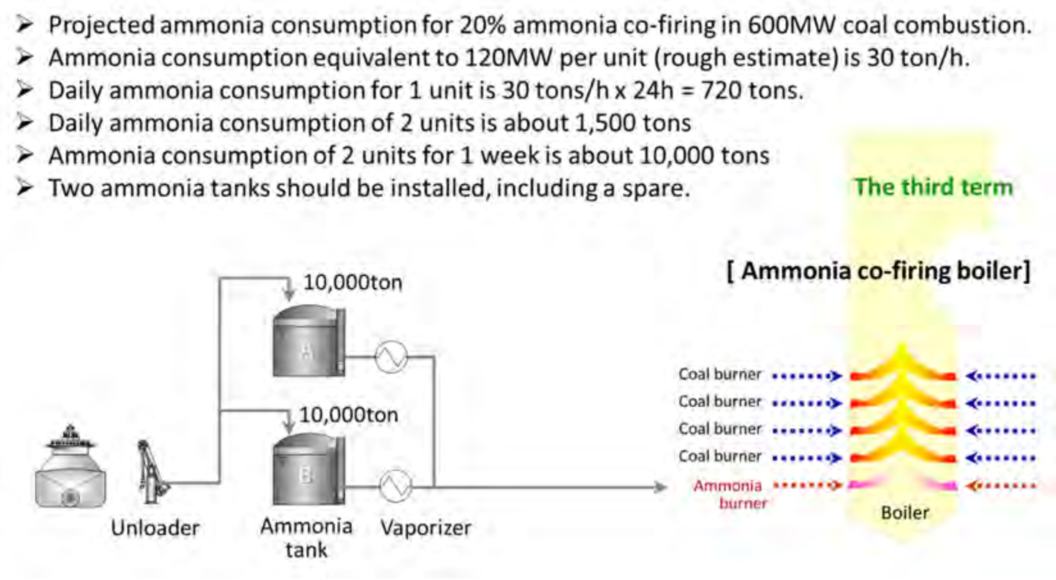
Therefore, the heat calculation formulas used to design boilers are similar for coal-fired boilers and natural gas-fired boilers.

In fact, when the Shinkokura No. 1 boiler (156 MW) was converted from coal-fired to natural gas-fired in 1977, only the burner was modified.

Therefore, the scope of conversion to ammonia co-firing can be handled by modifying only the burner area.

For the cost of boiler modification for ammonia co-firing, please refer to the Appendix-14.

4.4.4 Ammonia fuel supply facilities to realize ammonia co-firing



Source: Study Team

Figure 4.4-4 Ammonia fuel supply facilities to realize ammonia co-firing

Figure 4.4-4 shows the ammonia fuel supply system to achieve ammonia co-firing.

The estimated ammonia consumption for Unit 3/4 with 600 MW of coal mixed with 20% ammonia is as follows.

- Approximate ammonia consumption equivalent to 120 MW per unit is 30 ton/h
- Daily ammonia consumption of one unit is 30ton/h x 24h = 720ton
- The daily ammonia consumption of Units 3/4 is approximately 1,500 tons.
- The weekly ammonia consumption of Units 3/4 is approximately 10,000 ton.
- The diameter of the ammonia tank is approx. 30m.
- In consideration of maintenance, including a spare, two ammonia tanks will be installed.

Please refer to the Appendix-14 for the equipment cost to install additional ammonia fuel supply system.

4.4.5 Comparison between biomass co-firing and ammonia co-firing

Table 4.4-1 Comparison between biomass co-firing and ammonia co-firing

	Biomass co-firing	Ammonia co-firing
Boiler modification	➢ 6% biomass co-firing can be achieved without boiler modification. ➢ For biomass co-firing of 20% or more, it is necessary to add a dedicated biomass pulverizers.	➢ 20% ammonia co-firing can be achieved by simply converting one burner stage from a coal burner to an ammonia burner. ➢ In the future, 100% dedicated ammonia firing can also be achieved by basically only modifying the burner section.
Fuel supply facilities	➢ No new facilities are needed for biomass storage because the coal area can be used.	➢ Ammonia storage tanks need to be added.
Fuel procurement	➢ The world's forest resources are limited, making it difficult to procure biomass on a long-term and stable basis.	➢ There are two types of ammonia: blue ammonia and green ammonia. Blue ammonia is produced from fossil fuels and can be expected to be stably procured.
Economy	➢ Initial cost: The cost of the dedicated biomass pulverizers are about the same as the cost of the ammonia combustion burner section. ➢ Running cost (unit cost of power generation) Dedicated biomass burning: 100% increase over coal (Source: CRIEPI Research Report M13009, 2015)	➢ Initial cost: The cost of modifying the ammonia combustion burner is almost the same as the cost of a dedicated biomass pulverizers. Additional cost for ammonia storage tank is also required. ➢ Running cost (unit cost of power generation) Ammonia 20% co-firing: 20% increase compare to coal Ammonia 100% firing: 110% increase compared to coal (Source: Ministry of Economy, Trade and Industry, Public-Private Council for Fuel Ammonia Introduction, 2020)
CO2 reduction	➢ 20% biomass co-firing is realistic and can be expected to reduce CO2 emissions by about 20%.	➢ In the future, 100% dedicated ammonia firing is possible, and zero-emission thermal power can be realized.
Overall evaluation	➢ If biomass co-firing of about 6% is carried out, no equipment modification costs are required and a 6% reduction in CO2 emissions can be expected. ➢ In order to realize zero-emission thermal power in the future, difficulties in fuel procurement will be involved. ➢ Therefore, it is not a desirable choice from the viewpoint of zero-emission thermal power.	➢ In order to achieve zero-emission thermal power in the future, ammonia is the preferred choice as an alternative fuel to coal, as it is expected to provide a stable supply of fuel.

Source: Study Team

Table 4.4-1 shows a comparison between biomass co-firing and ammonia co-firing.

As stated in the overall evaluation, biomass co-firing of about 6% can be easily achieved without any equipment modification of the boiler.

However, procuring a large amount of biomass is difficult due to the finite nature of forest resources. Therefore, it is not a favorable choice from the viewpoint of zero-emission thermal power.

On the other hand, Ammonia is a good alternative to coal for zero-emission thermal power because it can be expected to provide a stable fuel supply in the future.

4.5 Trends of Super Critical Thermal (SC) / Ultra-Super Critical (USC)

4.5.1 The History of Thermal Efficiency in Japan

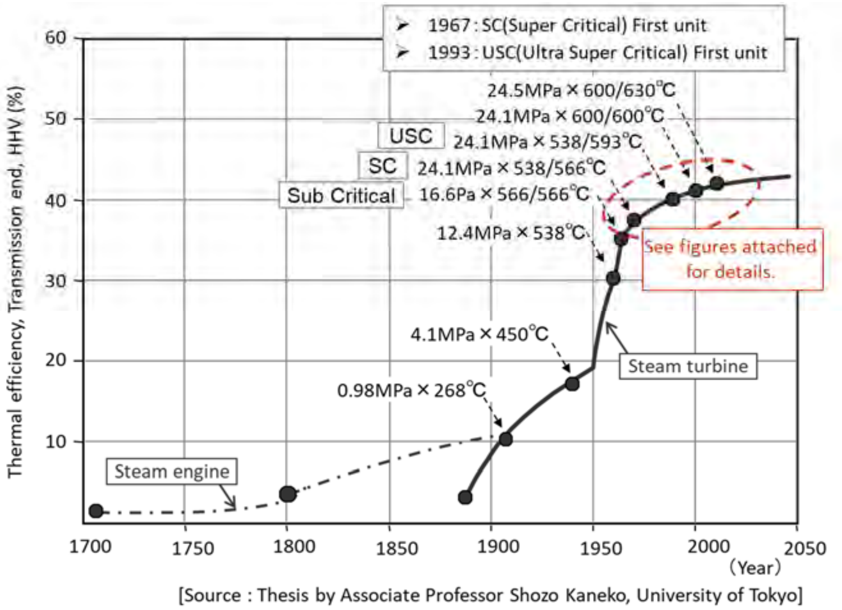


Figure 4.5-1 The History of Thermal Efficiency in Japan

Figure 4.5-1 shows the history of thermal efficiency in Japan. In Japan, the first SC (supercritical pressure thermal power) unit was introduced in 1967, and the first USC (ultra-supercritical pressure thermal power) unit was introduced in 1993 to improve efficiency and increase capacity from the Sub Critical (drum type boiler), which was the mainstay of thermal power until the 1960s in Japan.

In the Units 1/2 Project planned in 2012, the decision was made to introduce the USC based on baseload operation to meet the needs for higher efficiency. The main specifications of the USC are Main Steam Pressure (MSP) of 24.1 MPa and Main Steam Temperature (MST)/Reheat Steam Temperature (RST) of 600/600 °C. Around 10 years later, the technology for higher efficiency has advanced even further, and the latest specification of the USC has been improved to MSP of 24.5 MPa and a MST/RST of 600/630 °C.

Matarbari Units 3/4 are designed to meet the needs of the era of expanding RE installation, and would be proposed an optimal system with high performance and load flexibility capabilities.

4.5.2 Changes in SC/USC Steam Conditions

The following table shows the specifications (MSP, MST, and RST) of SC and USC plants that have been operated in Japan or are scheduled to be operated in the future, as well as the changes in the specifications of USC plants in major ASEAN countries.

Plants with a steam temperature of 593°C or higher are defined as USC (Ultra Super Critical), and plants with a steam temperature of less than 593°C are defined as SC (Super Critical).

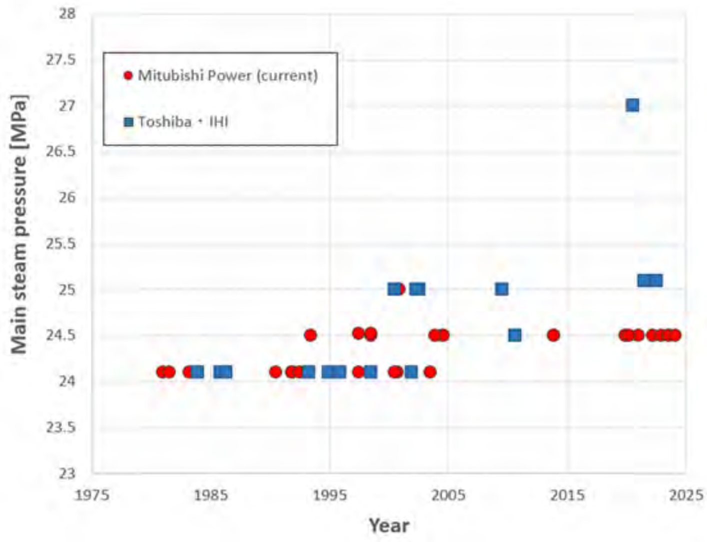
The red color in Figure 4.5-2, Figure 4.5-3 and Figure 4.5-4 indicates boilers manufactured by current Mitsubishi Power (former Mitsubishi Heavy Industries, former Hitachi, former Babcock-Hitachi, and former MHPS). The blue color indicates a steam turbine manufactured by Toshiba and IHI.

(1) Transition of MSP of Coal-fired USC in Japan

Figure 4.5-2 shows the transition of MSP of coal-fired USC in Japan.

As can be seen from the transition of MSP of domestic coal-fired SC/USC in Figure 4.5-2, most of the steam pressures manufactured by Mitsubishi Power are 24.5 MPa in USC plants, and recently 25.0 MPa is also available.

On the other hand, Toshiba and IHI groups have delivered one unit of 27.0 MPa in their USC plants, but the others have followed the 25.0 MPa.



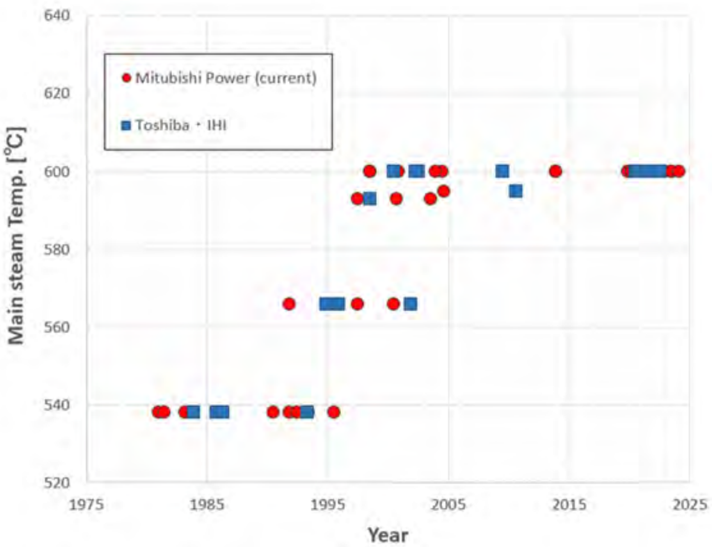
Source: Study Team

Figure 4.5-2　Transition of MSP of Coal-fired USC in Japan

(2) Transition of MST of Coal-fired USC in Japan

Figure 4.5-3 shows Transition of MST of Coal-Fired USC in Japan.

As can be seen from the transition of the MST, both Mitsubishi Power and Toshiba/IHI Group have followed the 600°C temperature in USC plants.



Source: Study Team

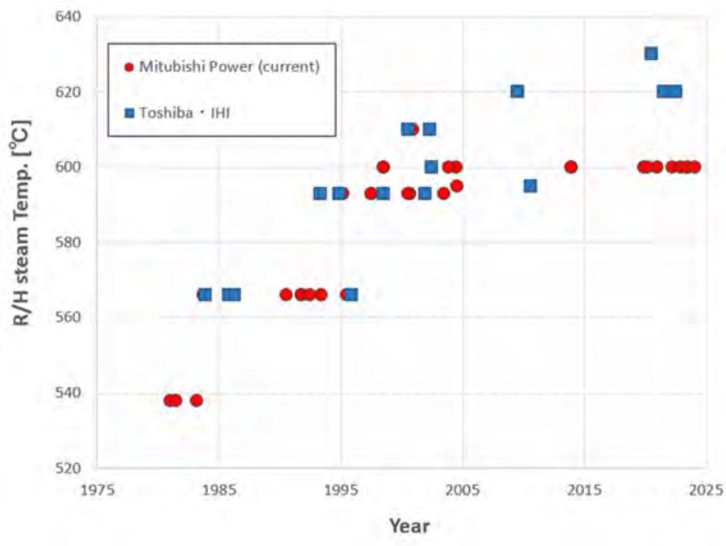
Figure 4.5-3　Transition of MST of Coal-fired USC in Japan

(3) Transition of RST of Coal-fired USC in Japan

Figure 4.5-4 shows Transition of RST of Coal-Fired USC in Japan.

As can be seen from the transition of the RST, Mitsubishi Power Corporation adopted 610°C in 2000 for its USC plant, but has since followed the 600°C temperature.

On the other hands, Toshiba and IHI Group's USC plants applied 600°C in plants before 1995, but have since gradually improved the RST to 610°C, 620°C, and the most recent plant is planned to use 630°C.



Source: Study Team

Figure 4.5-4 Transition of RST of Coal-fired USC in Japan

4.5.3 History of Coal-fired SC/USC in Japan

Table 4.5-1 SC/USC plants list in Japan

Company	Power station	COD (Year)	Type	Boiler manufacturer	Capacity (MW)	Pressure (MPa)	MST (℃)	RST (℃)	Turbine manufacturer	Generator manufacturer
J-Power	Matusima 1	1981	SC	MHI	500	24.1	538	538	Hitachi	Hitachi
J-Power	Matusima 2	1981	SC	MHI	500	24.1	538	538	Toshiba	Toshiba
Joban	Nakoso 8	1983	SC	MHI	600	24.1	538	566	Hitachi	Hitachi
J-Power	Takehara 3	1983	SC	BHK	700	24.1	538	538	Hitachi	Hitachi
Joban	Nakoso 9	1983	SC	IHI	600	24.1	538	566	Toshiba	Toshiba
Hokkaido	Tomatoatsuma 2	1985	SC	IHI	600	24.1	538	566	Hitachi	Hitachi
Chugoku	Shinonoda 1,2	1986	SC	IHI	500	24.1	538	566	Toshiba	Toshiba
Kyusyu	Matsuura 1	1989	SC	MHI	700	24.1	538	566	Hitachi	Hitachi
J-Power	Matsuura 1	1990	SC	BHK	1000	24.1	538	566	MHI	MELCO
JERA	Hekinan 1	1991	SC	MHI	700	24.1	538	566	Toshiba	Toshiba
Hokuriku	Tsuruga 1	1991	SC	MHI	500	24.1	566	566	Toshiba	Toshiba
JERA	Hekinan 2	1992	SC	BHK	700	24.1	538	566	Hitachi	Hitachi
Tohoku	Noshiro 1	1993	SC	BHK	600	24.5	538	566	Fuji	Fuji
JERA	Hekinan 3	1993	USC	IHI	700	24.1	538	593	MHI	MELCO
Soma	Shinchi 1	1994	SC	BHK	1000	24.1	538	566	Hitachi	Hitachi
Tohoku	Noshiro 2	1994	USC	IHI	600	24.1	566	593	Toshiba	Toshiba
Soma	Shinchi 2	1995	SC	MHI	1000	24.1	538	566	Toshiba	Toshiba
Hokuriku	Nanaoohta 1	1995	USC	BHK	500	24.1	566	593	MHI	MELCO
Kyusyu	Reihoku 1	1995	SC	IHI	700	24.1	566	566	Toshiba	Toshiba
Tohoku	Haramachi 1	1997	USC	MHI	1000	24.52	566	593	Toshiba	Toshiba
J-Power	Matsuura 2	1997	USC	BHK	1000	24.1	593	593	MHI	MELCO
Chugoku	Misumi 1	1998	USC	MHI	1000	24.5	600	600	MHI	MELCO
Tohoku	Haramachi 2	1998	USC	BHK	1000	24.52	600	600	Hitachi	Hitachi
Hokuriku	Nanaoohta 2	1998	USC	IHI	700	24.1	593	593	Toshiba	Toshiba
Hokuriku	Tsuruga 2	2000	USC	MHI	700	24.1	593	593	Toshiba	Toshiba
Shikoku	Tachibanawan 1	2000	USC	Hitachi	700	24.1	566	593	Toshiba	Toshiba
J-Power	Tachibanawan 2	2000	USC	Hitachi	1050	25	600	610	MHI	MELCO
J-Power	Tacibanawan 1	2000	USC	IHI	1050	25	600	610	Toshiba	GE
JERA	Hekinan 4、5	2001	USC	IHI	1000	24.1	566	593	Toshiba	Toshiba
Hkkkaido	Tamatoatsuma 4	2002	USC	IHI	700	25	600	600	Hitachi	Hitachi
J-Power	Isogoshin 1	2002	USC	IHI	600	25	600	610	Fuji	Fuji
Kyusyu	Reihoku 2	2003	USC	MHI	700	24.1	593	593	Toshiba	Toshiba
JERA	Hitachinaka 1	2003	USC	BHK	1000	24.5	600	600	Hitachi	Hitachi
JERA	Hirono 5	2004	USC	MHI	600	24.5	600	600	MHI	MELCO
Kansai	Maizuru 1	2004	USC	MHI	900	24.5	595	595	MHI	MELCO
J-Power	Isogoshin 2	2009	USC	IHI	600	25	600	620	Hitachi	Hitachi
Kansai	Maizuru 2	2010	USC	IHI	900	24.5	595	595	Toshiba	Toshiba
JERA	Hirono 6	2013	USC	MHI	600	24.5	600	600	MHI	MELCO
JERA	Hitachinaka 2	2013	USC	BHK	1000	24.5	600	600	Hitachi	Hitachi
Kyusyu	Matsuura 2	2019	USC	MHPS	1000	24.5	600	600	Toshiba	Toshiba
Tohoku	Nochiro 3	2020	USC	MHPS	600	24.5	600	600	Toshiba	Toshiba
J-Power	Takehara 1	2020	USC	IHI	600	27	600	630	Toshiba	Toshiba
Hitachinaka Gerenation	Hitachinakakyodo 1	2021	USC	Mitsubishi	650	24.5	600	600	Mitsubishi	MELCO
KOBELCO Kobe	Kobe 3	2021	USC	IHI	650	25.1	600	620	Toshiba	Toshiba
JERA Power Taketoyo	Taketoyo 5	2022	USC	Mitsubishi	1070	24.5	600	600	Mitsubishi	MELCO
Chugoku	Misumi 2	2022	USC	Mitsubishi	1000	24.5	600	600	Mitsubishi	MELCO
KOBELCO Kobe	Kobe 4	2022	USC	IHI	650	25.1	600	620	Toshiba	Toshiba
JERA Power Yokosuka	Yokosuka 1	2023	USC	Mitsubishi	650	24.5	600	600	Mitsubishi	MELCO
Shikoku	Saijyo 1	2023	USC	Mitsubishi	500	24.5	600	600	Mitsubishi	MELCO
JERA Power Yokosuka	Yokosuka 2	2024	USC	Mitsubishi	650	24.5	600	600	Mitsubishi	MELCO

Source: Study Team

Table 4.5-1 shows SC/USC plants list in Japan.

In the list of domestic coal-fired SC/USC plants in Table 4.5-1, the first USC units with improved steam conditions are as follows.

・In 1998, at Chugoku Electric Power Company Misumi #1, MST was 600°C and RST was 600°C.
・In 2000, at J-Power Shin Isogo #1, MST was 600°C and RST was 610°C.
・In 2009, at J-Power Shin Isogo #2, MST was 600°C and RST was 620°C.
・In 2020, at J-Power Takehara #1, MST was 600℃, and RST was 630℃.

4.5.4 Major USC Delivery Plants in ASEAN Countries

Table 4.5-2 USC Plants Lists regarding Steam Conditions in ASEAN Countries

No.	Manufacturer (Steam Turbine)	Manufacturer (Boiler)	Plant Owner	Plant		Country	Steam Condition	Unit Capacity	COD (YY/MM/DD)	Steam Conditions (MSP/MST/RST)
1	SHANGHAI TURBINE CO.	DONGFANG BOILER CO.	BANGLADESH CHINA PR CO LTD (BCPCL-CMC, NWPGCL)	DHANKHALI 1, PATHUAKHALI, PAYRA	Payra 1	BANGLADESH	USC	660	2020/12/1	26.25/600/610
2	SHANGHAI TURBINE CO.	DONGFANG BOILER CO.	BANGLADESH CHINA PR CO LTD (BCPCL-CMC, NWPGCL)	DHANKHALI 2, PATHUAKHALI, PAYRA	Payra 2	BANGLADESH	USC	660	2020/4/1	26.25/600/610
3	SIEMENS CO.	DOOSAN HEAVY INDUSTRIES CO.	PT INDO RAYA TENAGA	JAWA THERMAL POWER	Java 9	INDONESIA	USC	1000	2024/7/1	26.0/600/620
4	SIEMENS CO.	DOOSAN HEAVY INDUSTRIES CO.	PT INDO RAYA TENAGA	JAWA THERMAL POWER	Java 10	INDONESIA	USC	1000	2024/12/1	26.0/600/620
5	TOSHIBA	DOOSAN HEAVY INDUSTRIES CO.	VAPCO	Vung Ang2	1	VIETNAM	USC	600	2025/3/31	27.5/600/610
6	TOSHIBA	DOOSAN HEAVY INDUSTRIES CO.	VAPCO	Vung Ang2	2	VIETNAM	USC	600	2025/7/31	27.5/600/610
7	TOSHIBA	IHI	CPGCBL	Matarbari Power Station	1	BANGLADESH	USC	600	2024/1/1	24.5/600/600
8	TOSHIBA	IHI	CPGCBL	Matarbari Power Station	2	BANGLADESH	USC	600	2024/7/1	24.5/600/600
9	Mitsubishi Power	DOOSAN HEAVY INDUSTRIES CO.	NS2PC	Nghi Son2	1	VIETNAM	SC	600	2021/12/1	24.2/566/566
10	Mitsubishi Power	DooSAN HEAVY INDUSTRIES CO.	NS2PC	Nghi Son2	2	VIETNAM	SC	600	2022/6/1	24.2/566/566

MSP: Main Steam Pressure
MST: Main Steam Temperature
RSP: Reheater Steam Temperature

Source: Study Team

Table 4.5-2 shows USC plants lists regarding Steam conditions in ASEAN countries.

As can be seen from Table 4.5-2, the plants scheduled to be operated in the ASEAN countries are planned to have steam conditions such as 610°C and 620°C for RST in order to achieve high efficiency.

MSP of the DONGFANG and DOOSAN plants are 26.25MPa and 27.5MPa, respectively, which are higher than the 241.1MPa and 24.5MPa of the Japanese plants manufactured by Mitsubishi Power Corporation and Toshiba & IHI Corporation.

Reference: Japanese companies have experienced that MSP has little effect on efficiency improvement, and USC plants have set MSP at 24.1MPa and 24.5MPa as standard.

4.5.5 USC Initiatives in Major Countries around the World

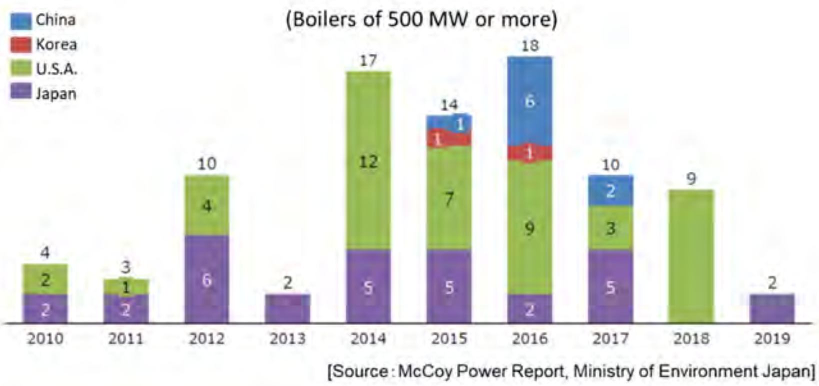


Figure 4.5-5 USC Boiler Export Results

Figure 4.5-5 shows USC Boiler Export Results.

Japan is shown in purple, the US (including OEM production in China) in green, Korea in red, and China in blue. USC was developed in Japan and spread to the world. Therefore, USC made in Japan is continuously manufactured every year and a total of 31 units are exported.

In contrast, the U.S. has exported a total of 47 units, which includes U.S.-branded Chinese products. A total of nine units of Chinese-branded USC have been exported since 2015. One unit of South Korea-made USC was exported in each of 2015 and 2016.

4.5.6 Status of Efforts to develop A-USC Technology in Major Countries

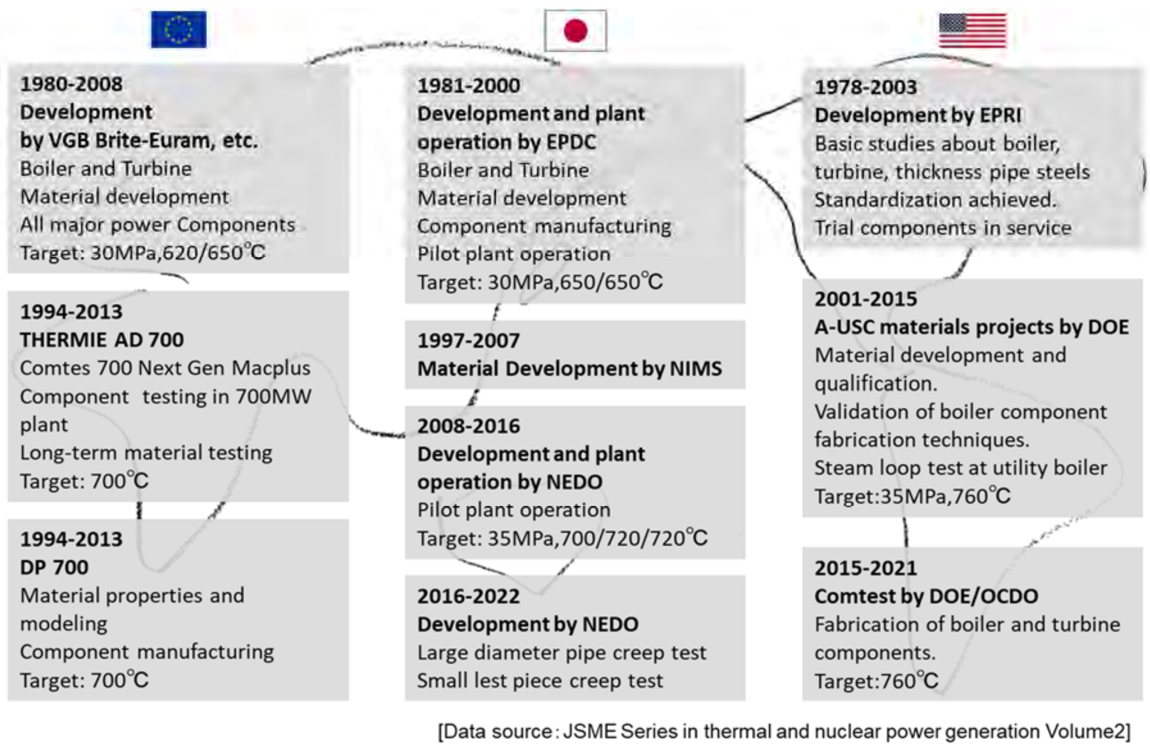


Figure 4.5-6 Status of Efforts to develop A-USC Technology in Major Countries

Figure 4.5-6 shows the status of efforts to develop A-USC technology in major countries. In order to meet the demand for environmentally friendly and inexpensive energy supply, it is necessary to improve the thermal efficiency of plants, and for this purpose, a development program to realize 600°C-class USC and

700°C-class A-USC (Advanced-USC) plants, which is the next generation technology, was started around 1980 by Japan, the United States, and Europe. During this period, manufacturers in Japan, the U.S., and Europe have been working on the development of USC plants. During this period, USC technology was provided by Japan, US, and European manufacturers to China and other countries, and spread throughout the world as shown in Figure 4.5-5.

Recently, A-USC project has been started in China, India, and Korea, and the target steam conditions are 35 MPa and 700-720°C. There is no significant difference.

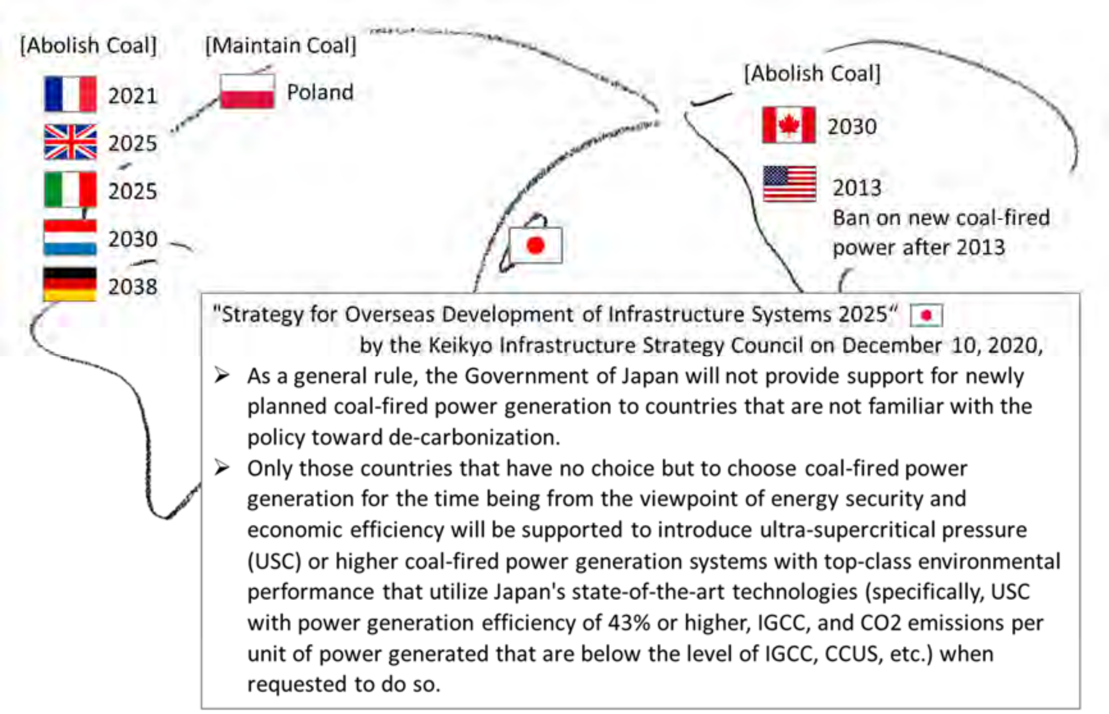
Looking back over the history, SC was commercialized with Europe and the U.S. taking the lead, while USC was commercialized with Japan taking the lead. The development ratio of the nine major steel grades of USC is Japan : Europe : U.S. = 6 : 2 : 1.

One of the most important factors in thermal power technology is the development of metallic materials, and most of the USC materials that have been commercialized were developed in Japan.

In the near future, the next generation of metallic materials will be commercialized through the development of A-USC technology, and Japan is one of the leading countries in the development of metallic materials for thermal power generation, as can be seen in the efforts shown in Figure 4.5-6.

4.6 Trends regarding Coal-fired Thermal Power in the World

4.6.1 Trends in Japan, the United States, and Europe toward coal-fired power generation



Source: Study Team

Figure 4.6-1 Trends in Japan, the United States, and Europe toward coal-fired power generation

Figure 4.6-1 shows Trends in Japan, the United States, and Europe toward coal-fired power generation.

As shown in the figure, major European countries (France, the United Kingdom, Italy, the Netherlands, and Germany) have declared that they will abolish coal.

However, Poland plans to continue to operate coal-fired thermal power in order to increase its energy self-sufficiency ratio by using coal that can be produced at home.

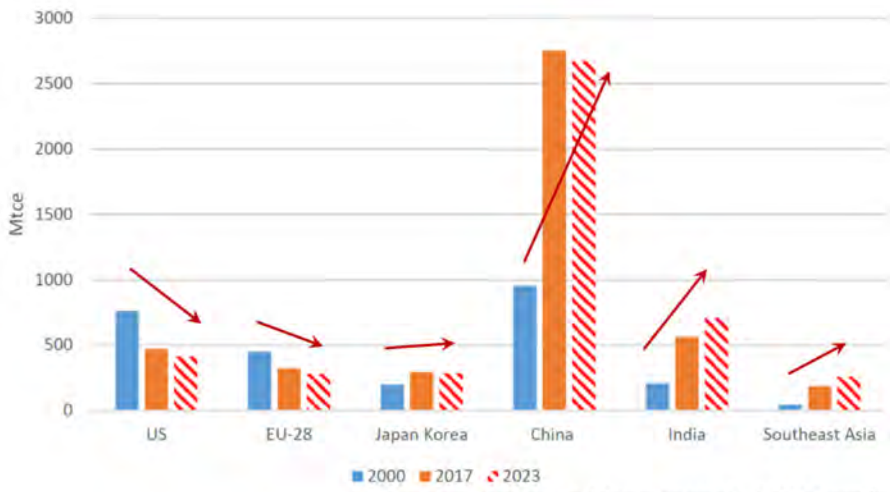
The U.S. has also banned new coal-fired thermal powers since 2013, and Canada aims to abolish coal by 2030.

On the other hand, Japan's future policy for coal-fired thermal power export was set out in the "Strategy for Overseas Development of Infrastructure Systems 2025" decided by the Keikyo Infrastructure Strategy Council on December 10, 2020, as follows.

- The basic policy is to "support infrastructure exports guided by the administration's transition away from coal" in order to contribute to carbon neutrality and achieve the goals of the Paris Agreement.
- As a general rule, the Government of Japan will not provide support for newly planned coal-fired power generation to countries that are not familiar with the policy toward decarbonization.
- On the other hand, only those countries that have no choice but to choose coal-fired power generation for the time being from the viewpoint of energy security and economic efficiency will be supported to introduce ultra-supercritical pressure (USC) or higher coal-fired power generation systems with top-class environmental performance that utilize Japan's state-of-the-art technologies (specifically, USC with power generation efficiency of 43% or higher, IGCC, and CO_2 emissions per unit of power generated that are below the level of IGCC, CCUS, etc.) when requested to do so.
  (IGCC CO_2 emissions is about 20% less than USC.)

However, the coal-fired power plants of Units 3-4 currently being planned were developed before the aforementioned "Strategy for Overseas Deployment of Infrastructure Systems 2025," and the above will be considered as reference conditions.

With this background, Matarbari Units 3/4 are planned to have the same power generation efficiency of 41.1% as Matarbari Units 1/2.



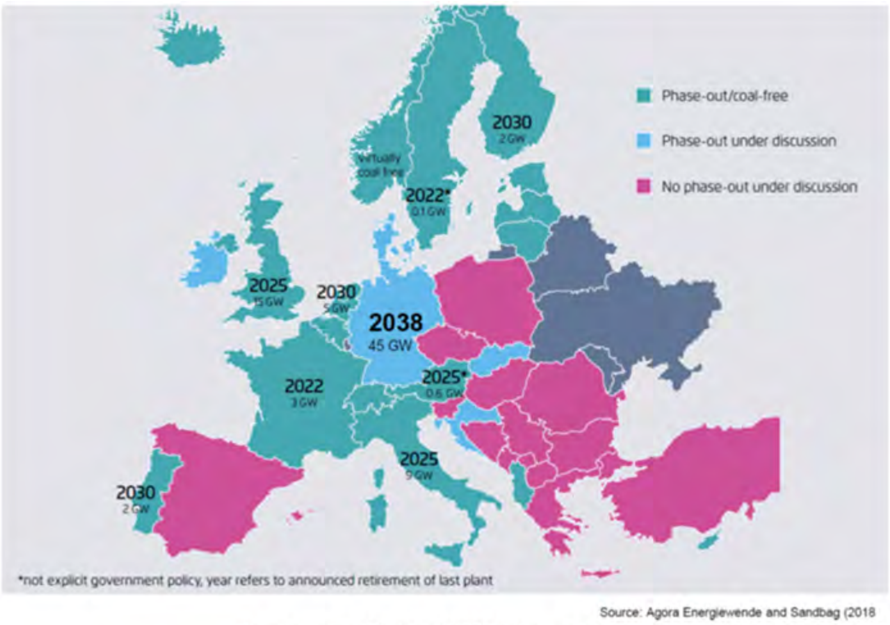
[Source: IEA (International Energy Agency) Coal 2018 Report]

Figure 4.6-2 Coal Demand in select countries/regions

Figure 4.6-2 shows the coal demand in select countries/regions. The figure shows the change in coal-fired thermal power capacity in 2000, 2017, and 2023.

The U.S. and Europe are on a downward trend, Japan and South Korea are on a slight increase, China is on a significant increase, and India and Southeast Asia are on an upward trend. This data confirms the trend shown in Figure 4.6-1.

4.6.2 Trends of Europe



[Data Source: 12th VGB-TENPES Technical Exchange Meeting 26 Feb.2019, Tokyo]

Figure 4.6-3 Coal phase out in Europe in the future

Figure 4.6-3 shows the coal phase out in Europe in the future. The countries in green have announced their intention to phase out coal, the countries in blue are considering it, and the countries in pink are those that will continue to use coal.

Figure 4.6-1 describes representative European countries, and as can be seen in Figure 4.6-3, Western and

Northern European countries, excluding Spain, will abolish coal, while Eastern European countries, led by Poland, and Spain are continuing to use coal.

4.6.3 Trends in U.S.A

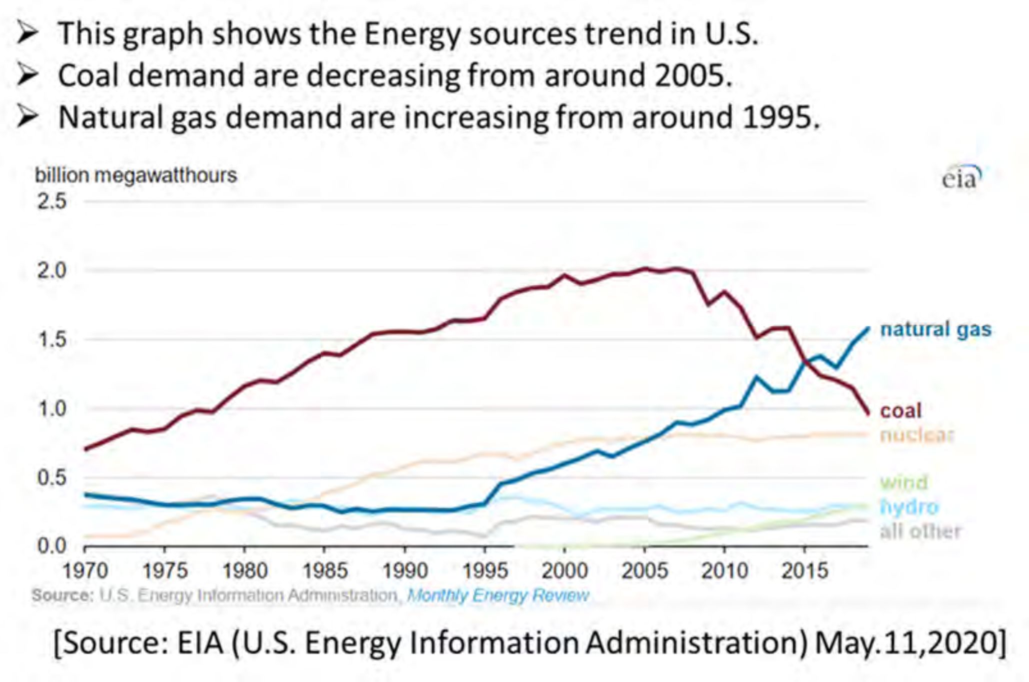


Figure 4.6-4 U.S. Annual Electricity Generation by Energy Source

Figure 4.6-4 shows U.S. annual electricity generation by energy source. The trend of coal-fired thermal power and natural gas-fired thermal power in the figure clearly shows the energy policy of the U.S. Coal-fired thermal power increased steadily from 1970 to 2005, and has been decreasing since 2005. In addition, natural gas thermal power has been increasing steadily since 1995. This is due to the increase in shale gas production in the 2000s as shown in Figure 4.6-4, indicating that the main role of thermal power has shifted from coal to natural gas since 2010.

4.6.4 Trends of ASEAN

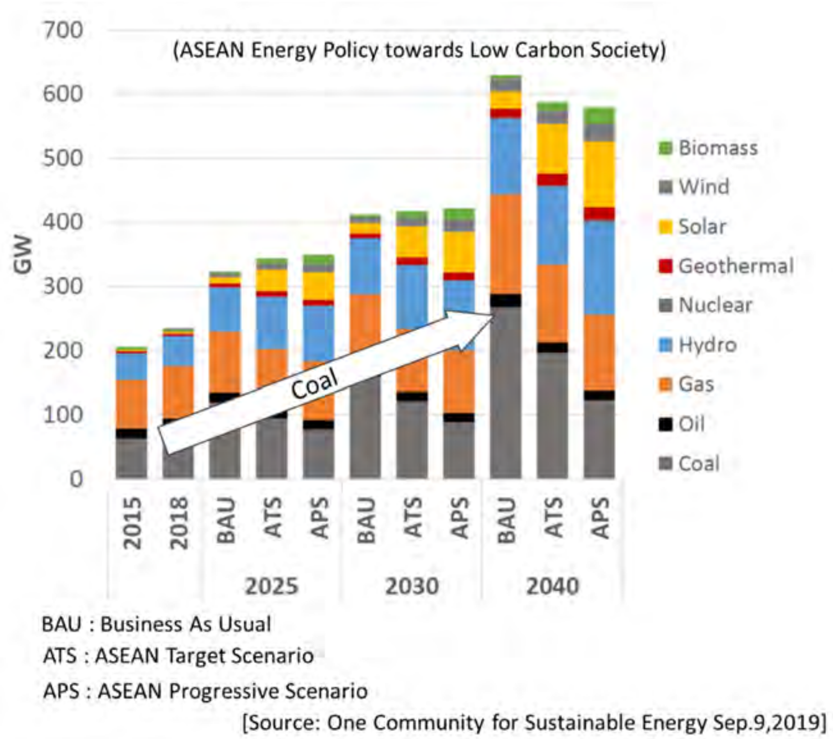


Figure 4.6-5 Installed Capacity Projection by Type of Fuel for ASEAN (GW)

Figure 4.6-5 shows the installed capacity projection by type of fuel for ASEAN (GW).

The figure shows projections for 2025, 2030, and 2040.

In both BAU (Business as Usual) and ATS (ASEAN Target) and APS (Innovative Projections), the average for ASEAN countries is that coal-fired thermal power will increase, as shown in gray.

As for renewable energy (RE), solar power (yellow) is expected to increase significantly.

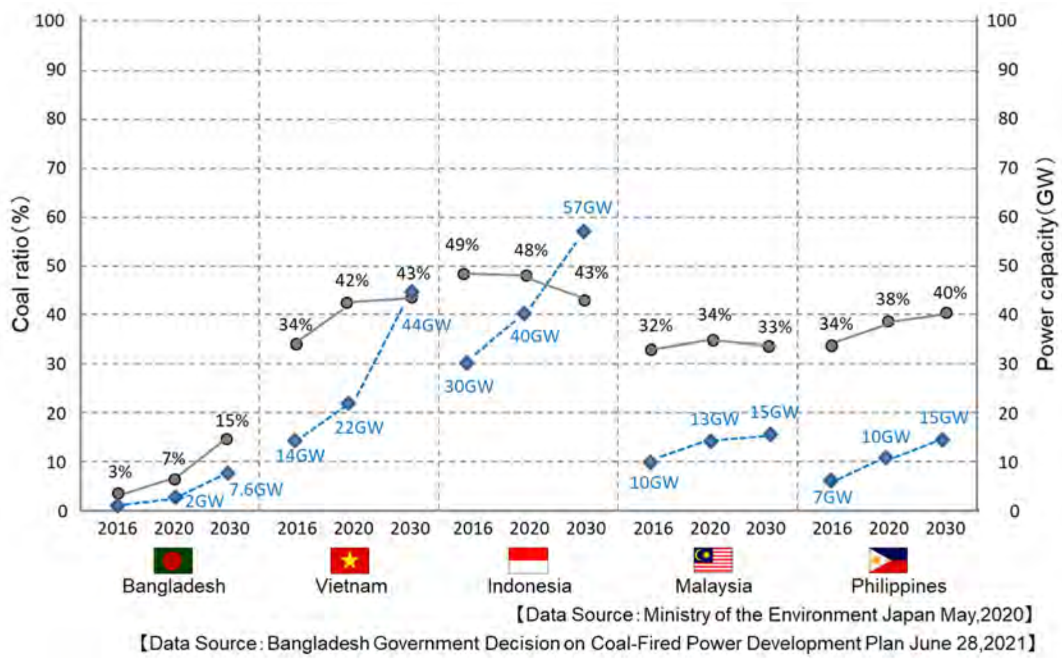


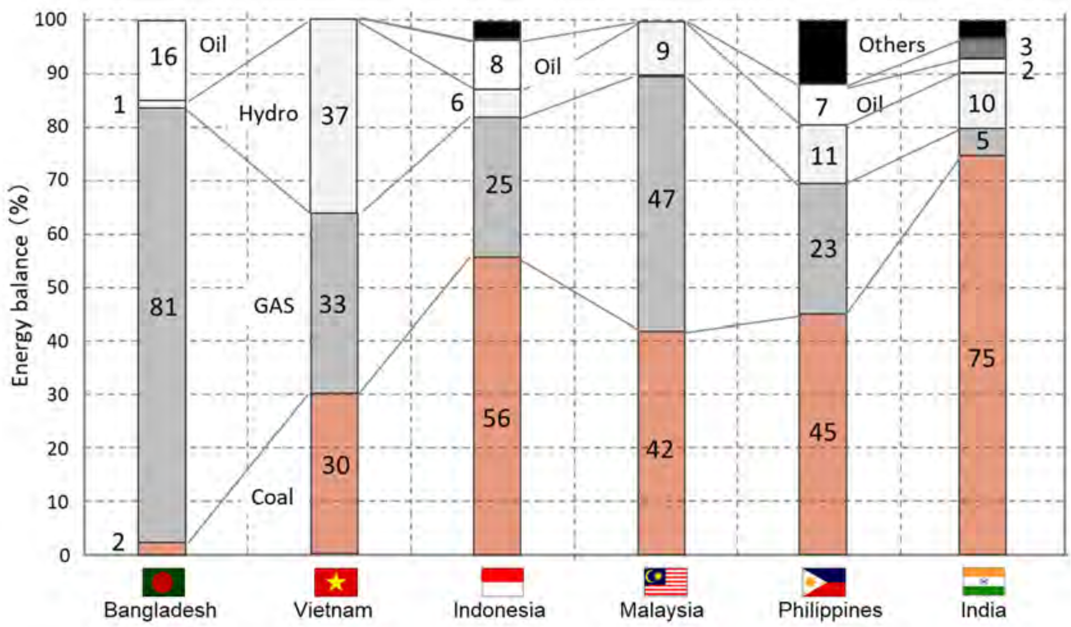
Figure 4.6-6 Trends of Coal-fired Thermal Power in Asian Countries

Figure 4.6-6 shows the trends of coal-fired thermal power in Asian countries.

Here, Bangladesh, Vietnam, Indonesia, Malaysia, and the Philippines are shown, and the installed capacity of coal-fired thermal power is expected to increase in all of these countries.

However, since the Climate Summit 2021 held in April 2021, each country has been reviewing its energy plan, and it seems that Bangladesh and Vietnam are reviewing their plans for coal-fired power generation, and the amount of coal-fired power generation is likely to decrease from the increase shown in Figure 4.6-~~7~~6.

The data for Bangladesh reflects the data reviewed in July 2021.



Source: Study Team

Figure 4.6-7 Comparison of the energy balance between ASEAN countries and India (2015)

Figure 4.6-7 shows a comparison of the energy balance of ASEAN countries and India (2015).

As can be seen in the figure, the energy balance, especially the ratio of coal, varies greatly depending on the policies of each country.

The policies of each country are described below.

(1) Vietnam

- Power generation power composition (2015):
  Coal 30%, natural gas 33%, hydro 37%

- Electricity Policy: revised PDP7
  Revised PDP7 "Revised Seventh National Electricity Master Plan
  In the current revised PDP7 (2016-2020), coal-fired power plants still account for a large share of the planned capacity, and in the medium term, the installed capacity will increase in the next few years as projects under construction or in preparation will be completed gradually. (Note 1)
  On the other hand, in PDP8, which is currently being prepared for issuance, the share of coal-fired power will be significantly reduced, and many of the coal-fired power planned in PDP7 will be suspended or frozen. (Note 2)
  GTCC (Note 3) and renewable energy are planned to be increased, and the ratio of coal-fired power is expected to gradually decrease in the future.
  (Note 1) Song Hau 1, Bang Phan 1, Vung Ang 2, Quang Chac 1, etc.
  (Note 2) Long Hau 1, Thai Binh 2, Bintan 3, Quang Chi 1, Quin Lap 1, etc.
  (Note 3) Nyongchuck 3&4, Aumong 2, 3, 4, Son My, Long Son, Kana, Quang Ninh, Bac Lieu, etc.

- Initiatives to address global warming:
  Reduce greenhouse gas emissions by 20% by 2030 compared to 2010 if no action is taken (BAU).

Also, 25% reduction under the condition that international support is received.
The Paris Agreement was ratified in April 2016.

(2) Indonesia

- Electricity generation composition (2015):
  Coal 56%, oil 8%, natural gas 25%, hydro 6%.

- Electricity policy
  The central government of Indonesia and the state-owned power company PLN have jointly formulated an electricity supply business plan (RUPTL).
  The RUPTL (2017-2026) calls for the electricity mix to be 0.39% oil, 50% coal, 26% natural gas, and 22% RE in 2026.
  The RUPTL is usually issued around June every year, but this year it has not yet been issued.

- Initiatives to address global warming:
  Reduce GHGs by 29% if no action is taken by 2030 (BAU).
  It will also reduce it by 41% under the condition that it receives international support.
  The Paris Agreement was ratified in October 2016.

- Indonesia is the world's fifth largest coal producer. It is also the world's second largest coal exporter after Australia.
  There are moves to curb production for its own consumption and to prevent depletion.

(3) Malaysia

- Power generation power mix (2015)
  Coal 42%, natural gas 47%, hydro 9%

- Electricity policy:
  11th National Five-Year Plan (2016-2020)

- Future Energy Outlook
  The electricity mix as of 2050 is expected to be 57% coal, 28% natural gas, 3.6% nuclear, 9% hydro, 1.4% solar and wind, and 0.8% biomass.

- Initiatives to address global warming:
  By 2030, GHGs will be reduced by 45% compared to 2005 levels.
  The Paris Agreement was ratified in November 2016.

- ASEAN Power Grid (APG)
  Malaysia, Singapore, Thailand, and Indonesia are grid-connected, with Malaysia exporting electricity.

(4) Philippines

- Electricity generation composition (2015):
  Coal 45%, oil 7%, natural gas 23%, hydro 11%

- Power Policy: Electricity
  Philippine Energy Plan (2017-2040)
  Philippine Energy Plan：PEP2017-2040

- Future Energy Outlook
  The electricity mix in 2050 will be 31% coal, 30% oil, 15% natural gas, 3.6% nuclear, and 23% other.

- Initiatives to address Global Warming
  By 2030, Philippines will reduce GHG by 70% in BAU, a target set in October 2015.
  The Paris Agreement was ratified in March 2017.

(5) India

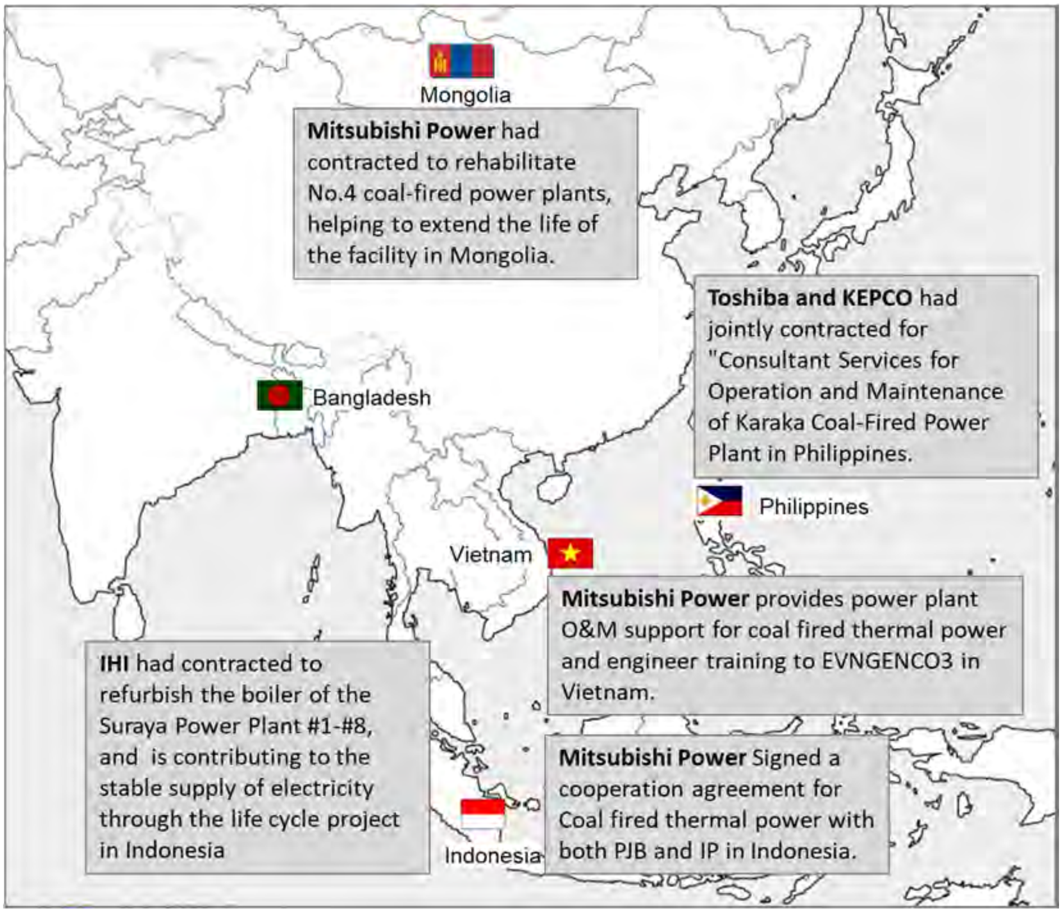
- Power generation power mix (2015)
  Coal 75%, oil 2%, natural gas 5%, nuclear 3%, hydro 10%

- Future energy outlook
  Electricity composition in 2040: 47% coal, 0.6% oil, 8% natural gas, 6% nuclear, 38% RE.

- Initiatives to address Global Warming
  By 2030, we will reduce GHG emissions by 30-35% compared to 2005 levels.
  The Paris Agreement was ratified in October 2015.

- Power Policy
  The draft of the National Electricity Policy (NEP) 2021 released by the Government of India has been revealed.
  It states that "India is committed to expanding its power generation capacity through non-fossil fuels, but coal remains the cheapest source of power and the country may still need to expand coal-based power generation capacity.
  It goes on to say that "new coal-fired power plants should adopt 'ultra-supercritical pressure technology' or 'other more efficient technology' to reduce carbon dioxide emissions." The report goes on to say.

4.7 Initiatives for Existing Coal-fired Thermal Power Plants in Asian Countries



Source: Study Team

Figure 4.7-1 Initiatives for Existing Coal-fired Thermal Power Plants in Asian

Figure 4.7-1 shows the initiatives for existing coal-fired thermal power plants in Asian.
This figure shows the efforts of Japanese plant manufacturers Mitsubishi Power, Toshiba, and IHI in Indonesia, Vietnam, the Philippines, and Mongolia.

4.7.1 Indonesia

As IHI has a base in Indonesia, active support is being provided for existing coal-fired thermal power plants. Specifically, IHI is in the process of rehabilitating existing units 1 through 8 at the Suraya Power Plant, the largest power plant in Indonesia.

In addition, Mitsubishi Power has signed cooperation agreements for existing coal-fired thermal power plants with PJB and IP, two of Indonesia's major power companies.

4.7.2 Vietnam

Mitsubishi Power will provide O&M for existing coal-fired thermal power plants and support to EVNGENCO3 for training.

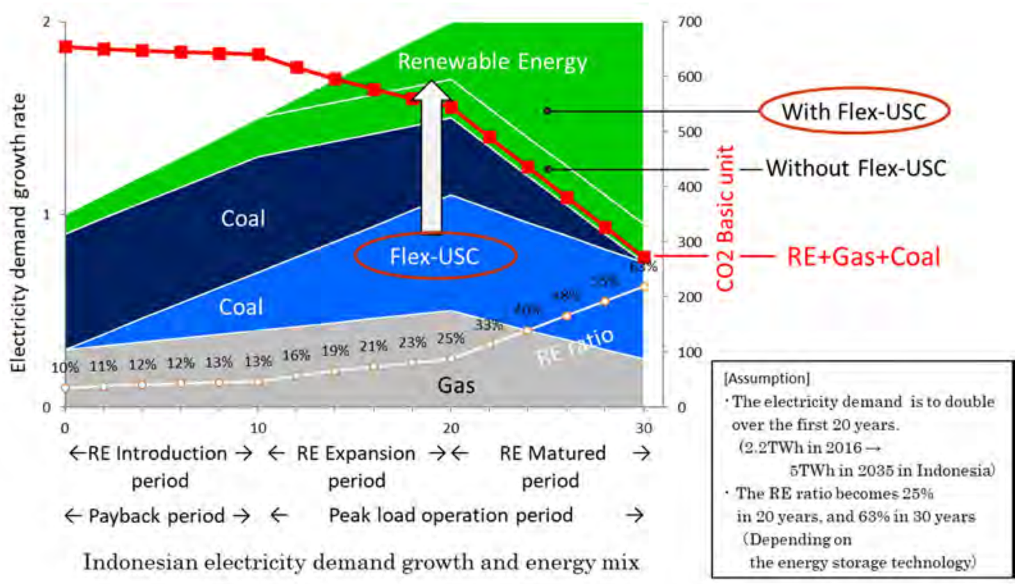
4.7.3 Philippines

Toshiba, together with Korea Electric Power, has signed on to provide O&M consultancy services for the Karaka coal-fired power plant.

4.7.4 Mongolia

Mitsubishi Power is handling the boiler rehabilitation work at the existing No. 4 thermal power plant.

4.7.5 Flex-USC Supports Renewable Energy Expansion in Indonesia



Source: Study Team

Figure 4.7-2 Flex-USC Supports Renewable Energy Expansion Plan in Indonesia

Figure 4.7-2 shows the Flex-USC supports renewable energy expansion plan in Indonesia.

Figure 4.7-2 shows a projection of Indonesia's energy balance for the next 30 years. Gray is gas, dark blue is conventional base-load coal-fired thermal power, bright blue is Flex-USC, and green is renewable energy, while the red line shows the average CO2 basic unit of all energy sources.

If Flex-USC is not applied at all and all coal-fired thermal power is used as baseload in the future, it will be necessary to add a limit (white line in Renewable Energy) to the amount of green renewable energy installed in order to maintain power system stability.

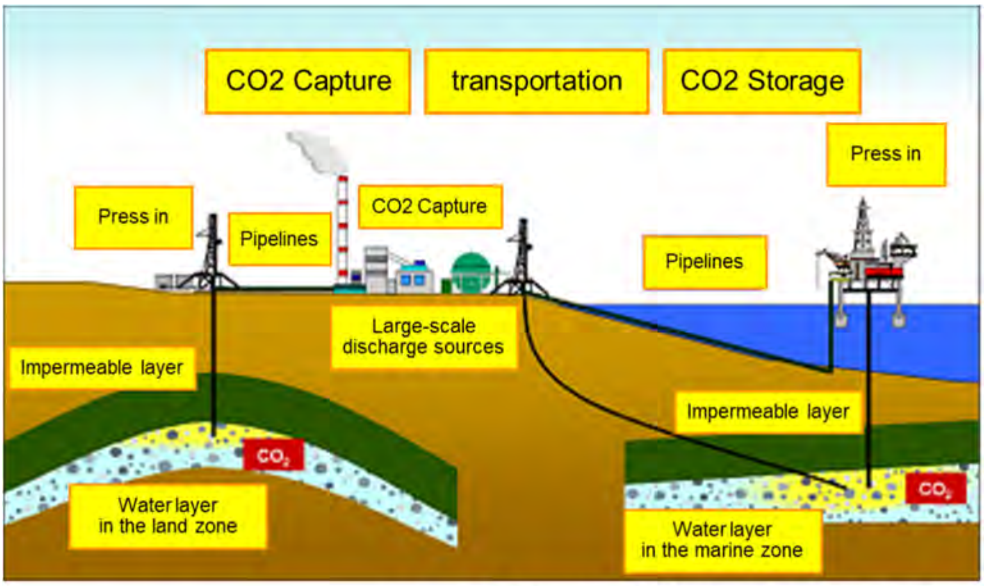
On the other hand, with the introduction of Flex-USC, there will be no need to place restrictions on the amount of renewable energy introduced due to the improved power system control function. As a result, it will be possible to increase the amount of renewable energy introduced, as shown in the area above the white line in Renewable Energy.

In this way, the application of Flex-USC can reduce the average CO2 intensity of all RE + Gas + Coal energy.

Considering this effect, Indonesia is now considering minimum load reduction, which is one of the functions of Flex-USC.

4.8 Feasibility of applying CCS to Bangladesh

4.8.1 Carbon Dioxide Capture and Storage Way



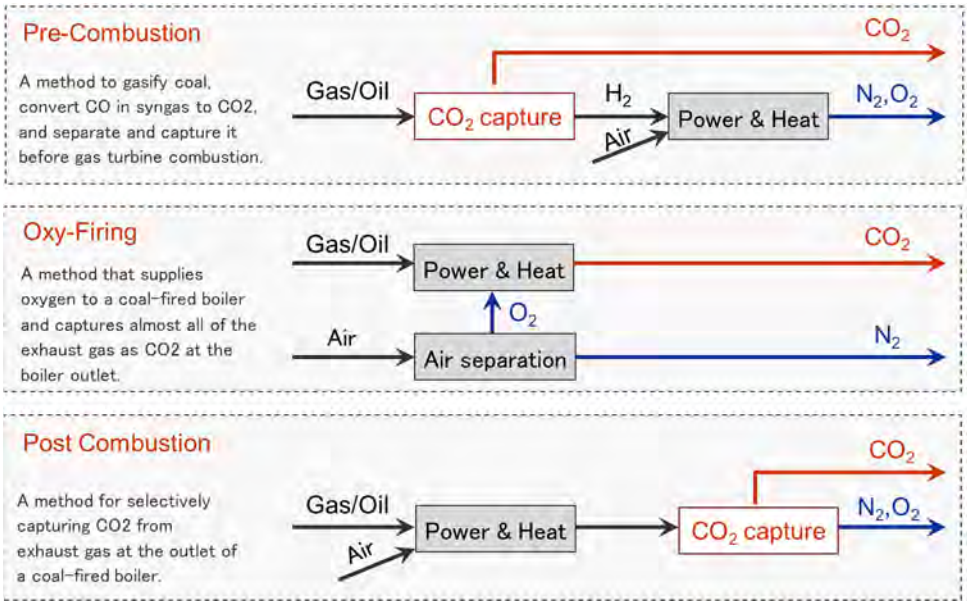
[Source: RITE(Research Institute of Innovative Technology for the Earth)]

Figure 4.8-1 Carbon Dioxide Capture and Storage Way

Figure 4.8-1 shows the carbon dioxide capture and storage way.

CO_2 is pressurized to about 20 MPa and stored in a water layer that is shielded by an impermeable layer. This aquifer exists in several layers at depths of approximately 1 km to 3 km below the ground and sea floor. For long-term storage, a capped and shielded aquifer is preferable, as shown in the left side of Figure 4.8-1.

4.8.2 CO_2 Capture Way



Source: Study Team

Figure 4.8-2 CO_2 Capture Way from Thermal Power Plants

Figure 4.8-2 shows the CO_2 capture way from thermal power plants.

(1) Pre-Combustion CO_2 Capture (Pre-Combustion)

A technology used in IGCC systems in which coal is gasified and the CO in the syngas is converted to CO_2, which is then separated and recovered prior to gas turbine combustion.

(2) Oxy-Firing (Oxy-Firing)

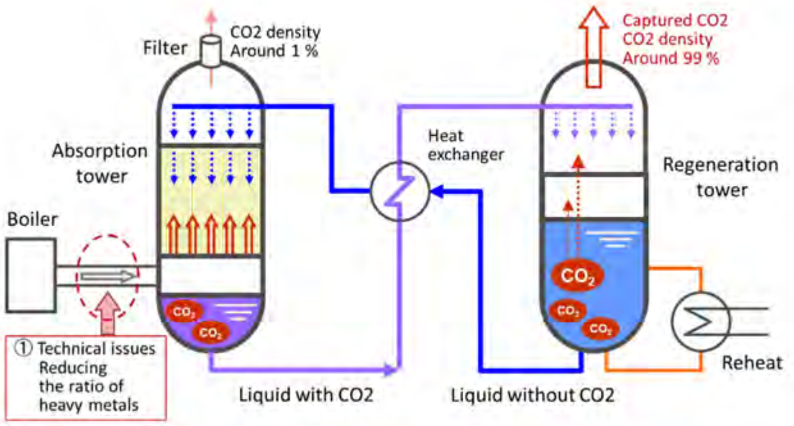
A technology currently under development in which oxygen is supplied to a coal-fired boiler and almost all of the exhaust gas is recovered as CO.

This method is currently under development.

(3) Post Combustion (CO_2 Capture)

This is a technology used for CO_2 capture in USC boilers, in which CO_2 is selectively captured from the exhaust gas at the outlet of a coal-fired boiler.

4.8.3 CO2 Capture Technology (Amine Chemical Absorption Method)



Source: Study Team

Figure 4.8-3 CO2 Capture Technology (Amine Chemical Absorption Method)

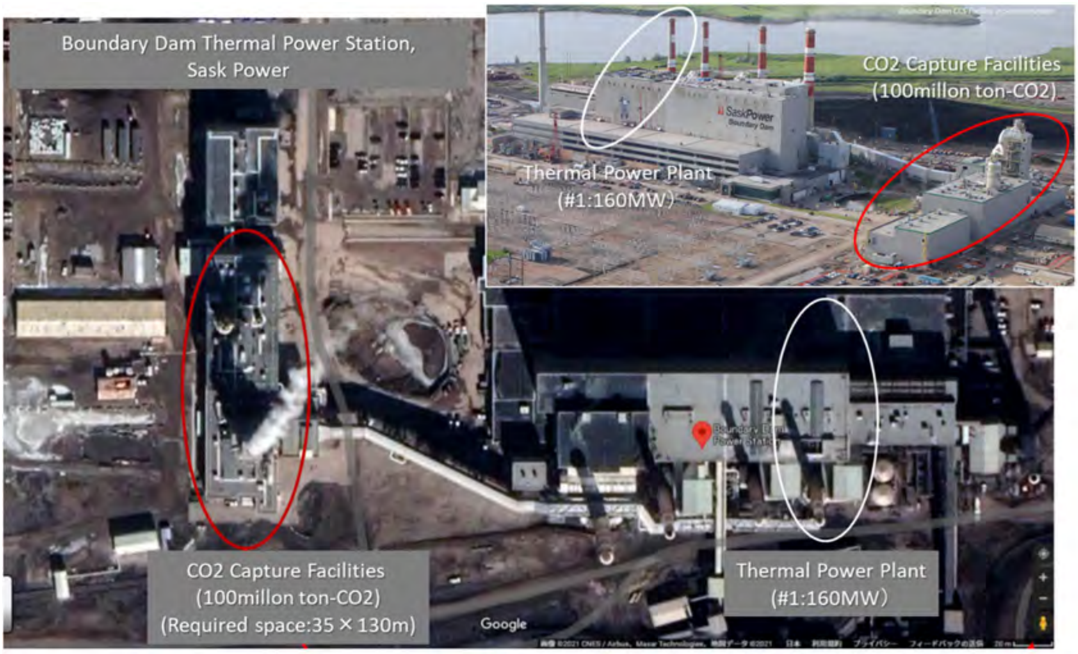
Figure 4.8-3 shows the CO2 capture technology (amine chemical absorption method). After absorbing CO2 in the "absorption tower" on the left of the figure, the absorbed liquid is sent from the bottom of the absorption tower to the "regeneration tower," where it is heated by steam to release CO2, and the regenerated absorbed liquid is returned to the "absorption tower" for reuse.

This figure shows the case where the exhaust gas from the boiler does not contain many heavy metals, and the final CO2 capture rate is 99%.

However, heavy metals are contained in the actual boiler exhaust gas. In practical application tests, it has been found that when gas containing such heavy metals enters the CO2 capture tower, the amine reacts with these heavy metals and the reaction to CO2, which is the original purpose of absorption, is reduced.

Therefore, improving the CO2 capture rate is an issue for the future.

4.8.4 Example of CO2 capture system installation (Sask Power in Canada)



[Picture Source: International CCS Knowledge Centre, Public report 2018]

Figure 4.8-4 Required installation space for CO2 capture facilities

Figure 4.8-4 shows the required installation space for the CO2 capture facilities. The CO2 capture facility used in Sask Power is the Amine Chemical Absorption Method shown in Figure 4.8-3. The photo in Figure 4.8-4 shows the CO2 capture facilities delivered to Sask Power's Boundary Dam Power Plant Unit 3 (160 MW at the generation end and 150 MW at the transmission end) in Canada. The CO2 captured here is sold for EOR (about 1.4 km depth) and some of it is injected into the deep saline layer (3.2 km depth).
EOR: Enhanced Oil Recovery

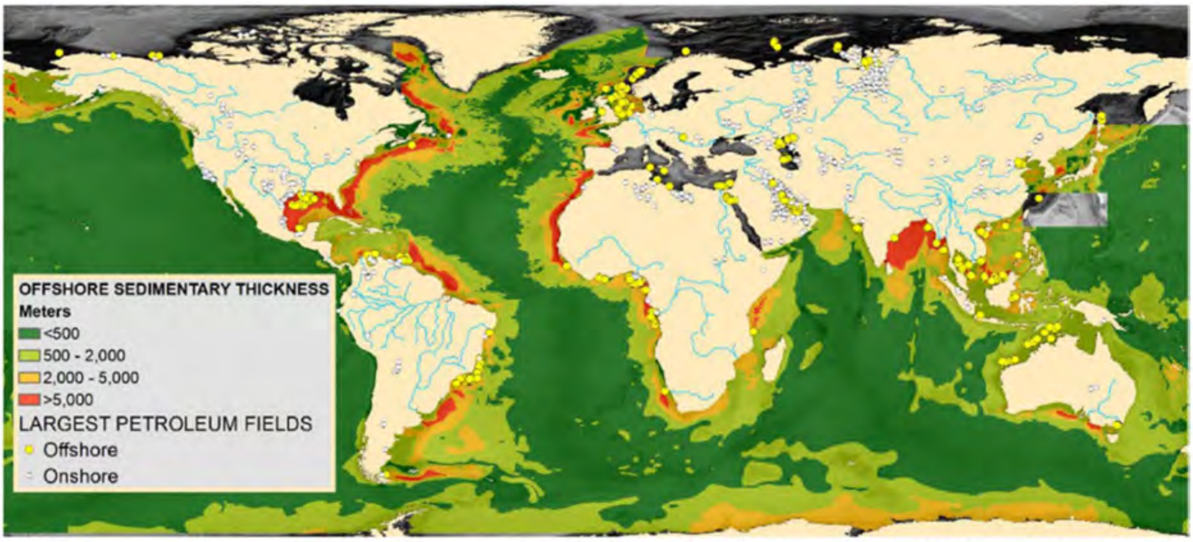
(1) Capacity of CO2 Capture facilities
The CO2 capture facilities has a capture capacity of about 1 million ton-CO2 /year, and captures all the CO2 from the exhaust gas from Unit 3, which has 160 MW at the generation end and 150 MW at the transmission end.

(2) The power required for CO2 capture facilities
The power required for the CO2 capture facilities with a capture capacity of 1 million ton-CO2/year is about 30 MW, which is about 20% of the power required at the transmission end of 150 MW.

(3) Installation space required for the CO2 capture facilities
As shown in Figure 4.8-4, the space required for the CO2 capture facilities is 35×130m ≒ 4,500m2, which is about 1 million tons of CO2/year for a 160MW power generation facility.

(4) Cost of the CO2 capture facilities
When installed in 2015, the cost of the CO2 capture facilities is about 1.4 times the cost of a 160 MW power generation facility. Therefore, the overall cost including the power generation equipment and CO2 capture equipment is 2.4 times higher than that of the power generation equipment alone.

4.8.5 Potential for CO2 storage in the water layer



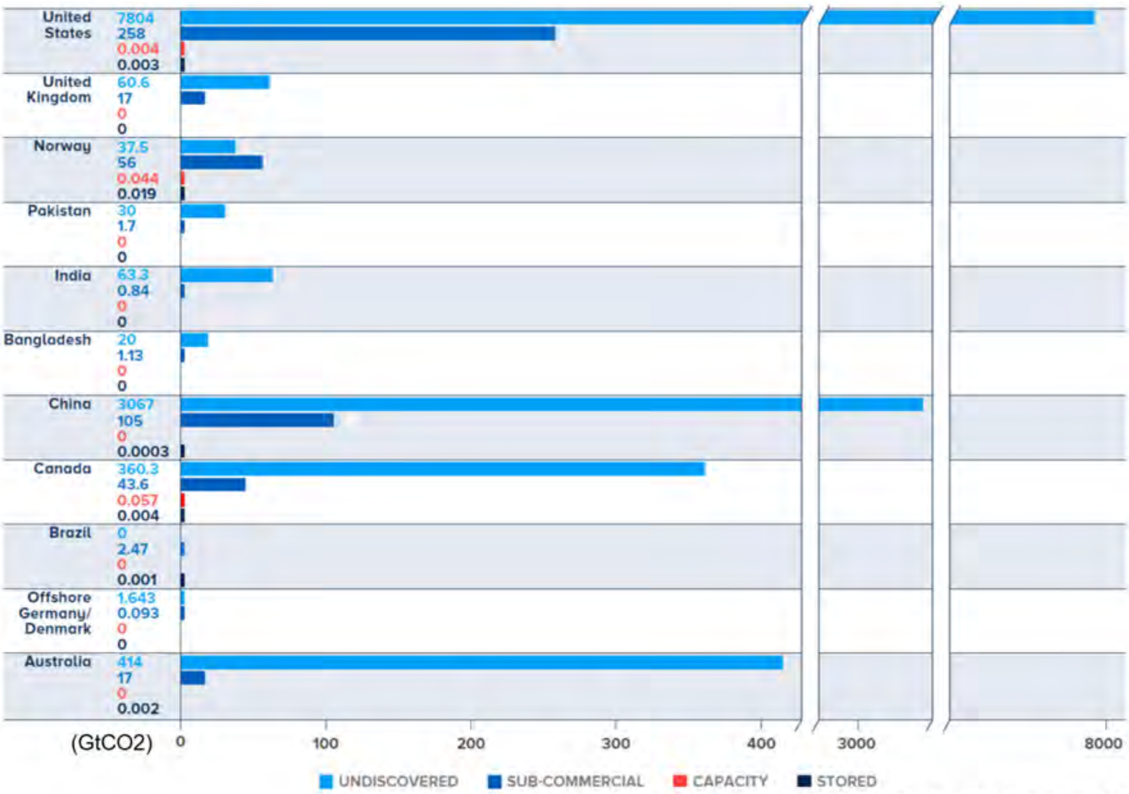
[Source: T. A. Meckel The University of Texas, Scientific reports, 2019]

Figure 4.8-5 CO2 reservoirs on the seafloor (Gton class)

Figure 4.8-5 shows a CO2 reservoir (Gton class) on the seafloor. The colors shown in the figure (green, light green, yellow, and red) indicate the thickness of the reservoir (m).

This shows that there are 5,000m class reservoirs off shores of India and Bangladesh, indicating that there is potential for CCS in Bangladesh.

4.8.6 Global CO2 Storage Resource Assessment

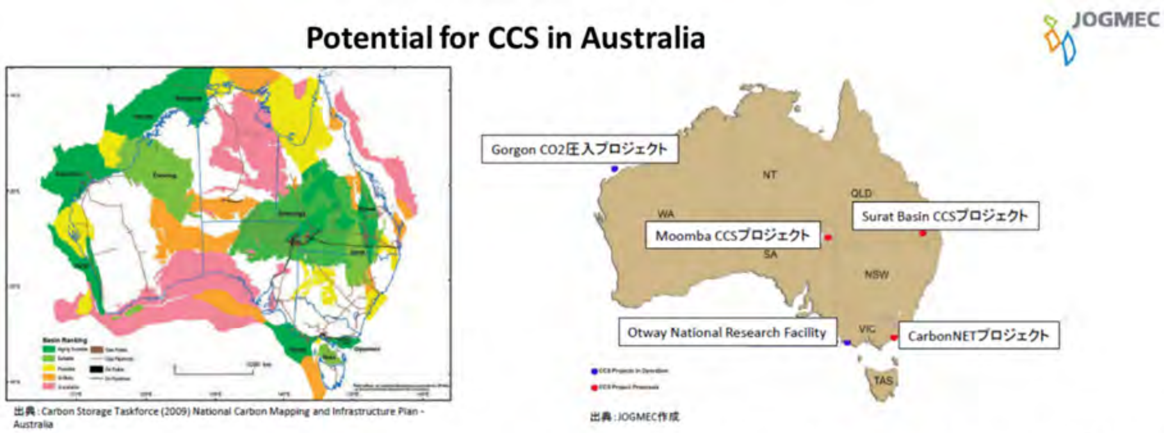


[Source: Global status of CCS 2020, Global CCS Institute]

Figure 4.8-6 Global CO2 Storage Assessment

Figure 4.8-6 shows the global CO2 storage assessment. This figure is the latest data published in 2020, and these assessments will be updated in the future. According to this figure, the potential for storage is 20 GtCO2 in Bangladesh.

4.8.7 Potential of CCS in Australia



[Source: Japan Oil, Gas and MEtals national Corporation(JOGMEC)]

Figure 4.8-7 Potential of CCS in Australia

Figure 4.8-7 shows the potential of CCS in Australia. Australia is currently one of the countries actively involved in CCS, and projects like the one shown in the right figure are being promoted. The left figure also shows the potential for CO_2 storage.

As for ammonia, the use of which is expected to expand in Japan in the future, it is planned to reform Australian coal to ammonia and transport it to Japan. It is also being considered to storage the CO_2 generated during the reforming process in Australia. If this can be realized, ammonia used in thermal power plants will become a fuel equivalent to green ammonia.

In Japan, a process that involves CO_2 storage at the location where the fuel is reformed as described above is being considered.

4.8.8 Issues to be addressed to achieve CCS in Matarbari Units 3/4

When considering how to achieve CCS in Matarbari Units 3/4, the following issues can be listed.

(1) In CO_2 capture

(a) Improvement of CO_2 capture technology

As described in clause 4.8.3, improvement of CO_2 capture technology is desirable for the CO_2 capture stage.

(b) Space required for installation of CO_2 capture facilities.

It is necessary to install the CO_2 capture facilities in an area next to and larger than the power generation facilities (Boiler, Turbine and Generator area).

Based on the case study of Sask Power's Boundary Dam power plant in Canada, the space required for the installation of CO_2 capture facilities for the 1,200MW of Matarbari Units 3/4.

To capture the entire 1,200 MW of CO_2 from Matarbari Units 3/4

1,200MW / 160MW (Boundary Dam Unit 3) ≒ 8 times

To Matabari Units 3/4

Assuming that 8 units of the CO_2 capture facilities of Boundary Dam Unit 3 are to be installed, the required space is

(35 x 130m) x 8 ≈ 36,000m2

(2) In CO_2 transportation.

How will the captured CO_2 be transported to the area where it can be stored? Consideration needs to be given to securing a transport line, such as whether to install a pipeline on land, or whether to transport it by ship and inject it from an offshore base.

(3) In CO_2 storage

As shown in Figure 4.8-1, in the case of injection into the aquifer off Bangladesh, the CO_2 storage capacity is 20 Gton-CO_2 in the published value in 2020.

As shown in clause 4.4.2, CO_2 reduction from Matabari Units 3/4 by ammonia co-firing.

The annual CO_2 emission from 1,000MW coal-fired power plant is about 5million ton-CO_2.

20Gton-CO_2/year / 5million ton-CO_2/year = 4,000 years

The CO_2 emitted from a 1,000 MW coal-fired power plant would be enough to store for 4,000 years.

(4) Economic feasibility of CCS

In the case of the Sask Power Boundary Dam in Canada, the total cost of the power generation facilities plus the CO_2 capture system is increased by 1+1.4=2.4 times by installing the CO_2 capture facilities.

And, it is necessary to take into account the fact that the power loss due to CO_2 capture facilities is about 20%.

In addition, the economic efficiency varies greatly depending on the CO_2 storage location and the transportation method.

However, looking ahead to the future, the CO_2 capture facilities is expected to improve significantly due to the merits of scale and mass production.

(5) Summary

As described in (1) to (4), it is difficult to apply CCS in this project because of the wide range of issues that need to be solved, such as CO_2 capture technology, securing space for CO_2 capture equipment, consideration of CO_2 transportation routes, and consideration of CO_2 storage sites.

However, if we look into the future of CO_2 capture equipment, the economics of introducing CCS is expected to be greatly improved through economies of scale and mass production.

In this way, economic efficiency is a major issue in the introduction of CCS, but the world is currently aiming to reduce costs through economies of scale (larger-scale CCS projects), accumulation of experience, and technological development, and it is necessary to continue to pay attention to these trends.

Chapter 5 Overview of the surrounding area for the planned Power Plant Construction Area

5.1 Overview of the environment

Regarding the environmental conditions of the project site and its surroundings, the Study Team has referred / reviewed “Bangladesh Coal-Fired Power Plant Construction Project Preparatory Survey Report on Units 1/2 Construction Project”, “The Environmental monitoring report on Units 1/2 Construction Work”, and the results of the rainy and dry season surveys (including interview surveys) conducted in this survey.

The details of the survey results are organized in each Appendix.

Referred Literature/ document	Survey period	Remarks
Preparatory Survey on Matarbari Ultra Super Critical Coal-Fired Power Plant Development Project Phase 2 in Bangladesh	February, July, 2021	February is dry season and July is rainy season. Gathering information related to natural environment is mainly field surveys and literature surveys. Regarding gathering information related to social environment, interviews with related organizations and local residents, surveys through questionnaire were conducted, in addition to literature surveys.
Bangladesh Coal-Fired Power Plant Construction Project Preparatory Survey Report on Units 1/2 Construction Project	October 2012, January,2013	
The Environmental monitoring report on Units 1/2 Construction Work	From January, 2019 to January, 2020	[Natural environment] Regarding survey data from January 2019 to January 2020, this period was before the spread of Covid-19. Construction works such as dredging work, foundation ground work, and port construction work were carried out. In Covid-19 crisis, there was the time when parts of construction works were suspended. But, after 2021, construction works have been become ordinary condition. Environmental monitoring of construction works has being continued.
	From January, 2018 to July, 2021	[Social environment] Information on social environment was reviewed from the start of monitoring to the latest July 2021.

Current situation of the proposed project site for Units 3/4 is show in Figure 5.1-1.

Currently, the proposed project site has been using as construction materials and equipment storage for Units 1/2.

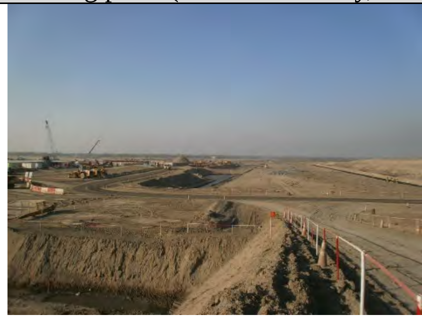
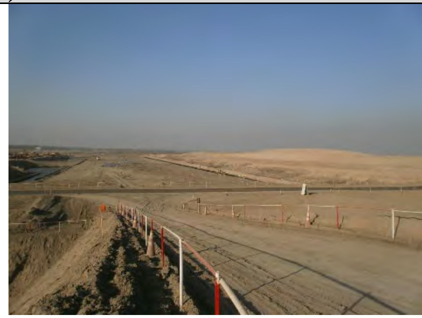
When Units 3/4 starts construction work, storage area for construction materials and equipment will be set up in the project site, likewise Units 1/2.

Source: Study Team from Google Earth

Figure 5.1-1 Current situation of the proposed project site for Units 3/4

No	Shooting from left side to right side at standing point (dated 27 January, 2021)
1	   

No	Shooting from left side to right side at standing point (dated 27 January, 2021)
2	
3	
4	

No	Shooting from left side to right side at standing point (dated 27 January, 2021)
5	   
6	   
7	   

Source: Study Team

5.1.1 Air quality (Refer to Appendix 5.1.1)

(1) Meteorology

The climate of Bangladesh belongs to the tropical monsoon climate.

Around the project, Kutubdia weather station is set up about 10km north and Cox's Bazar weather station is set up about 30km south.

Since Cox's Bazar weather station could not measure data from August to December 2020, observation results of temperature and precipitation from 2012 to 2020 of Cox's Bazar published by Japan Meteorological Agency are also summarized.

There are no meteorological observations data at the project site, so the results of from 2018 to 2020 of meteorological model (MM5[1]) are organized.

The details of the survey are as follows.

Source: Study Team

Figure 5.1-2 Location of weather station

[1] The Fifth-Generation NCAR/Penn State Mesoscale Model; Pennsylvania State University and NCAR (National Center for Atmospheric Research) has been developing meteorological model of Mesoscale

(1-1) Overview of the weather station near the project site (Cox's Bazar, Kutubdia)

(1-1-1) Temperature

According to the observation results from 2012 to 2020 (9 years) published by Japan Meteorological Agency in Table 5.1-1, 19.3 ℃ (January) is the lowest and 29.1 ℃ (May) is the highest.

Table 5.1-2 shows the temperature of Kutubdia. Annual average temperature is 26.3 ℃, maximum temperature is 36.6 ℃ (May), minimum temperature is 11.7 ℃ (February).

(1-1-2) Precipitation

According to the observation results from 2012 to 2020 (9 years) published by the Japan Meteorological Agency in Table 5.1-1, the annual precipitation is 3,678 mm, precipitation in July is the highest month.

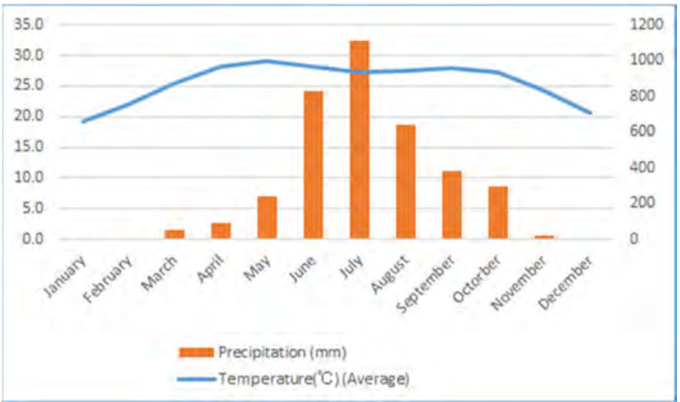
According to Table 5.1-2, the annual precipitation of Kutubdia is 3,165 mm, precipitation is low in December to March and high in June to August.

(1-1-3) Wind conditions

About the wind conditions of Kutubdia (Table 5.1-2), the average annual wind speed is 5.1 m/s.

Table 5.1-1 Meteorology of Cox's Bazar (2012-2020)

Month	Temperature(℃) (Average)	Temperature(℃) (Highest)	Temperature(℃) (Lowest)	Precipitation (mm)
January	19.3	26.9	15.6	7
February	22.0	29.9	18.1	5
March	25.4	31.9	21.6	49
April	28.1	33.2	24.8	93
May	29.1	33.2	25.8	239
June	28.3	31.8	25.9	830
July	27.4	30.7	25.5	1112
August	27.5	31.2	25.6	639
September	28.0	31.9	25.6	385
October	27.2	31.9	24.7	292
November	24.2	31.0	21.1	20
December	20.7	28.0	17.3	8
Annual	25.6	31.0	22.6	3,678



Note: Survey period from January, 2012 to November, 2020

Source: Japan Meteorological Agency

Table 5.1-2 Meteorology of Kutubdia (2020)

Year	Month	Temperature (℃) (Average)	Temperature (℃) (Highest)	Temperature (℃) (Lowest)	Humidity (%) (Average)	Precipitation (mm)	Wind speed (m/s) (Average)	Missing rate (%)
2020	January	20.1	28.4	12.2	76.2	41	4.1	-
	February	21.3	29.5	11.7	70.8	2.0	4.1	-
	March	25.9	34.0	17.5	73.5	0.0	4.2	-
	April	27.9	33.5	21.7	77.3	62.0	4.4	-
	May	29.2	36.6	22.8	78.6	155.0	5.2	-
	June	28.7	34.5	19.0	84.4	554.0	7.3	-
	July	28.5	33.5	25.0	85.7	830.0	6.8	6.5
	August	27.9	34.0	24.8	87.8	892.0	7.4	-
	September	29.2	35.0	24.7	81.4	246.0	4.9	-
	Octorber	29.3	35.0	24.5	79.9	297.0	3.7	-
	November	25.8	32.2	17.4	78.6	86.0	4.3	-
	December	21.1	29.3	13.7	67.3	0.0	4.7	-
Annual		26.3	-	-	78.5	3165.0	5.1	0.5

Source: Study Team

(1-2) Overview of the weather at the project site

(1-2-1) Temperature

As shown in Table 5.1-3 and Figure 5.1-3, the average temperature is 18.2 ℃ in January, which is the lowest in the year, and 27.6 ℃ in June, July, it is the highest in the year.

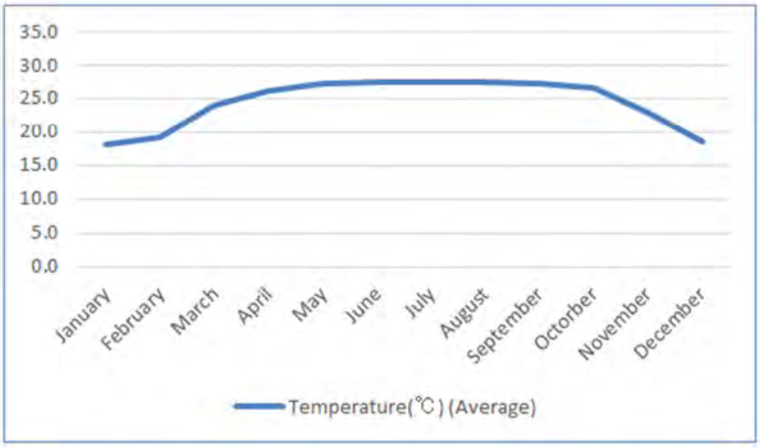
(1-2-2) Wind conditions

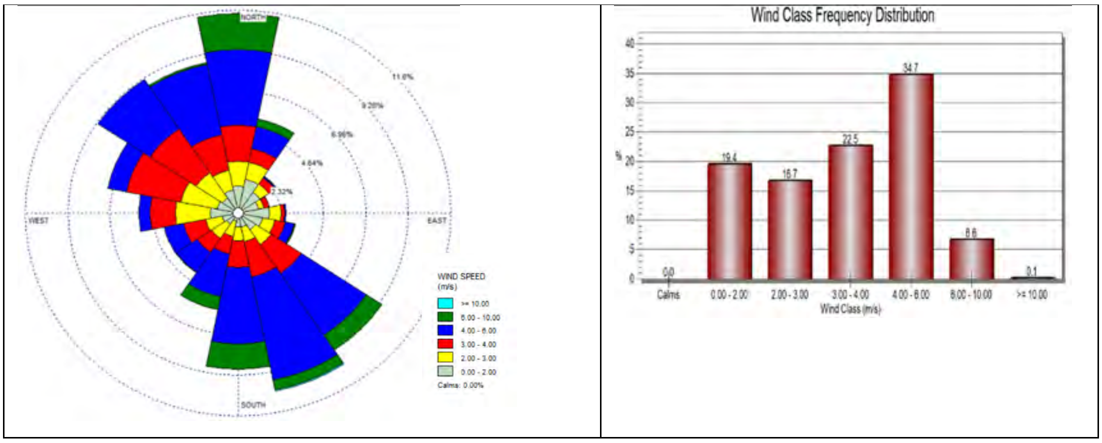
As shown in Table 5.1-3 and Figure 5.1-3, the westerly wind is predominant in the dry season January and February, and the southerly wind is predominant in the rainy season May-August.

The average annual wind speed is 3.4 m/s, and the average wind speed tends to be higher in the rainy season than in the dry season. Appendix 5.1.1 shows wind rose and occurrence rate of wind speed from 2018 to 2020.

Table 5.1-3 Meteorology of project site (2020) [Weather model data]

Year	Month	Temperature(℃) (Average)	Temperature(℃) (Highest)	Temperature(℃) (Lowest)	Humidity (%) (Average)	Prevailing direction wind	Wind speed (m/s)(Average)	Wind speed (m/s)(Highest)
2020	January	18.2	21.8	13.8	75.6	NW	2.5	6.7
	February	19.2	23.7	14.9	73.8	NW	2.4	5.7
	March	24.0	29.0	18.7	72.2	NNW	2.9	7.7
	April	26.1	30.1	22.7	77.8	W	2.9	9.3
	May	27.2	31.8	23.5	80.8	SSE	3.8	9.3
	June	27.6	30.7	24.3	88.4	SSE	4.2	9.3
	July	27.6	30.8	24.5	89.2	SSE	4.1	8.2
	August	27.5	31.3	24.9	90.1	SSE	4.2	9.3
	September	27.3	31.4	24.1	88.4	SSE	3.5	7.7
	Octorber	26.6	30.7	23.3	85.0	SE	3.3	10.8
	November	22.9	28.1	18.7	79.7	NNW	3.6	8.7
	December	18.5	22.7	14.9	73.0	N	3.0	7.7
Annual		24.4	28.5	20.6	81.2	---	3.4	8.4





Note: Wind rose by MM5 at project site (2020.1.1-2020.12.31)
Source: Study Team

Figure 5.1-3 Wind rose

(2) Air pollutants (Refer to Appendix 5.1.1)

The project site has a good air environment that meets environmental standards. The details of the survey are as follows.

(2-1) Results of the survey for this study

The concentration of suspended particulate matter (SPM) was slightly high, but SOx and NOx were low, which were lower than air quality standards.

(2-2) Information from "Bangladesh Coal-Fired Power Plant Construction Project Preparatory Survey Report on Units 1/2 Construction Project"

The concentration of suspended particulate matter (SPM) was slightly high in both the rainy season and the dry season, but SOx and NOx were low, which were below the national standards.

(2-3) Information from "The Environmental monitoring report on Units 1/2 Construction Work"

Throughout the year, the site and its surroundings were below the national environmental standards.

5.1.2 Noise / Vibration (Refer to Appendix 5.1.2)

(1) Results of the survey for this study

[Noise]

Noise level of Matarbari village, Dhalghata village exceeded Noise standards of "Complex area (mainly residential area, and also applied to commercial and industrial area)". This reason is that daily life noise is ordinary high in residential area.

It is almost same as the noise level reported in the environmental monitoring conducted for Units 1/2 construction work, which is described later.

[Vibration]

According to the observation results of microtremor survey at Matarbari village and Dhalghata village, H/V spectral ratio, peak amplitude, and predominant period at both observation points are similar, indicating a tendency of soft ground/soil.

In addition, at the time of the observation, no large vibration source was confirmed around Matarbari village and Dhalghata village.

Vibration survey results of Matarbari village and Dhalghata village are also sufficiently low, and it is considered that there is no effect of vibration on livelihood.

(2) Information from "Bangladesh Coal-Fired Power Plant Construction Project Preparatory Survey Report on Units 1/2 Construction Project"

The survey was conducted during the daytime. Noise level exceeds the environmental standard of residential area. Daily life noise is relatively high due to vehicle traffic/ voice of residents and so on around the project site from before construction work for Units 1/2.

(3) Information from "The Environmental monitoring report on Units 1/2 Construction Work"

Throughout the year, the boundary of the site on the residential area side is well below the standard value applied to the commercial / industrial area, but slightly exceeds the standard value applied to the residential area.

The boundary of the site and the residential area are a little far (about 50m), moreover, it is more than 100m from site boundary to construction area. As a result, there will be little noise due to construction work for this project.

As the Environmental monitoring report on Units 1/2 Construction Work, EPC has been conducting focus group discussion every quarterly, there were any concerns against noise of construction works by pile drivers in night time from local resident at focus group meeting in November 2020.

Contractor (EHS unit) has promptly dealt with avoidance of construction works in night time near the residential area for solving these problems.

5.1.3 Odor (Refer to Appendix 5.1.3)

According to the "The Environmental monitoring report on Units 1/2 Construction Work", malodorous substances (Ammonia, Hydrogen sulfide) in and around the site were not detected throughout the year.

5.1.4 Water quality (Refer to Appendix 5.1.4)

(1) Water quality

(1-1) Seawater

The water quality (salinity, suspended solids, etc.) in the sea area around the project is affected by rainfall in the rainy season and inflow water from rivers, and their values greatly fluctuate.

The concentration of heavy metals is low except for iron. The details of the survey are as follows.

(1-1-1) Results of the survey for this study

Average water temperature (water depth 0.5 to 8 m) is 23 ℃ in dry season, and it is 27 ℃ in rainy season.

Salinity is 25 ppt (part per thousand) in dry season, and it is 21 ppt in rainy season. Rainy season is affected due to precipitation. SS is 128 mg/L in dry season, and it is 259 mg/L in rainy season. Heavy metals were below the detection limit in many items.

(1-1-2) Information from "Bangladesh Coal-Fired Power Plant Construction Project Preparatory Survey Report on Units 1/2 Construction Project"

(a) Rainy season

Water temperature is 28.5-30.5 ℃. The water temperature tends to high in the surface layer, to low in the deeply layer.

Salinity is 15.8-21.6 ppt. It tends to low in the surface layer, to high in the deeply layer. Suspended solids (SS) is as high as 640-910 mg/L due to the influence of river water.

COD was also very high at 160-197 mg/L, but BOD was 0.6-1.1 mg/L. The concentration of iron (Fe) is relatively high, but the concentration of other heavy metals is low.

(b) Dry season

Water temperature was 18.0 -19.0 ℃. Salinity is 34.3 -77.3 ppt, and there was no difference depending on the water depth.

Due to the influence of river water, SS is as high as 46-329 mg/L (especially in the bottom layer). COD is as high as 203-235 mg/L, but the BOD is 0.2-0.6 mg/L.

Heavy metals tended to be similar to rainy season.

(1-1-3) Information from "The Environmental monitoring report on Units 1/2 Construction Work"

Water temperature is 16 to 30 ℃ (water depth 0.5 to 8 m) throughout the year.

Salinity is 13 to 32 ppt and is affected by rivers and rainfall.

SS is 128-1,020 mg/L and tends to be high in the rainy season. COD is 15 to 340 mg/L (The analysis method of COD was changed during the referred period, and there were large difference in both analysis values. The corrected/converted value is 8 to 38 mg/L), BOD is 1.1 to 2.7 mg/L. Heavy metals[2] were below the detection limit in many items.

(1-2) Surface water (Kohelia Canal)

There are 6 criteria for surface water in Bangladesh. The Kohelia canal corresponds to "B: Recreation" out of the six criteria (environmental standards). The details of the survey are as follows.

(1-2-1) Results of the survey for this study

Water quality is almost same as the environmental monitoring results carried out at Unit 1/2, and the level which corresponds to "B: recreation".

Water temperature of Dry season is 24°C, that of Rainy season is 27°C. BOD values are always low and are less than environmental standard.

[2] Posted as a reference because the quantification limit value setting for heavy metal analysis is high.

(1-2-2) Information from “Bangladesh Coal-Fired Power Plant Construction Project Preparatory Survey Report on Units 1/2 Construction Project”

In this survey, water temperature of dry season was 18°C, salinity was 35 ppt, Kohelia canal is a brackish water area where seawater flows in, based on salinity data, and is affected by the water quality of the sea area.

Water temperature of dry season was 30.6°C, salinity was 9.8 ppt slightly less than that of dry season due to dilution of rainwater. In addition, BOD values are always low and are less than environmental standard.

(1-2-3) Information from “The Environmental monitoring report on Units 1/2 Construction Work”

The water quality is same level of survey results of the above-mentioned “Bangladesh Coal-Fired Power Plant Construction Project Preparatory Survey Report on Units 1/2 Construction Project".

Water temperature through 1 year was 19 to 29°C, salinity was 6 to 28 ppt, BOD values are always low and are less than environmental standard.

(1-3) Groundwater

Status of groundwater around the project site are as follows.

(1-3-1) Results of the survey for this study

About water quality of wells that located in Matarbari village, Dhalghata village, Turbidity, SS, Nitrogen (Total), Coliform have exceed drinking quality standards.

Other items are less than the standards, but it is necessary to take measures such as boiling, filtering, if drinking.

(1-3-2) Information from “Bangladesh Coal-Fired Power Plant Construction Project Preparatory Survey Report on Units 1/2 Construction Project”

Both the rainy season and the dry season met the country's drinking water standards.

(1-3-3) Information from “The Environmental monitoring report on Units 1/2 Construction Work”

About the quality of ground water in project site, Fecal Coliform has exceeded drinking water quality standard, in addition, other items have not exceeded, but it is necessary to take measures such as boiling, if drinking.

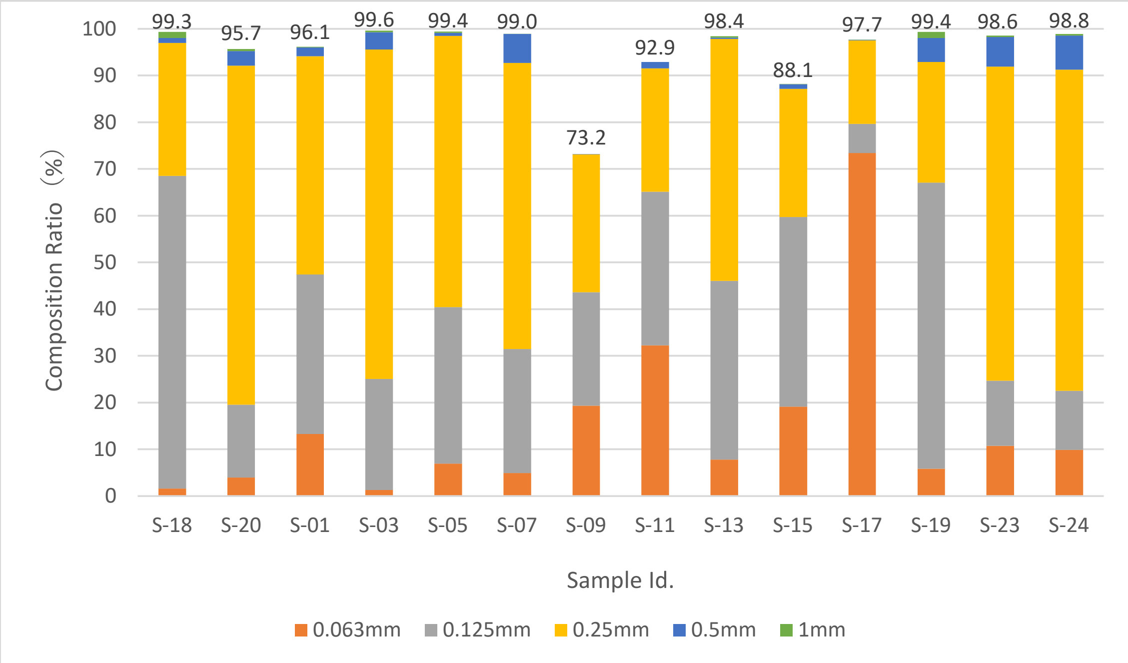
(2) Sediment

(2-1) Kohelia Channel (Refer to Appendix 5.1.4)

The Study Team conducted the Sedimentation survey on 14 points in the Kohelia Channel during the dry season and the rainy season. The survey position is shown in the Figure 5.1-4. Here, from grain size analysis, a grain size of 0.063 mm or less was classified as silt, 0.063 to 0.125 mm as very fine sand, 0. 125 to 0.25 mm as fine sand, 0.25 to 0.5 mm as medium sand, 0.5 to 2 mm as coarse sand, 1 to 2 mm as very coarse sand, and 2 mm or more as gravel Composition Ratio of sand distribution (dry season) is shown in the Figure 5.1-5. Composition Ratio of Sand distribution (rainy season) is shown in the Figure 5.1-6. As a result, the composition ratio of sand distribution at the survey site is 73.2 to 99.6% in the dry season and 70.2 to 98.7% in the rainy season, and the sand content is very high, so it can be said that the sediment of the Kohelia Channel is sandy.

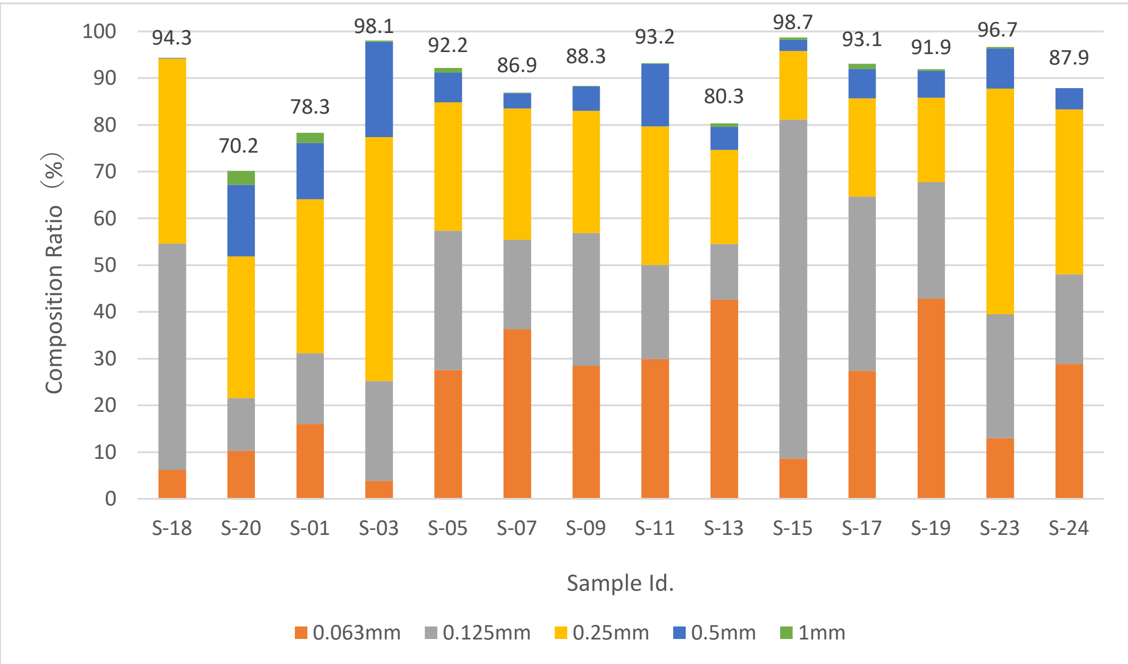
Figure 5.1-7 shows the grain size distribution and transport mode of sediments based on Visher (1969) (dry season). Figure 5.1-8 shows the grain size distribution and transport mode of sediments based on Visher (1969) (rainy season). Visher (1969) categorized the movement patterns of sediments into suspension that floats in water, traction that moves at the bottom, and saltation. The grain size distribution was considered to be composed of these sub-populations. From the graph, it was found that the sand in the Kohelia Channel is mainly moved by saltation.

Source: Study Team
Figure 5.1-4 Survey Point



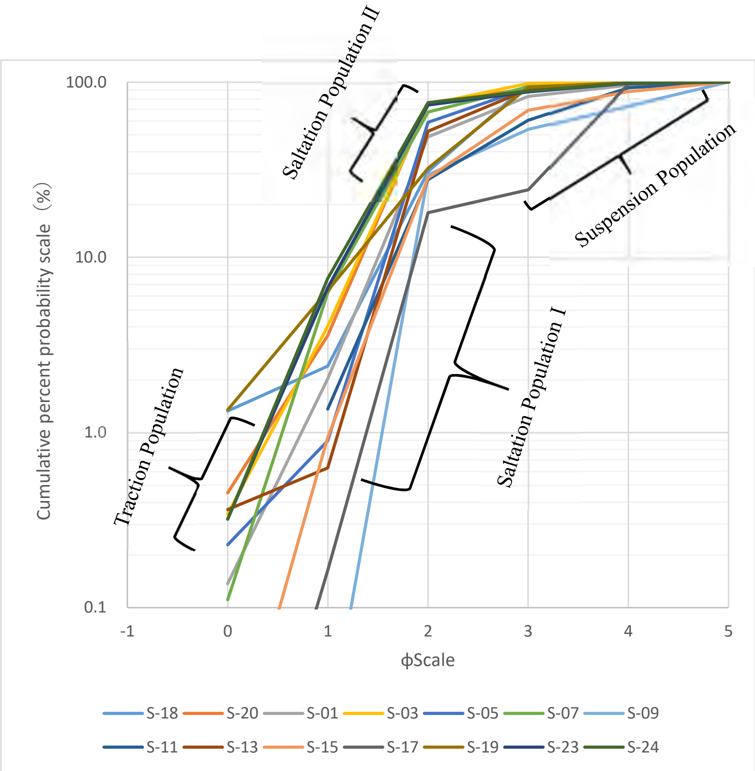
Source: Study Team

Figure 5.1-5 Composition Ratio of Sand distribution (dry season)



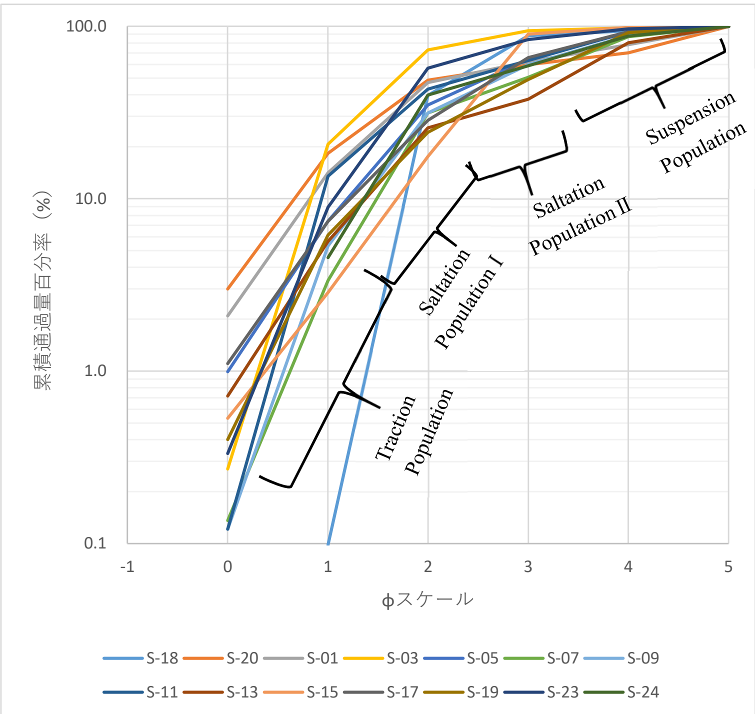
Source: Study Team

Figure 5.1-6 Composition Ratio of Sand distribution (rainy season)



Source: Study Team

Figure 5.1-7 Grain size distribution and transport mode of sediments based on Visher (1969) (dry season)



Source: Study Team

Figure 5.1-8 Grain size distribution and transport mode of sediments based on Visher (1969) (rainy season)

(2-2) Sea area

According to the “Bangladesh Coal-Fired Power Plant Construction Project Preparatory Survey Report on Units 1/2 Construction Project”, there is no standard value for heavy metals in sediments in Bangladesh.

The National Oceanic and Atmospheric Administration (NOAA) in United States has concentration guidelines[3] that affect benthic organisms, and ERL (Effects Range-Low) [4] and ERM (Effects Range-Median) [5] for heavy metals and organochlorine compounds are set.

5.1.5 Hydrographic Conditions

(1) Hydrography of Kohelia Channel

(a) Bathymetric Survey of Kohelia Channel (Refer to Appendix 5.1.5 (1))

The Study Team conducted the Bathymetric survey in the Kohelia Channel during the dry season, the normal season and the rainy season.

dry season	: from February 6th, 2021 to February 11th, 2021
normal season	: from April 8th, 2021 to April 11th, 2021
rainy season	: from June 28th, 2021 to July 3rd, 2021

The survey location is shown in Figure 5.1-9. The water depth contour is shown in Figure 5.1-10.

Comparing the results of the Bathymetric Survey in the dry season, the normal season and the rainy season around the project site (Cross section 05, 06-1, 06-2, 07, 08, 09, 10, 11, 12), the results were similar except for Cross-section 06-2. From this, it can be seen that no external force (waves and currents) that changes the water depth is generated between the dry season, the normal season and the rainy season. On the other hand, in Cross Section 06-2, the water depth became deeper by a maximum of about 3.0 m on the Left Side (x-axis: between 50 and 100 m) between the dry season and the normal season. Further the water depth became shallower by a maximum of about 2.0 m in the same section between the normal season to the rainy season, As mentioned above, there is no external force that changes the water depth between the dry season and the normal season (two months), and between the normal season and the rainy season (two months). From this, it is considered that the change of water depth is not naturally occurring dredging (between the dry season and the normal season) and sedimentation (between the normal season and the rainy season).

The reason is inferred as follows. Cross-Section06-2 is near the road bridge construction site by the RHD (Roads and Highways Department). The RHD is temporarily reclaiming the east of waterway in this area for road bridge construction. Therefore, the west side of the waterway will be used as a shipping route. Focusing on the cross section of section 06-2, the water depth on the west side is shallower than the water depth on the east side, which may interfere with the navigation of ships. Therefore, dredging was carried out to secure the depth of the navigation channel during the dry season and the normal season when the rainfall is low. During the normal season and the rainy season, when the rainfall is a lot of, the depth of the navigation channel can be secured sufficiently, so sedimentation was carried out and the topography was restored to the original.

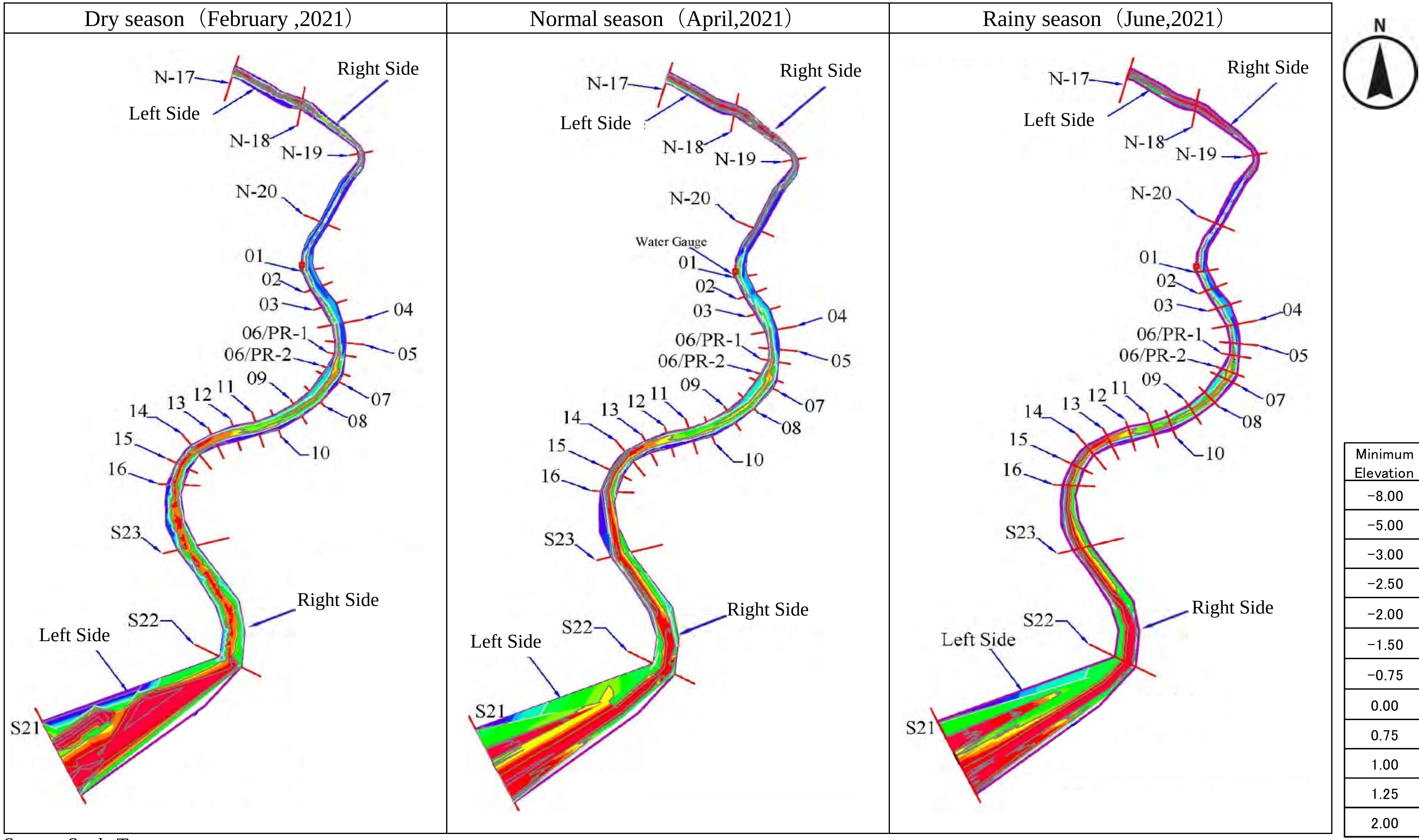
[3] NOAA (USA): Sediment Quality Guidelines for the National Status and Trends Program (http://response.restoration.noaa.gov/book_shelf/121_sedi_qual_guide.pdf (1999))

[4] ERL: When the concentrations in which toxicity was observed are arranged in order in the database for observing biological effects, the ranking value is 10% of the total, and adverse effects rarely occur at concentrations lower than this.

[5] ERM value: A ranking value equivalent to 50%, and adverse effects often occur at higher concentrations.

Source: Study Team

Figure 5.1-9 Survey Location (Cross Section)



単位：m

Minimum Elevation	Maximum Elevation	
-8.00	-5.00	
-5.00	-3.00	
-3.00	-2.50	
-2.50	-2.00	
-2.00	-1.50	
-1.50	-0.75	
-0.75	0.00	
0.00	0.75	
0.75	1.00	
1.00	1.25	
1.25	2.00	
2.00	8.00	

Source: Study Team

Figure 5.1-10 Water Depth Contour

(b) Tidal level of Kohelia Channel (Refer to Appendix 5.1.5 (2))

The Study Team conducted the Tidal level survey in the Marine (T1), the Rangakhali Channel (T2) and the Kohelia Channel (T3) during the dry season (from February 5th, 2021 to March 6th, 2021) and the rainy season (from June 18th, 2021 to July 18th, 2021). The tidal level of the Marine (T1) was used the tidal level of Matarbari Tide Gauge (CPA). The Survey Point of Tidal Level is shown in Figure 5.1-11. The Tidal circulation at 3 points (dry season) is shown in Figure 5.1-12. The Tidal circulation at 3 points (rainy season) is shown in Figure 5.1-13.

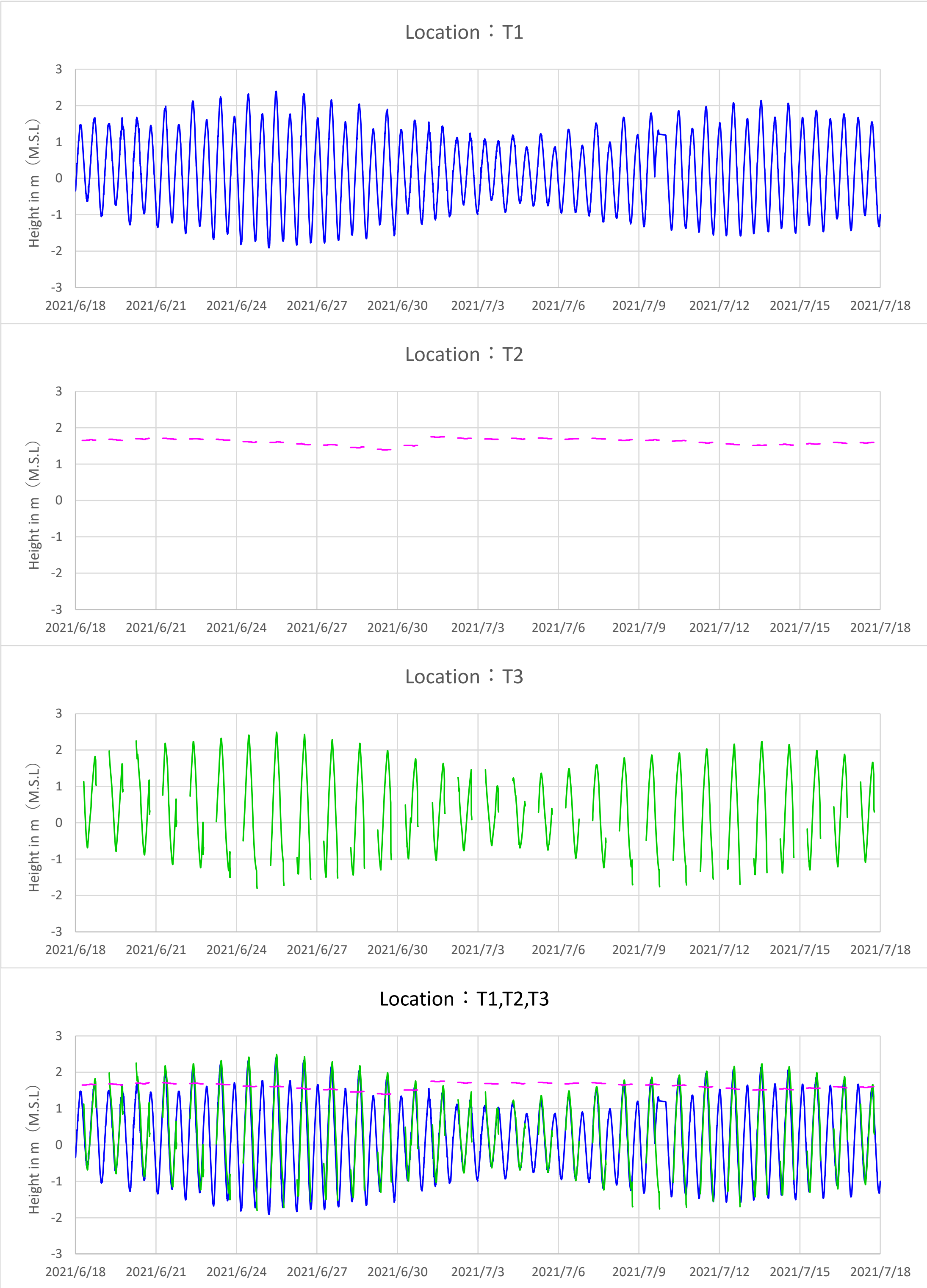
Comparing the tidal level at the 3 points, the tidal circulation in the Marine (T1) and The Kohelia Channel (T3) show similar tidal circulation. But the tidal level of the Rangakhali Channel (T2) was 0.5m (MSL) during the dry season and 1.4 – 1.7 m (MSL) during the rainy season, and the tidal level remained constant. The Kohelia Channel (T3) and the Marine (T1) are connected. So the tidal level of the Kohelia Channel and the tidal level of Marine are linked. On the other hand the Rangakhali Channel is not connected to the Kohelia Channel and the Marine. So the tidal level of the Rangakhali Channel is unaffected by the tidal level of the Kohelia Channel and the tidal level of Marine.

Source: Study Team

Figure 5.1-11 Survey Point of Tidal Level

Source: Study Team

Figure 5.1-12 Tidal Circulation at 3 points (dry season)



Source: Study Team

Figure 5.1-13 Tidal Circulation at 3 points (rainy season)

(c) Wave measurement of Kohelia Channel (Refer to Appendix 5.1.5 (3))

The Study Team conducted the wave and wind measurement surveys on the north side of the power plant (WC-01), around the power plant (WC-02), and on the south side of the power plant (WC-03) during the dry season (from February 14th , 2021 to March 15th, 2021) and the rainy season (from June 20th, 2021 to July 19th, 2021). The survey point of wave and wind measurement is shown in Figure 5.1-14. The Wave height distribution at 3 points (dry season) is shown in Figure 5.1-15. The Wave direction distribution at 3 points (dry season) is shown in Figure 5.1-16. Comparison of waves and wind conditions at survey point (dry season) is shown in Figure 5.1-17 - Figure 5.1-19. The Wave height distribution at 3 points (rainy season) is shown in Figure 5.1-20. The wave direction distribution at 3 points (rainy season) is shown in Figure 5.1-21. Comparison of waves and wind conditions at survey point (rainy season) is shown in Figure 5.1-22 - Figure 5.1-24.

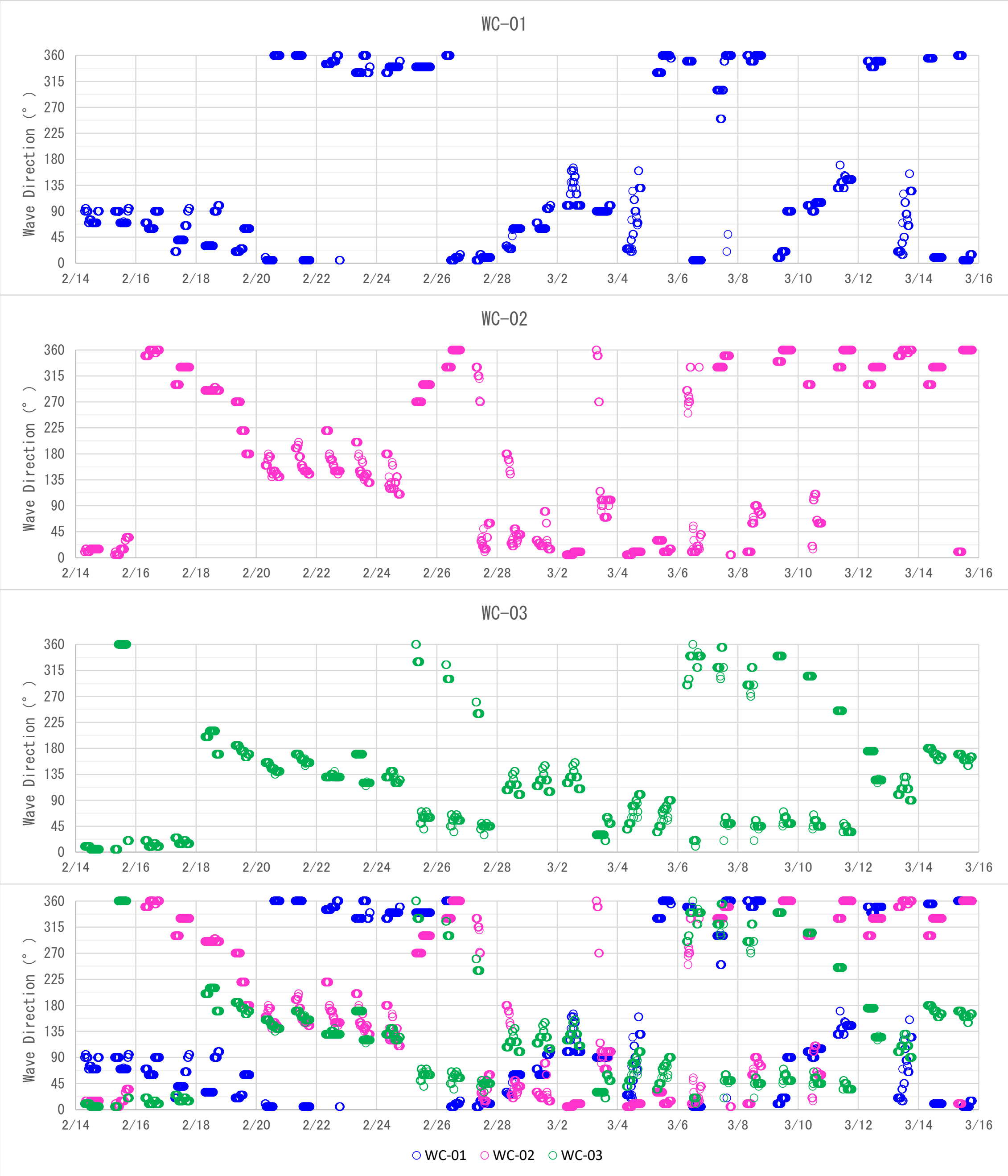
Comparing the waves and wind conditions at each point, the fluctuations in wave height and wind speed, and the wave direction and wind direction are similar. For this reason, the waves are thought to be caused by wind conditions.

Source: Study Team

Figure 5.1-14 Survey Point of Wave and Wind Measurement

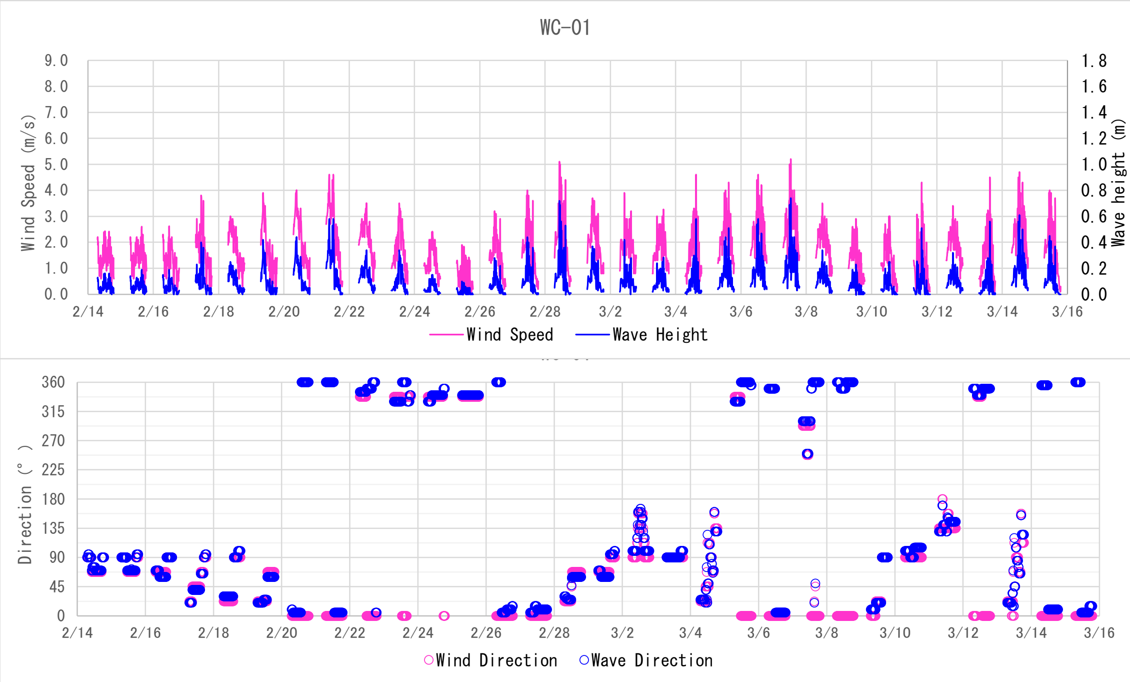
Source: Study Team

Figure 5.1-15 Wave Height Distribution at 3 points (dry season)



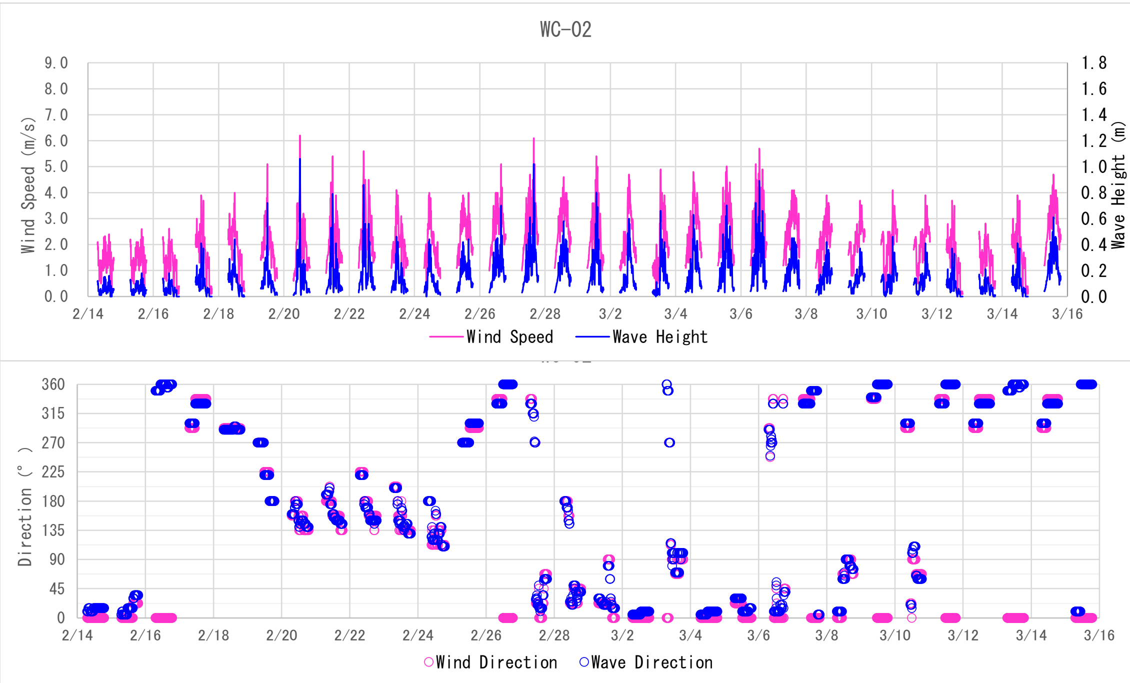
Source: Study Team

Figure 5.1-16 Wave Direction Distribution at 3 points (dry season)



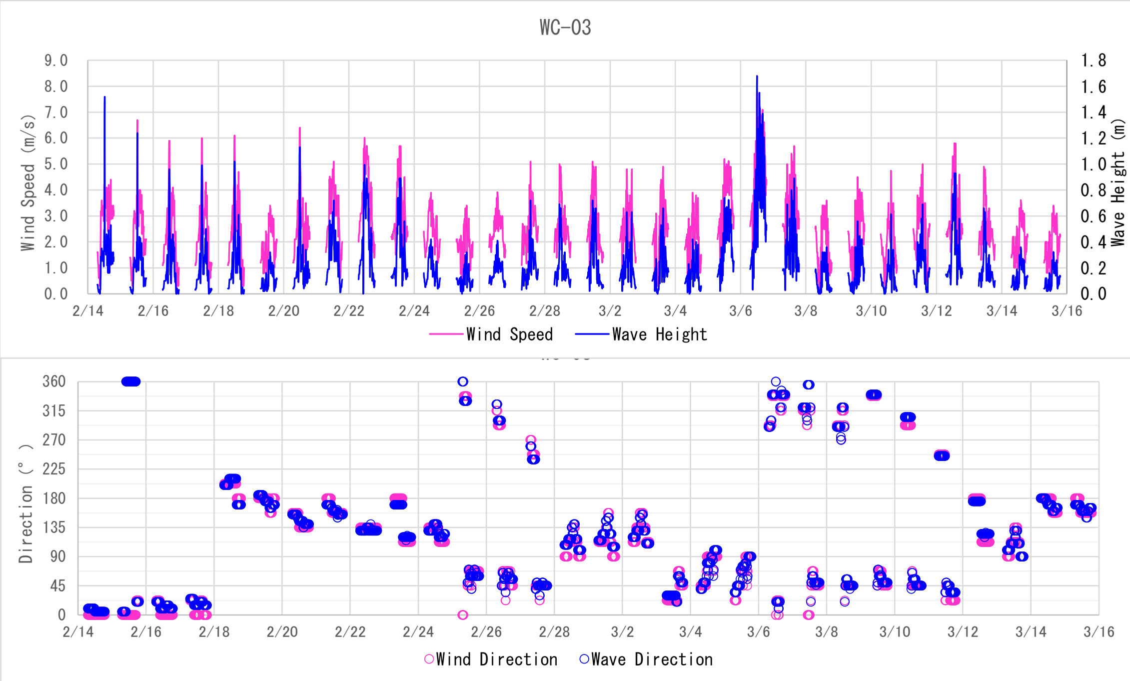
Source: Study Team

Figure 5.1-17 Comparison of waves and wind conditions at WC-01 (dry season)



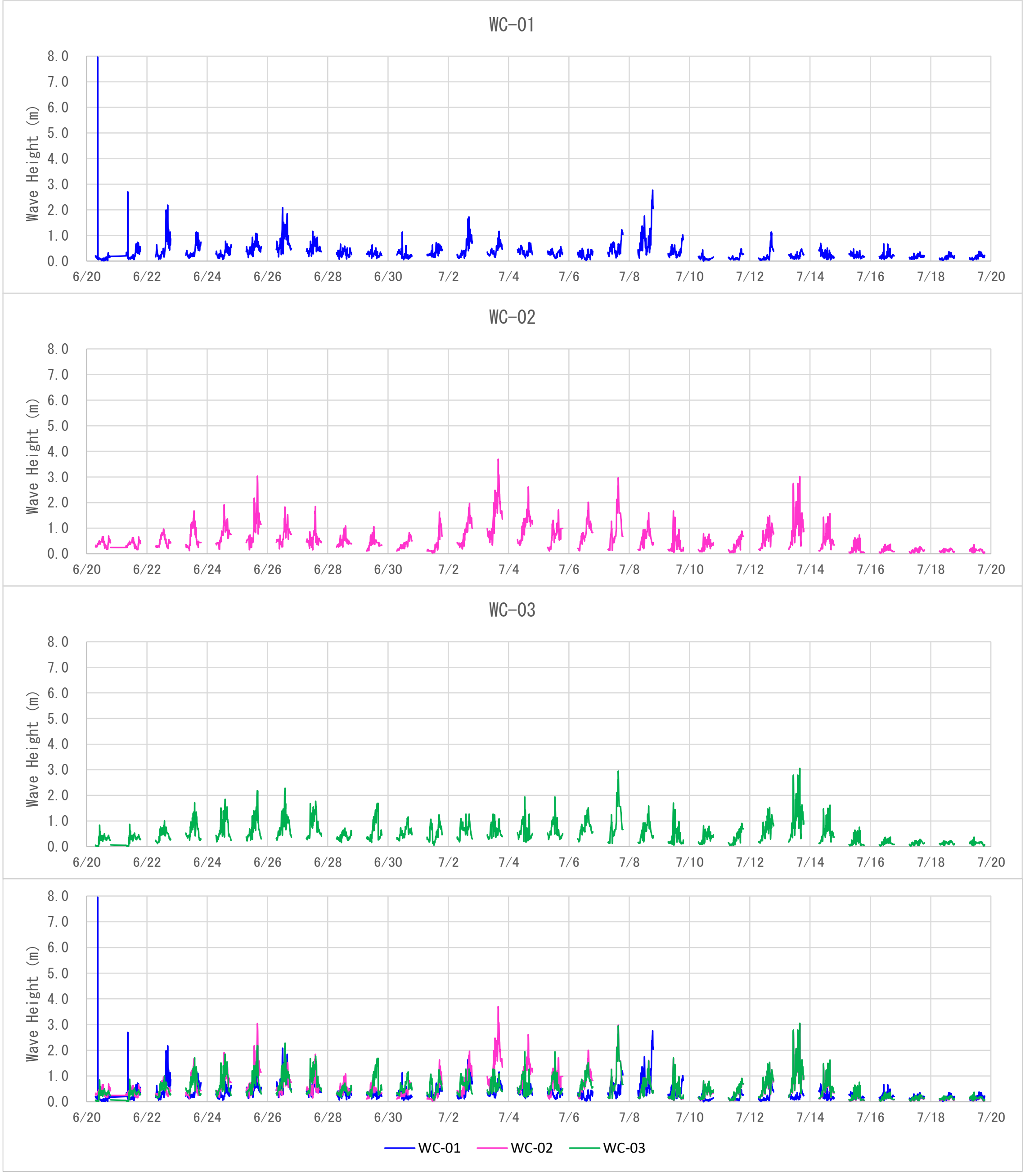
Source: Study Team

Figure 5.1-18 Comparison of waves and wind conditions at WC-02 (dry season)



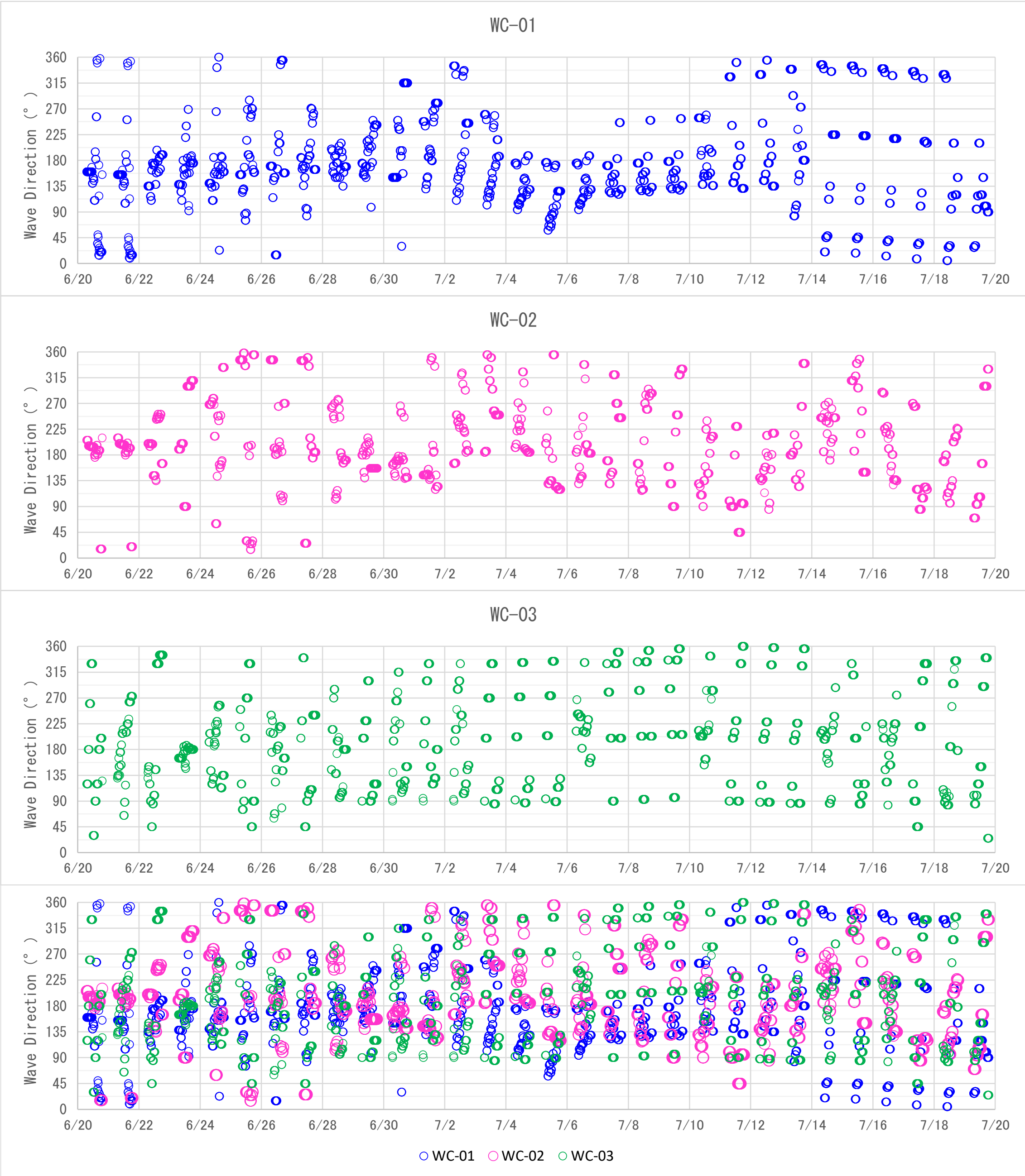
Source: Study Team

Figure 5.1-19 Comparison of waves and wind conditions at WC-03 (dry season)



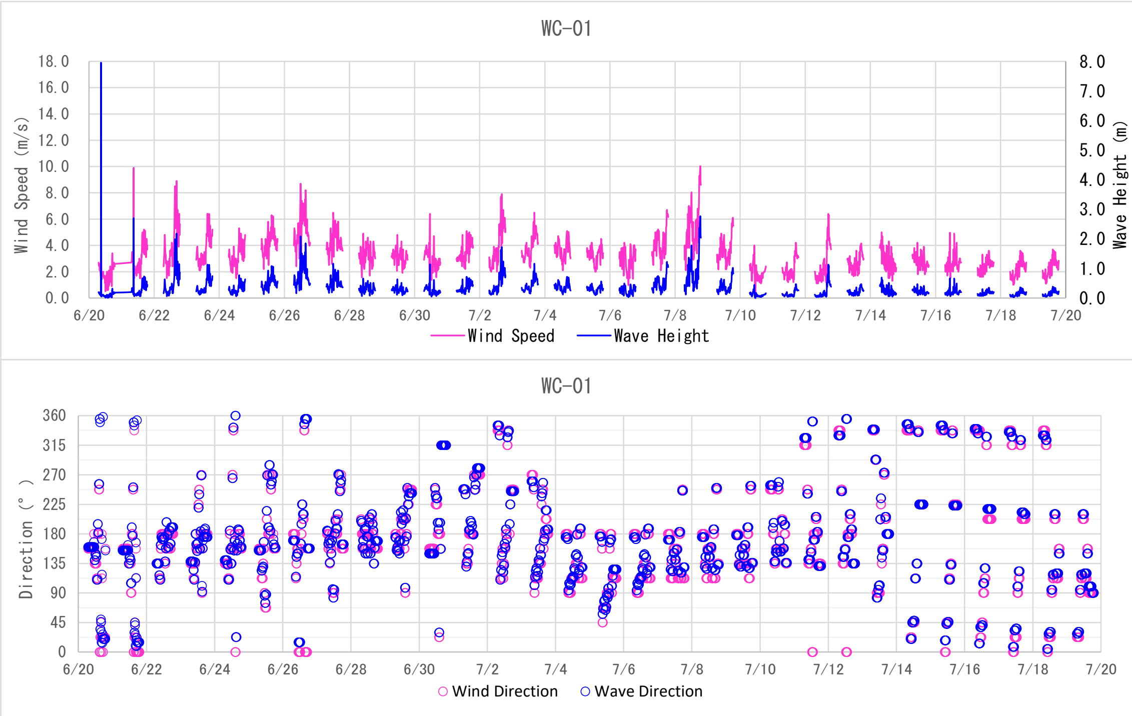
Source: Study Team

Figure 5.1-20 Wave Height Distribution at 3 points (rainy season)



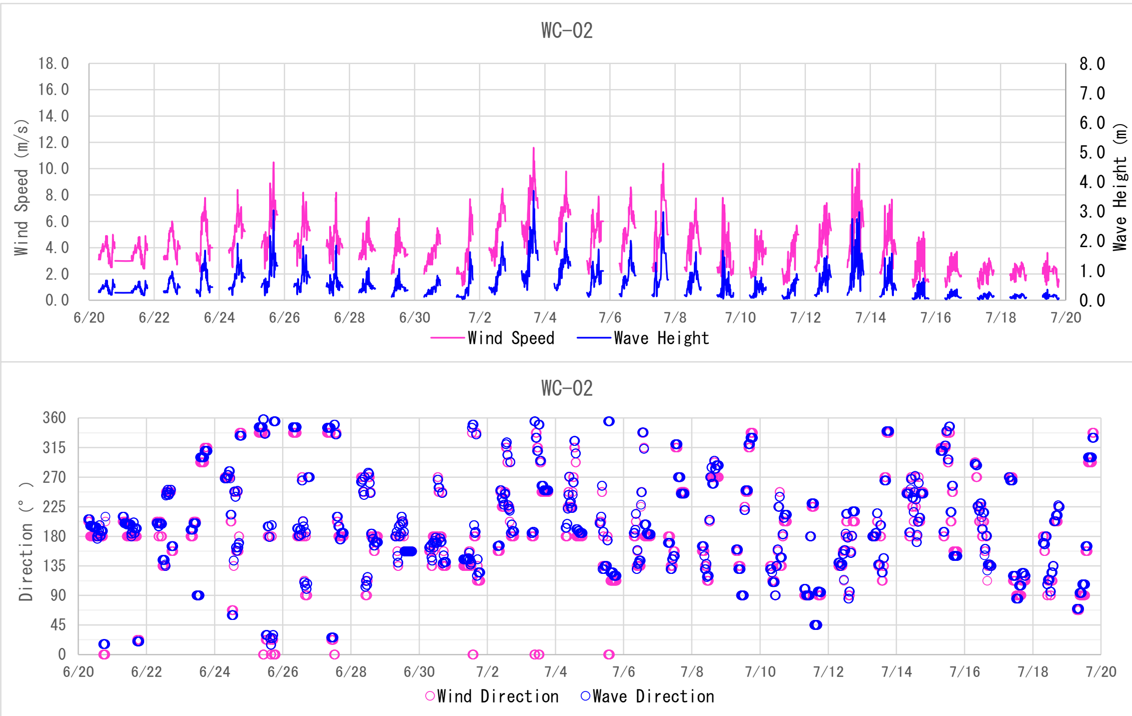
Source: Study Team

Figure 5.1-21 Wave Direction Distribution at 3 points(rainy season)



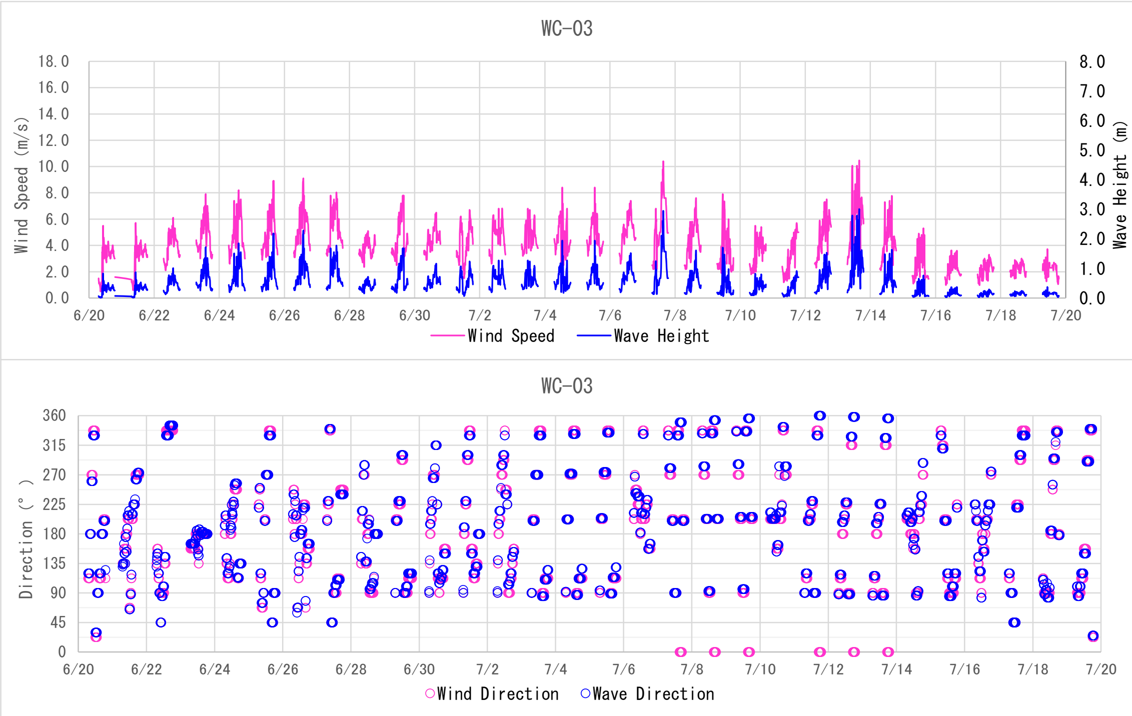
Source: Study Team

Figure 5.1-22 Comparison of waves and wind conditions at WC-01 (rainy season)



Source: Study Team

Figure 5.1-23 Comparison of waves and wind conditions at WC-02 (rainy season)



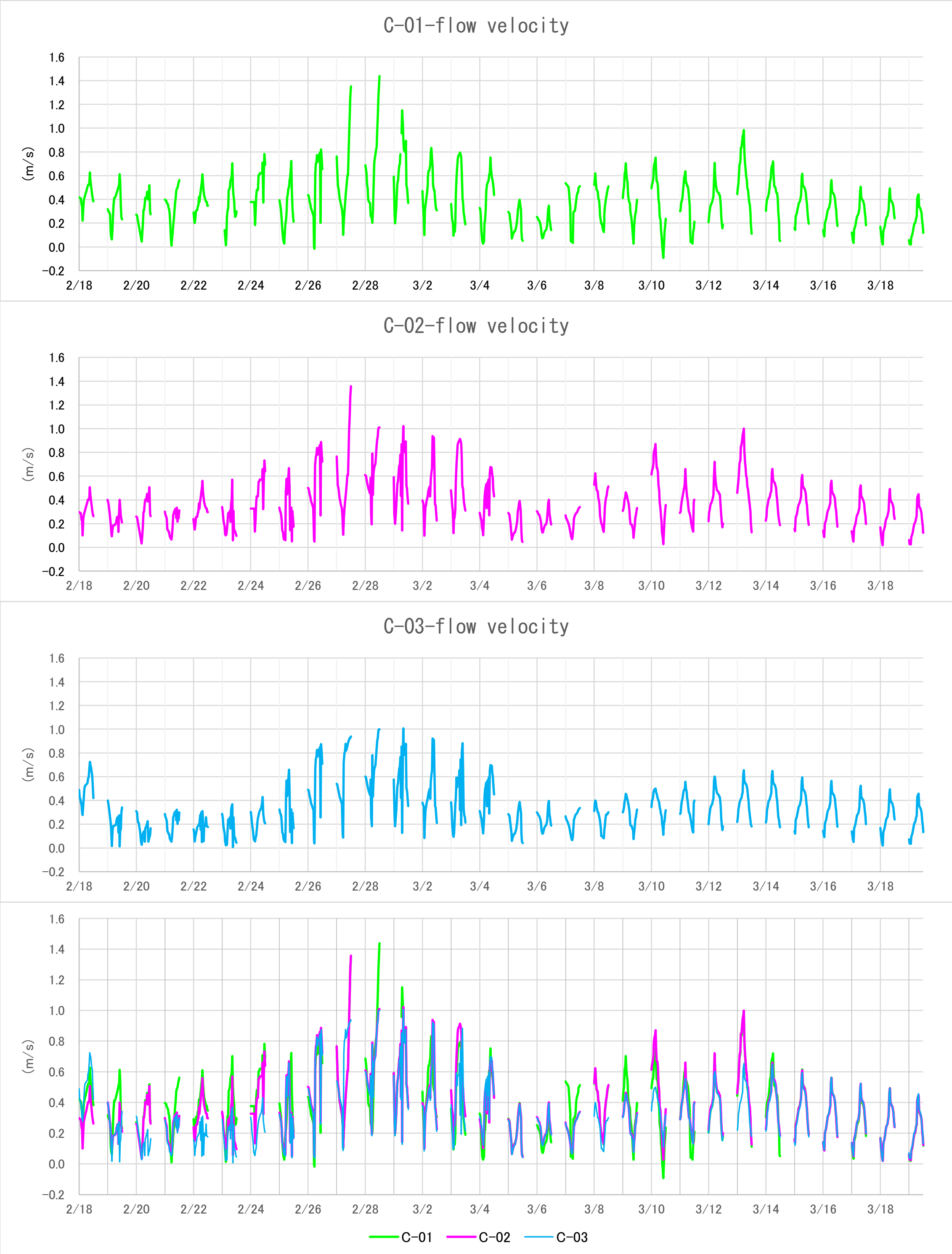
Source: Study Team

Figure 5.1-24 Comparison of waves and wind conditions at WC-03 (rainy season)

(d) Current measurement of Kohelia Channel (Refer to Appendix 5.1.5 (4))

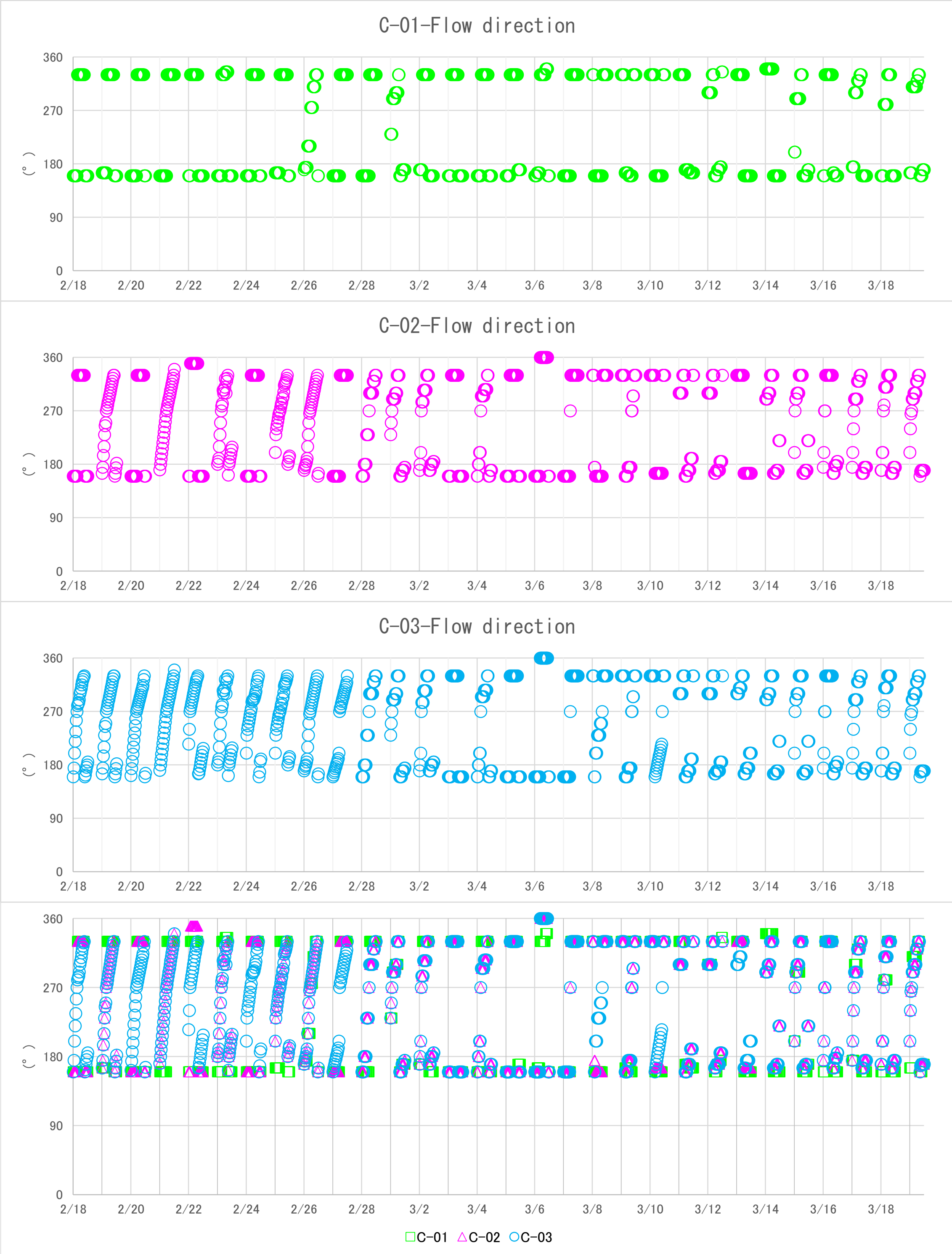
The Study Team conducted the current measurement surveys on the north side of the power plant (C-01), around the power plant (C-02), and on the south side of the power plant (C-03) during the dry season (from February 18th, 2021 to March 19th, 2021) and the rainy season (from June 20th, 2021 to July 19th, 2021). The Survey Point of Current measurement is shown in Figure 5.1-14 (same position as the wave measurement survey). The Flow velocity distribution at 3 points (dry season) is shown in Figure 5.1-25. The Flow direction distribution at 3 points (dry season) is shown in Figure 5.1-26. The Flow velocity distribution at 3 points (rainy season) is shown in Figure 5.1-27. The Flow direction distribution at 3 points (rainy season) is shown in Figure 5.1-28.

The flow velocity fluctuations at the survey points in the dry season were similar, and the flow directions that appeared were also similar. The flow velocity fluctuations at the survey points in the rainy season were similar, but there were variations in the flow direction.



Source: Study Team

Figure 5.1-25 Flow Velocity Distribution at 3 points (dry season)



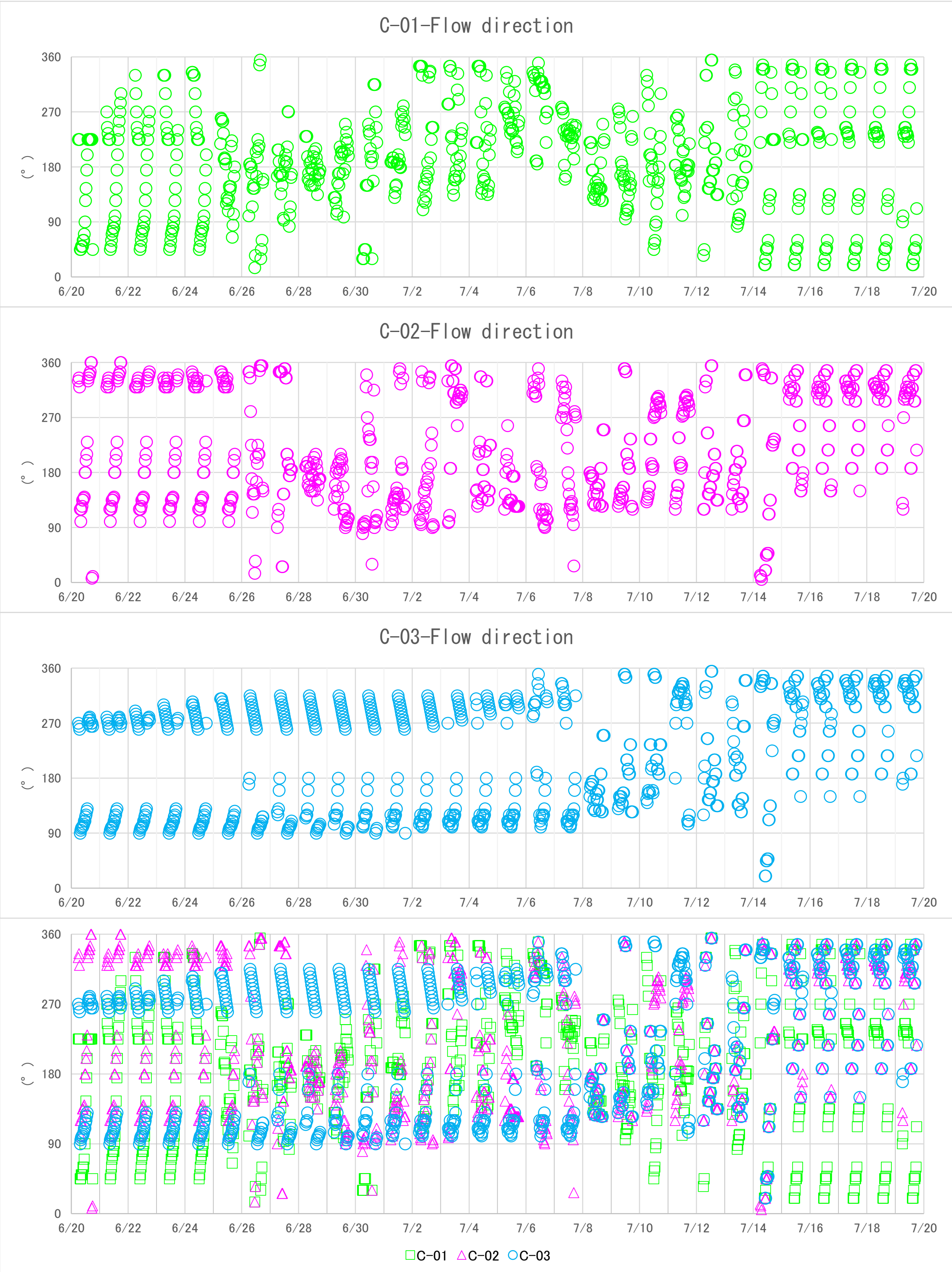
(Direction: 0º: N, 90º: E, 180º: S, 270º: W)

Source: Study Team

Figure 5.1-26 Flow Direction Distribution at 3 points (dry season)

Source: Study Team

Figure 5.1-27 Flow Velocity Distribution at 3 points (rainy season)



(Direction: 0°: N, 90°: E, 180°: S, 270°: W)

Source: Study Team

Figure 5.1-28 Flow Direction Distribution at 3 points (rainy season)

(e) Turbidity survey of Kohelia Channel (Refer to Appendix 5.1.5 (5))

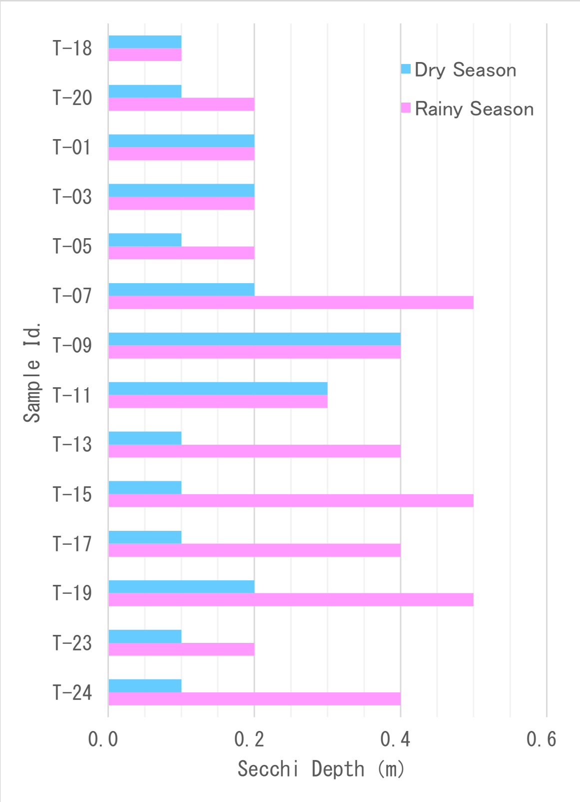
The Study Team conducted the turbidity surveys on 14 points in the Kohelia Channel during the dry season and the rainy season. The survey position is shown in the Figure 5.1-4 (same position as sediment survey). The results of turbidity analysis is shown in Table 5.1-4. The secchi depth distribution is shown in Figure 5.1-29. Total Suspended Solid (SS) for surface and bottom water is shown in Table 5.1-5. Surface and bottom water Suspended Solid (SS) is shown in Figure 5.1-30. Focusing on Suspended Solid (SS), the total SS of surface water and the total SS of bottom water at each points was similar except for the north side (T-18 to T-01) and south side (T-19 to T-23). In general, the SS value, etc. differs between the marine area and the channel (including rivers) because the water conditions are different. Therefore, the hydrographic conditions of channel inlet are subject to marine conditions. It is probable that the north and south sides, which are the inlets of the Kohelia Channel, were also affected by the hydrographic conditions of the marine, so the surface and bottom water could not be sufficiently mixed and a difference occurred. At other points, the difference between the total SS of surface water and the total SS of bottom water is small, and because they are well mixed, there is no rolling up or movement of the sediment. The channel is thought calm.

Table 5.1-4 Results of Turbidity analysis

	Dry season				Rainy Season			
Sample Id.	Depth (m)	Secchi Depth (m)	Secchi Depth (ft)	Turbidity (FNU)	Depth (m)	Secchi Depth (m)	Secchi Depth (ft)	Turbidity (FNU)
T-18	5.00	0.1	0.33	9.44	6.80	0.1	0.33	252.50
T-20	0.50	0.1	0.33	9.44	2.90	0.2	0.66	85.05
T-01	0.50	0.2	0.66	6.07	0.50	0.2	0.66	85.05
T-03	0.50	0.2	0.66	6.07	0.50	0.2	0.66	85.05
T-05	1.50	0.1	0.33	9.44	0.50	0.2	0.66	85.05
T-07	0.30	0.2	0.66	6.07	3.00	0.5	1.64	20.18
T-09	3.50	0.4	1.31	3.90	3.00	0.4	1.31	28.65
T-11	2.00	0.3	0.98	4.69	1.50	0.3	0.98	45.00
T-13	0.50	0.1	0.33	9.44	1.90	0.4	1.31	28.65
T-15	0.40	0.1	0.33	9.44	4.90	0.5	1.64	20.18
T-17	1.00	0.1	0.33	9.44	3.20	0.4	1.31	28.65
T-19	2.75	0.2	0.66	6.07	5.10	0.5	1.64	20.18
T-23	0.50	0.1	0.33	9.44	0.80	0.2	0.66	85.05
T-24	0.40	0.1	0.33	9.44	2.60	0.4	1.31	28.65

FNU : Formazin Nephelometric Unit

Source: Study Team



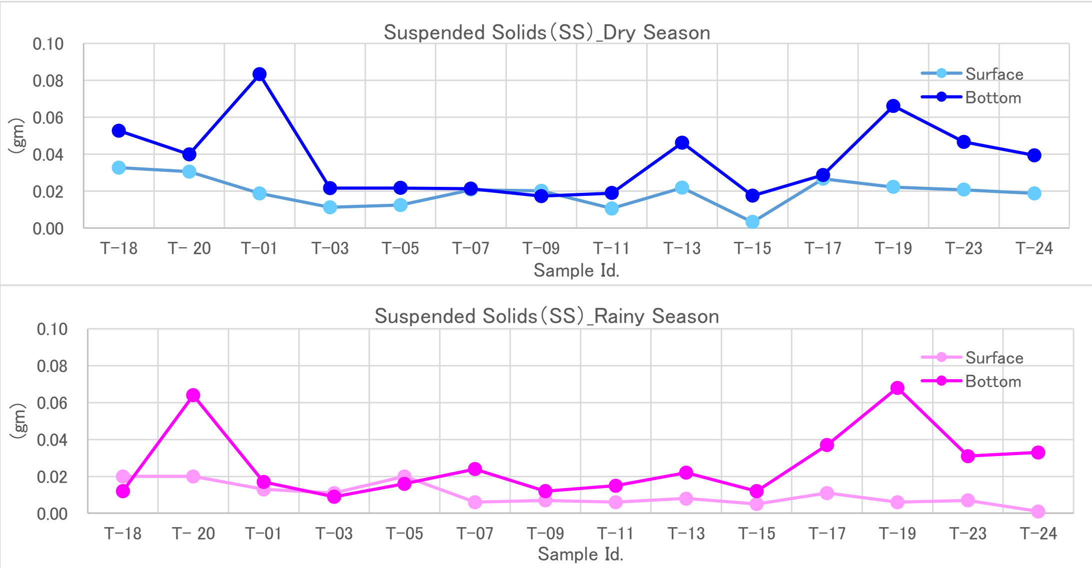
Source: Study Team

Figure 5.1-29 Secchi Depth Distribution

Table 5.1-5 Total Suspended Solid (SS) for surface and bottom water

	Dry season		Rainy season	
Sample ID	Wt(gm) Surface	Wi (gm) Bottom	Wt(gm) Surface	Wi (gm) Bottom
T-18	0.0327	0.0527	0.0200	0.0120
T-20	0.0306	0.0399	0.0200	0.0640
T-01	0.0187	0.0833	0.0130	0.0170
T-03	0.0112	0.0216	0.0110	0.0090
T-05	0.0124	0.0217	0.0200	0.0160
T-07	0.0208	0.0213	0.0060	0.0240
T-09	0.0202	0.0173	0.0070	0.0120
T-11	0.0106	0.0189	0.0060	0.0150
T-13	0.0218	0.0462	0.0080	0.0220
T-15	0.0033	0.0175	0.0050	0.0120
T-17	0.0267	0.0287	0.0110	0.0370
T-19	0.0222	0.0661	0.0060	0.0680
T-23	0.0208	0.0466	0.0070	0.0310
T-24	0.0187	0.0394	0.0010	0.0330

Source: Study Team



Source: Study Team

Figure 5.1-30 Surface and bottom water Suspended Solid (SS)

(f) Conclusion (Refer to Appendix 5.1.5 (6))

The Study team considered about topography of the Kohelia Channel from past aerial photographs and survey results. From aerial photographs, it was speculated that the topographical changes in the Kohelia channel were small even before the power plant was developed, and that the water depth in the channel changed significantly due to tidal circulation. From the survey results, it was inferred that the influence of hydrographic conditions in the channel on topographical changes is small, and that the water depth changes significantly due to tidal circulation.

(2) Marine Part

Refer to Appendix 5.1.5

Surveys regarding current condition were conducted at three locations in sea around the project site. In the dry season survey from February to March 2021, the average current velocity was 0.4 to 0.6 m/s, and the current direction was south to southeast at low tide and north to northwest at high tide.

Similar fluctuations were observed about the tide level at the survey point on the side of Bengal Bay (T-01) and the survey point on Kohelia Channel (T-03). But since T-02 location is not connected with the marine water body, tide data of T-02 location was showing different from others (T-01, 03). Refer to clause 5.1.5 (1) (b) in detail.

5.1.6 Soil (Refer to Appendix 5.1.6)

(1) Results of the survey for this study

Chromium, lead have been confirmed. No arsenic, mercury were detected. Analysis results were resemble to those at the project site boundary of “The Environmental monitoring report on Units 1/2 Construction Work”.

(2) Information from “The Environmental monitoring report on Units 1/2 Construction Work”

Arsenic (~ 6.3 ppm), chromium (~ 34.7 ppm), and lead (~ 26 ppm) have been confirmed. No mercury was detected. Bangladesh has no soil environment standards. At present, there are no plans to carry soil out of the project site in the projects concerning Units 1/2 and Units 3/4.

5.1.7 Topography and geology

(1) Topography

The Study Team carried out a site survey at around the Project area. The planned area of Units 3/4 Project is located inside the area of Project for Units 1/2.

There is the Kohelia Channel on the East side, the Bay of Bengal on the West side, a Homestead of

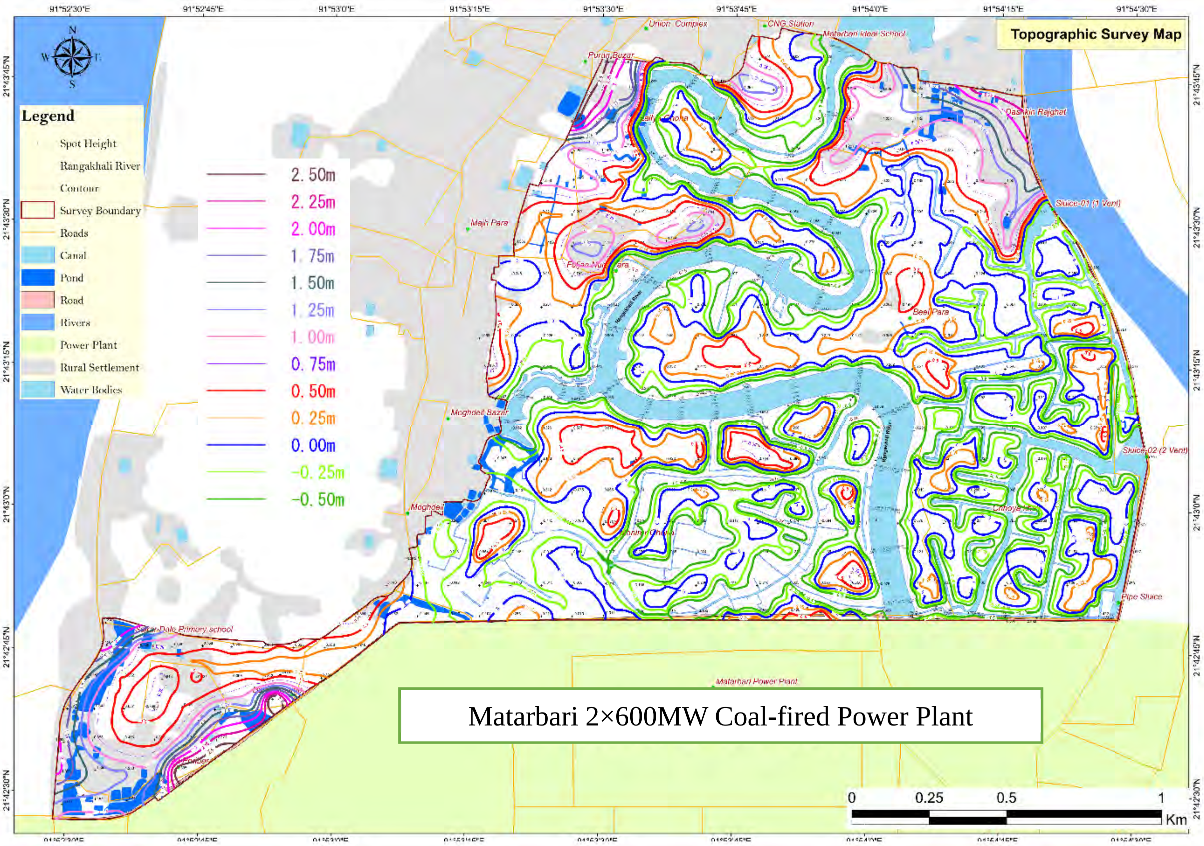
Dhalghata village on the South side, and a Homestead of Matarbari village on the North side of the project site for Matarbari Coal Power Plant.

At the planned area of Units 3/4, the reclamation works is ongoing by the Contractor of the project for Units 1/2. And also, the planned area is temporarily used as laydown area for construction equipment and manufacture plant for concrete precast block by the Contractor of the project for Units 1/2. (as of February 2021)

(a) Topographic Survey Results (Refer to Appendix 5.1.7 (1) Section (3))

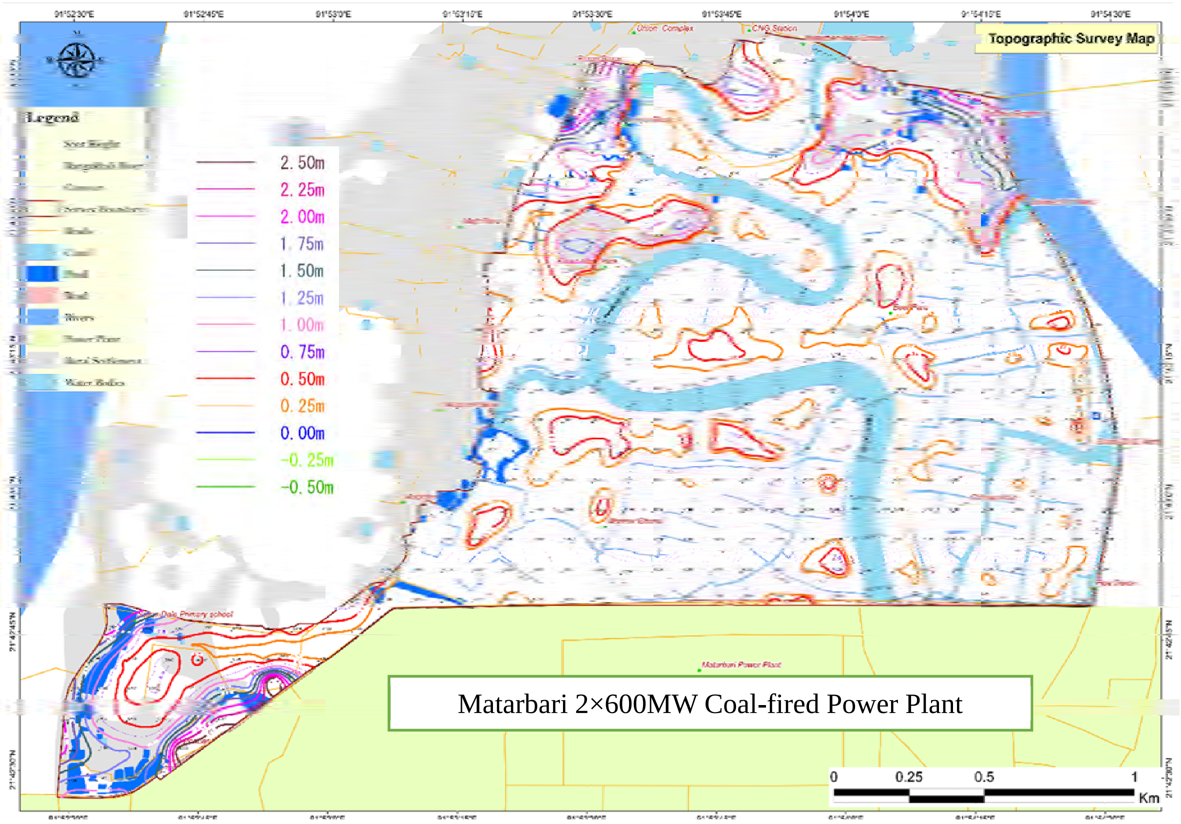
The Topographic survey results and topographic contours on the north side of the project site is shown in Figure 5.1-31. Around the Rural Settlement on the north side of the Topographic survey area and on the west side of the project site, the ground surface altitude is over 0.25m, and the ground level is high area. But, the ground surface altitude of other areas are below 0m, and the ground level is low altitude area. Low altitude areas are expected to inundate land during floods if drainage is impaired.

The Topographic contours above 0.25m above sea level is shown in Figure 5.1-32. The Topographic contours below 0m above sea level is shown in Figure 5.1-33.



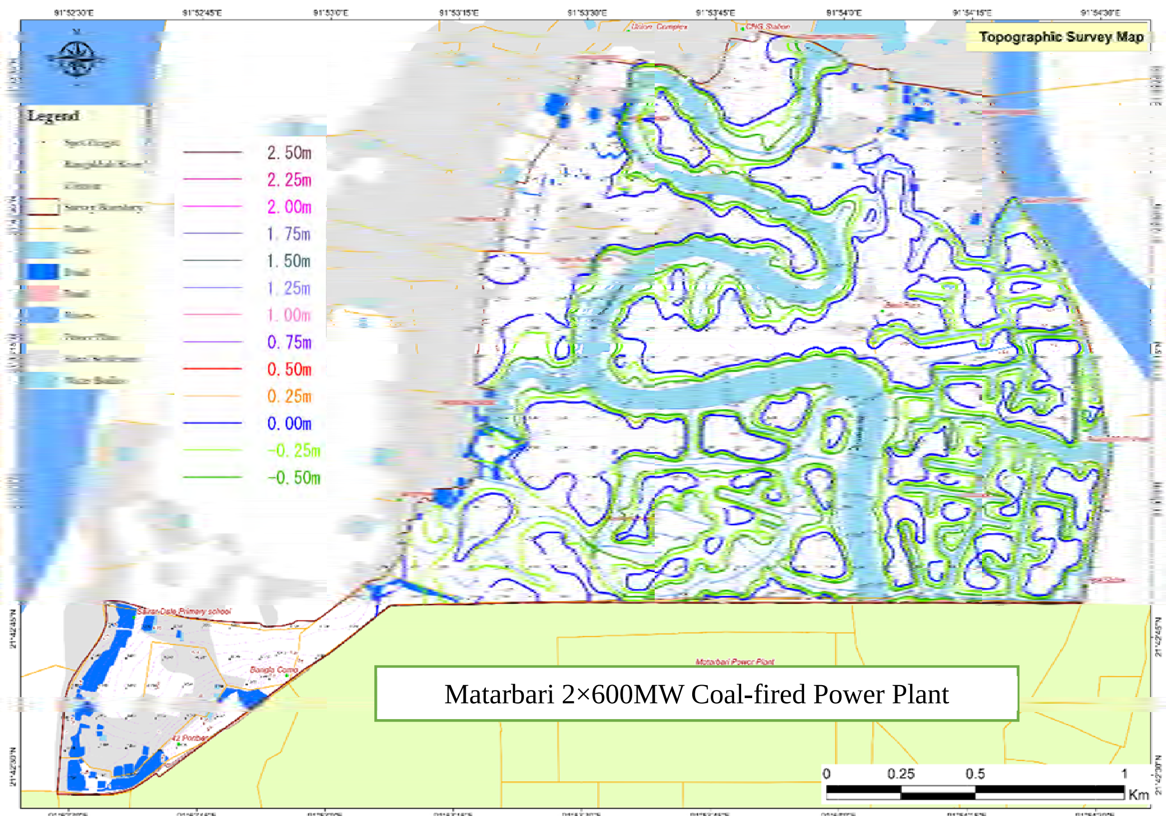
Source: Study Team

Figure 5.1-31 Topographic Survey Results and Topographic Contours on the North Side of the Project Site



Source: Study Team

Figure 5.1-32 Topographic Contours above 0.25m above Sea Level



Source: Study Team

Figure 5.1-33 Topographic Contours below 0m above Sea Level

(b) Consideration (Refer to Appendix 5.1.7 (1) Section(4))

As shown in "(a) Topographic survey results", low altitude areas are expected to inundate land during floods if drainage is impaired. Therefore, the Study Team considered under what circumstances inundation occurs from "Hydraulic characteristics" and "Topographical features".

In "Hydraulic characteristics", the Study Team considered from the sea area, the tide level fluctuations of the Kohelia Channel and the Rangakhali Channel. The tide level fluctuations in the sea area and the Kohelia Channel show similar fluctuations, but the Rangakhali Channel maintained a constant water level and was not affected by the tide level fluctuations. At high tides, the water levels of the sea area and the Kohelia Channel are high, but the water level of the Rangakhali Channel is low, so it was considered that inundation due to flooding from the Rangakhali Channel would not occur. In "Topographical features", the Study Team considered from past aerial photographs. Inundation had occurred around the project site even before the power plant was developed. It is probable that the cause of the inundation was that it overflowed the embankment at high tide and stayed in an area with low altitude.

From the above, it was speculated that before the power plant was developed, it overflowed the embankment at high tide and inundation occurred, and after the inundation, it stayed in the low altitude areas.

(2) Geology

The Study Team has carried out a detail soil investigation at the planned area for Units 3&4.

Ground investigation work will be a main feature when designing the foundation of important structures in an intelligent, economic and satisfactory way. It will provide necessary information on the strength and compressibility characteristics of the sub-soil to the design engineers to enable the selection of suitable depths and types of foundation for the proposed structures.

The investigation work will include the execution of eight borings from the existing ground level and execution of an SPT test, collection of disturbed samples at specified depths under consideration, and a record of ground water levels, etc. All of these items of the field investigation will have subsequently been followed up by the performance of laboratory tests.

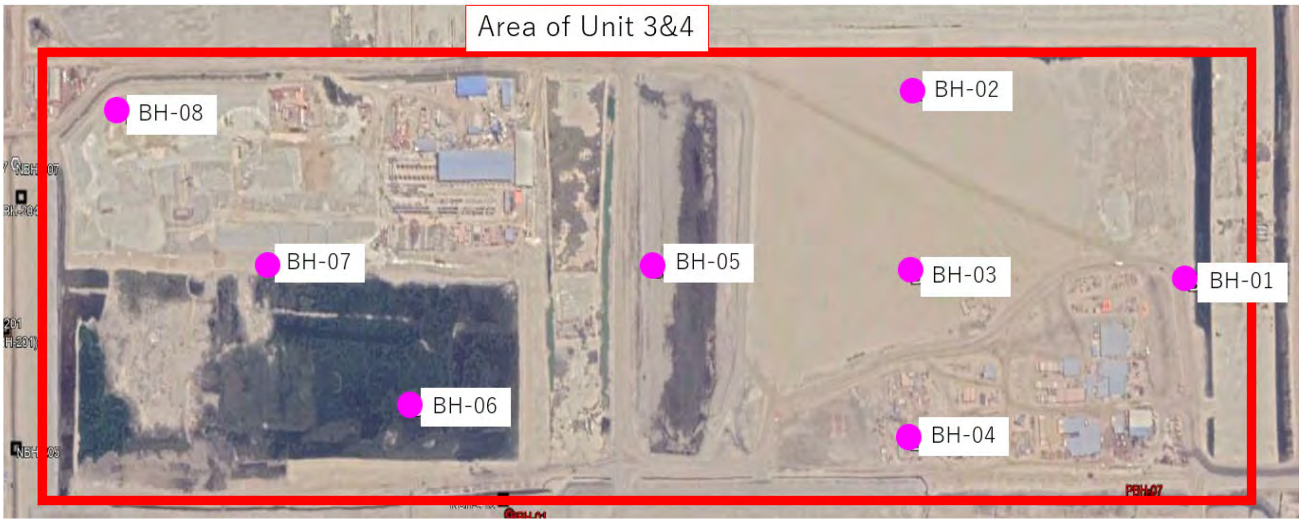
The Study Team will also consider the results of previous soil investigation around the area of Units 3/4 which were carried out by the Contractor of the project for Units 1/2. And then, the Study Team will make some soil profiles of the planned area for Units 3/4 with considering the above eight soil investigation and previous soil investigations.

Detail results of the soil investigation can be referred to Appendix 5.1.7 (2).

Table 5.1-6 Soil Investigation (Boring)

Borehole No.	Coordinates (UTM - Zone 46N)		Elevation (m_MSL)
	Northing	Easting	
BH-01	2,400,600.00	385,231.00	4.68
BH-02	2,400,781.00	384,907.00	4.30
BH-03	2,400,612.00	384,904.00	4.97
BH-04	2,400,455.00	384,901.00	4.19
BH-05	2,400,617.00	384,596.00	4.33
BH-06	2,400,493.00	384,316.00	7.18
BH-07	2,400,624.00	384,147.00	6.77
BH-08	2,400,763.00	383,978.00	5.89

Source: Study Team



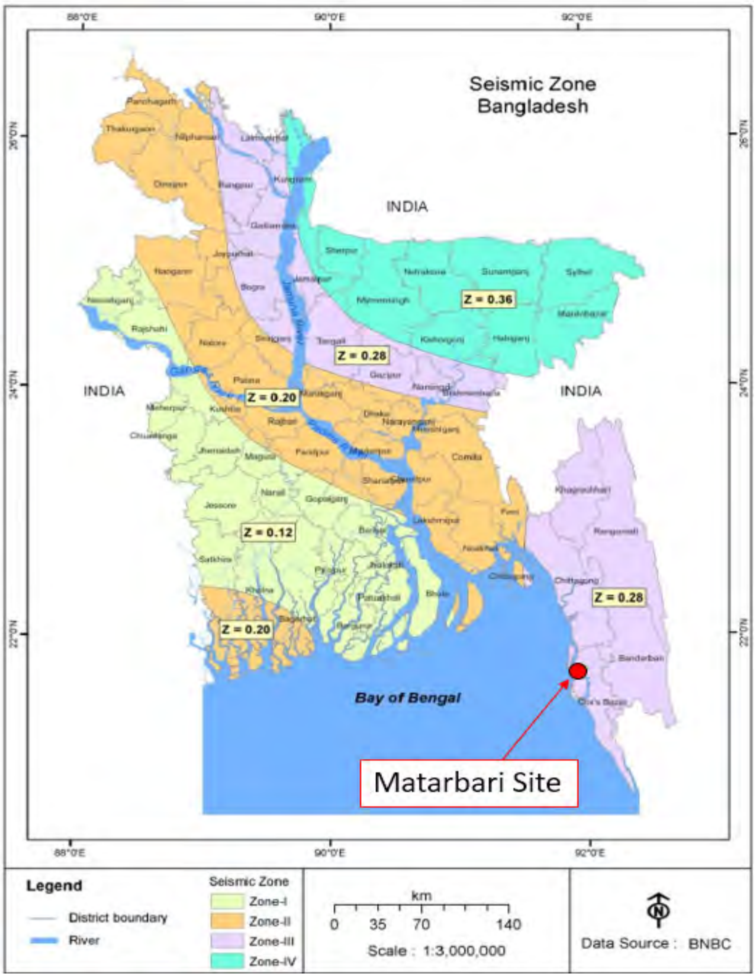
Source: Study Team from Google Earth

Figure 5.1-34 Plan of Soil Investigation (Boring)

(3) Seismic Coefficient

Bangladesh is divided into four seismic zones, and the design strength of buildings is stipulated in each seismic zone. The project site is located in Zone -3, the same as Chittagong, where moderate levels of strength designs for buildings will be necessary. (Figure 5.1-35)

And also, site classification is specified based on the soil properties at the site (Figure 5.1-36). This soil classification will be decided by the average values in 30m ground surface layer about shear wave velocity, N-value and so on. For this project, the soil classification will be considered after the completion of land development by detailed soil investigations which will be conducted in the execution stage.



Source: Bangladesh National Building Code 2015

Figure 5.1-35 Seismic Zone in Bangladesh

Table 6.2.13: Site Classification Based on Soil Properties

Site Class	Description of soil profile up to 30 meters depth	Average Soil Properties in top 30 meters		
		Shear wave velocity, $\bar{V}_s$ (m/s)	SPT Value, $\bar{N}$ (blows/30cm)	Undrained shear strength, $\bar{S}_u$ (kPa)
SA	Rock or other rock-like geological formation, including at most 5 m of weaker material at the surface.	> 800	--	--
SB	Deposits of very dense sand, gravel, or very stiff clay, at least several tens of metres in thickness, characterised by a gradual increase of mechanical properties with depth.	360 – 800	> 50	> 250
SC	Deep deposits of dense or medium dense sand, gravel or stiff clay with thickness from several tens to many hundreds of metres.	180 – 360	15 - 50	70 - 250
SD	Deposits of loose-to-medium cohesionless soil (with or without some soft cohesive layers), or of predominantly soft-to-firm cohesive soil.	< 180	< 15	< 70
SE	A soil profile consisting of a surface alluvium layer with V_s values of type SC or SD and thickness varying between about 5 m and 20 m, underlain by stiffer material with V_s > 800 m/s.	--	--	--
S_1	Deposits consisting, or containing a layer at least 10 m thick, of soft clays/silts with a high plasticity index (PI > 40) and high water content	< 100 (indicative)	--	10 - 20
S_2	Deposits of liquefiable soils, of sensitive clays, or any other soil profile not included in types SA to SE or S_1	--	--	--

Source: Bangladesh National Building Code 2015

Figure 5.1-36 Site Classification

Design response spectrum which shall be used for building structural design will be decided in accordance with Bangladesh National Building Code as below;

$$S_a = \frac{2}{3}\frac{ZI}{R}C_s$$

where、*Sa* = Design response spectrum
Z = Seismic zone coefficient (Figure 5.1-35, *Z* = 0.28 at Matarbari Site)
I = Importance factors for building and structures (Figure 5.1-37 & Figure 5.1-38, *I* = 1.50)
R = Response reduction factor (Figure 5.1-39)
Cs = Normalized acceleration response spectrum

Importance factors for building and structures, *I* will be classified as Figure 5.1-37 with considering the occupancy category for of buildings and other structures.

The occupancy category for of buildings and other structures will be classified as Figure 5.1-38.

The buildings and/or structures which shall have some important roles in emergency situations, such a power generating station and other public utility facility, will categorized in class IV the most important in this classification. In this regards, for this project, the importance factors *I* will be set 1.50 for power house building, boiler structure and other critical structures as the most important buildings/structures. But for the other structures, such a structure for balance of power plant and the other civil structures, the importance factors *I* will be set 1.00 as class II in the occupancy category.

Table 6.2.17: Importance Factors for Buildings and Structures for Earthquake design

Occupancy Category	Importance factor I
I, II	1.00
III	1.25
IV	1.50

Source: Bangladesh National Building Code 2015

Figure 5.1-37 Importance factors for building and structure, I

Table 6.1.1: Occupancy Category of Buildings and other Structures for Flood, Surge, Wind and Earthquake Loads.

Nature of Occupancy	Occupancy Category
Buildings and other structures that represent a low hazard to human life in the event of failure, including, but not limited to: • Agricultural facilities • Certain temporary facilities • Minor storage facilities	I
All buildings and other structures except those listed in Occupancy Categories I, III and IV	II
Buildings and other structures that represent a substantial hazard to human life in the event of failure, including, but not limited to: • Buildings and other structures where more than 300 people congregate in one area • Buildings and other structures with day care facilities with a capacity greater than 150 • Buildings and other structures with elementary school or secondary school facilities with a capacity greater than 250 • Buildings and other structures with a capacity greater than 500 for colleges or adult education facilities • Healthcare facilities with a capacity of 50 or more resident patients, but not having surgery or emergency Treatment facilities • Jails and detention facilities Buildings and other structures, not included in Occupancy Category IV, with potential to cause a substantial economic impact and/or mass disruption of day-to-day civilian life in the event of failure, including, but not limited to: • Power generating stations[a] • Water treatment facilities • Sewage treatment facilities • Telecommunication centers Buildings and other structures not included in Occupancy Category IV (including, but not limited to, facilities that manufacture, process, handle, store, use, or dispose of such substances as hazardous fuels, hazardous chemicals, hazardous waste, or explosives) containing sufficient quantities of toxic or explosive substances to be dangerous to the public if released.	III
Buildings and other structures designated as essential facilities, including, but not limited to: • Hospitals and other healthcare facilities having surgery or emergency treatment facilities • Fire, rescue, ambulance, and police stations and emergency vehicle garages • Designated earthquake, hurricane, or other emergency shelters • Designated emergency preparedness, communication, and operation centers and other facilities required for emergency response • Power generating stations and other public utility facilities required in an emergency • Ancillary structures (including, but not limited to, communication towers, fuel storage tanks, cooling towers, • Electrical substation structures, fire water storage tanks or other structures housing or supporting water, or other fire-suppression material or equipment) required for operation of Occupancy Category IV structures during an emergency • Aviation control towers, air traffic control centers, and emergency aircraft hangars • Water storage facilities and pump structures required to maintain water pressure for fire suppression • Buildings and other structures having critical national defense functions Buildings and other structures (including, but not limited to, facilities that manufacture, process, handle, store, use, or dispose of such substances as hazardous fuels, hazardous chemicals, or hazardous waste) containing highly toxic substances where the quantity of the material exceeds a threshold quantity established by the authority having jurisdiction.	IV

[a] Cogeneration power plants that do not supply power on the national grid shall be designated Occupancy Category II

Source: Bangladesh National Building Code 2015

Figure 5.1-38 Occupancy category for building and other structures

Response reduction factor, R will be decided in accordance with Figure 5.1-39 with considering the structure systems.

Table 6.2.19: Response Reduction Factor, Deflection Amplification Factor and Height Limitations for Different Structural Systems

Seismic Force–Resisting System	Response Reduction Factor, R	System Overstrength Factor, Ω_o	Deflection Amplification Factor, C_d	Seismic Design Category B	Seismic Design Category C	Seismic Design Category D
				Height limit (m)		
A. BEARING WALL SYSTEMS (no frame)						
1. Special reinforced concrete shear walls	5	2.5	5	NL	NL	50
2. Ordinary reinforced concrete shear walls	4	2.5	4	NL	NL	NP
3. Ordinary reinforced masonry shear walls	2	2.5	1.75	NL	50	NP
4. Ordinary plain masonry shear walls	1.5	2.5	1.25	18	NP	NP
B. BUILDING FRAME SYSTEMS (with bracing or shear wall)						
1. Steel eccentrically braced frames, moment resisting connections at columns away from links	8	2	4	NL	NL	50
2. Steel eccentrically braced frames, non-moment-resisting, connections at columns away from links	7	2	4	NL	NL	50
3. Special steel concentrically braced frames	6	2	5	NL	NL	50
4. Ordinary steel concentrically braced frames	3.25	2	3.25	NL	NL	11
5. Special reinforced concrete shear walls	6	2.5	5	NL	50	50
6. Ordinary reinforced concrete shear walls	5	2.5	4.25	NL	NL	NP
7. Ordinary reinforced masonry shear walls	2	2.5	2	NL	50	NP
8. Ordinary plain masonry shear walls	1.5	2.5	1.25	18	NP	NP
C. MOMENT RESISTING FRAME SYSTEMS (no shear wall)						
1. Special steel moment frames	8	3	5.5	NL	NL	NL
2. Intermediate steel moment frames	4.5	3	4	NL	NL	35
3. Ordinary steel moment frames	3.5	3	3	NL	NL	NP
4. Special reinforced concrete moment frames	8	3	5.5	NL	NL	NL
5. Intermediate reinforced concrete moment frames	5	3	4.5	NL	NL	NP
6. Ordinary reinforced concrete moment frames	3	3	2.5	NL	NP	NP
D. DUAL SYSTEMS: SPECIAL MOMENT FRAMES CAPABLE OF RESISTING AT LEAST 25% OF PRESCRIBED SEISMIC FORCES (with bracing or shear wall)						
1. Steel eccentrically braced frames	8	2.5	4	NL	NL	NL
2. Special steel concentrically braced frames	7	2.5	5.5	NL	NL	NL
3. Special reinforced concrete shear walls	7	2.5	5.5	NL	NL	NL
4. Ordinary reinforced concrete shear walls	6	2.5	5	NL	NL	NP
E. DUAL SYSTEMS: INTERMEDIATE MOMENT FRAMES CAPABLE OF RESISTING AT LEAST 25% OF PRESCRIBED SEISMIC FORCES (with bracing or shear wall)						
1. Special steel concentrically braced frames	6	2.5	5	NL	NL	11
2. Special reinforced concrete shear walls	6.5	2.5	5	NL	NL	50
3. Ordinary reinforced masonry shear walls	3	3	3	NL	50	NP
4. Ordinary reinforced concrete shear walls	5.5	2.5	4.5	NL	NL	NP
F. DUAL SHEAR WALL-FRAME SYSTEM: ORDINARY REINFORCED CONCRETE MOMENT FRAMES AND ORDINARY REINFORCED CONCRETE SHEAR WALLS	4.5	2.5	4	NL	NP	NP
G. STEEL SYSTEMS NOT SPECIFICALLY DETAILED FOR SEISMIC RESISTANCE	3	3	3	NL	NL	NP

Notes:

1. Seismic design category, NL = No height restriction, NP = Not permitted. Number represents maximum allowable height (m).
2. Dual Systems include buildings which consist of both moment resisting frame and shear walls (or braced frame) where both systems resist the total design forces in proportion to their lateral stiffness.
3. See Sec. 10.20 of Chapter 10 of this Part for additional values of R and C_d and height limits for some other types of steel structures not covered in this Table.
4. Where data specific to a structure type is not available in this Table, reference may be made to Table 12.2-1 of ASCE 7-05.

Source: Bangladesh National Building Code 2015

Figure 5.1-39 Response reduction factor, R

Normalized acceleration response spectrum, Cs will be decided as the formulas below. Refer to the Figure 5.1-40 which shows graphs of Cs for each site classification (Figure 5.1-36)

C_s = Normalized acceleration response spectrum, which is a function of structure (building) period and soil type (site class) as defined by Equations 6.2.35a to 6.2.35d.

$$C_s = S\left(1+\frac{T}{T_B}(2.5\eta-1)\right) \text{ for } 0 \le \mathrm{T} \le \mathrm{T_B} \quad (6.2.35a)$$

$$C_s = 2.5S\eta \quad \text{for} \quad \mathrm{T_B} \le \mathrm{T} \le \mathrm{T_C} \quad (6.2.35b)$$

$$C_s = 2.5S\eta\left(\frac{T_C}{T}\right) \quad \text{for} \quad \mathrm{T_C} \le \mathrm{T} \le \mathrm{T_D} \quad (6.2.35c)$$

$$C_s = 2.5S\eta\left(\frac{T_C T_D}{T^2}\right) \quad \text{for} \quad \mathrm{T_D} \le \mathrm{T} \le 4\,\mathrm{sec} \quad (6.2.35d)$$

C_s depends on S and values of T_B, T_C and T_D, (Figure 6.2.25) which are all functions of the site class. Constant C_s value between periods T_B and T_C represents constant spectral acceleration.

S = Soil factor which depends on site class and is given in Table 6.2.16

T = Structure (building) period as defined in Sec 2.5.7.2

T_B = Lower limit of the period of the constant spectral acceleration branch given in Table 6.2.16 as a function of site class.

T_C = Upper limit of the period of the constant spectral acceleration branch given in Table 6.2.16 as a function of site class

T_D = Lower limit of the period of the constant spectral displacement branch given in Table 6.2.16 as a function of site class

η = Damping correction factor as a function of damping with a reference value of η=1 for 5% viscous damping. It is given by the following expression:

$$\eta = \sqrt{10/(5+\xi)} \ge 0.55 \quad (6.2.36)$$

Where, ξ is the viscous damping ratio of the structure, expressed as a percentage of critical damping. The value of η cannot be smaller than 0.55.

Table 6.2.16: Site Dependent Soil Factor and Other Parameters Defining Elastic Response Spectrum

Soil type	*S*	T_B(s)	T_C (s)	T_D (s)
SA	1.0	0.15	0.40	2.0
SB	1.2	0.15	0.50	2.0
SC	1.15	0.20	0.60	2.0
SD	1.35	0.20	0.80	2.0
SE	1.4	0.15	0.50	2.0

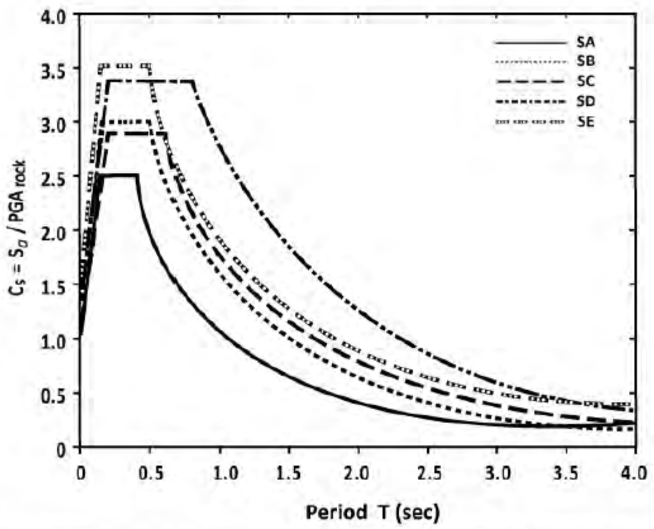


Figure 6.2.26 Normalized design acceleration response spectrum for different site classes.

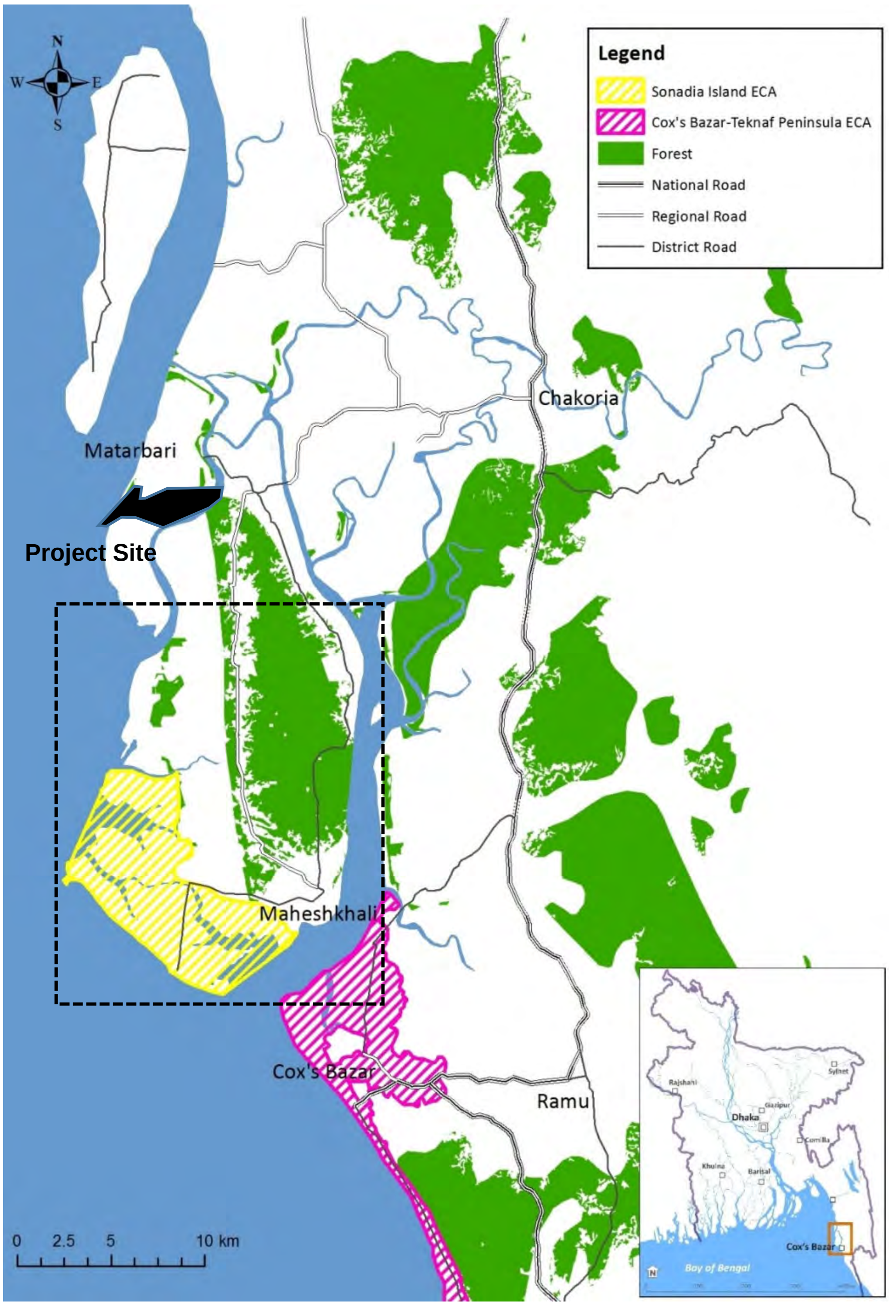
Source: Bangladesh National Building Code 2015

Figure 5.1-40 Normalized acceleration response spectrum, Cs for each site classification

5.2 Flora and Fauna

5.2.1 Environmentally Protected Areas around the Study Site

Figure 5.2-1 shows the regional vegetation and nearby environmentally protected areas around the study site. The enlarged map of the environmental management status of Sonadia Island ECA, bounded by a dotted rectangular box, is shown within Figure 5.2-2



Source: Data Collection Survey on Integrated Development for Southern Chittagong Region (2015)

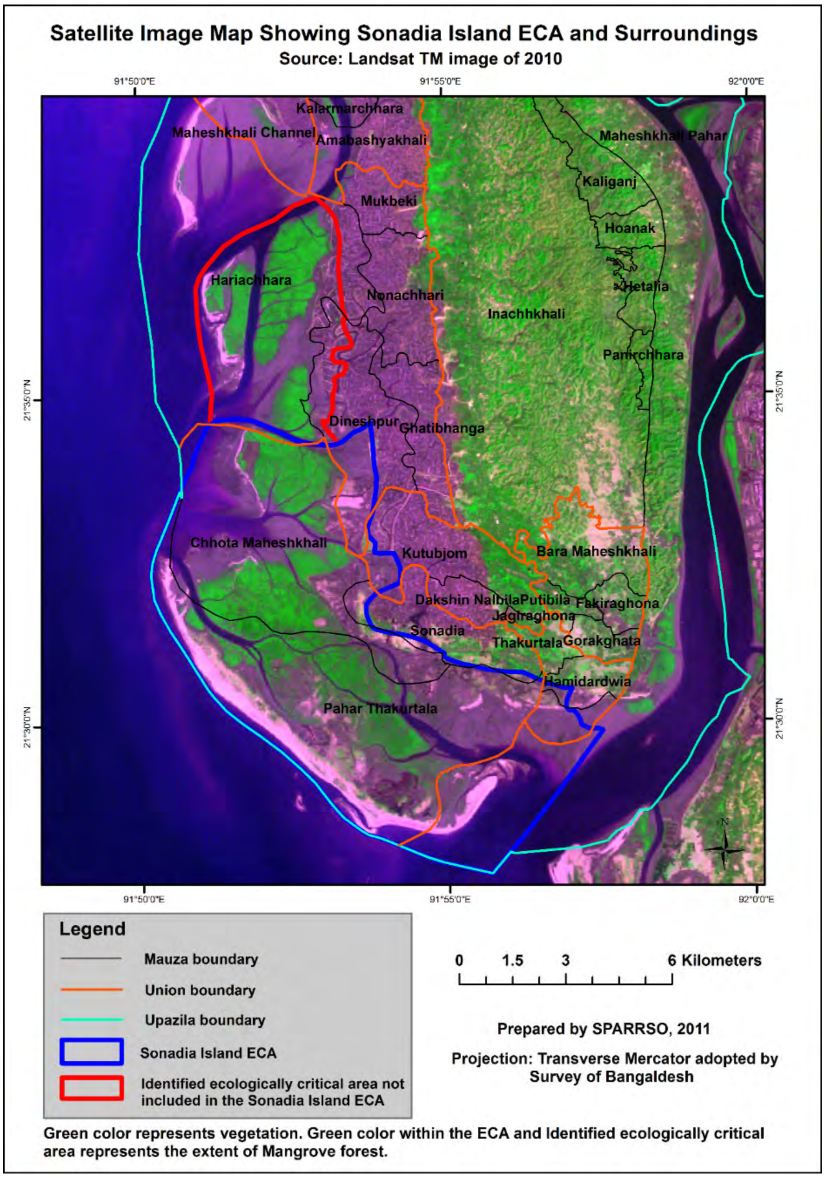
Figure 5.2-1 Environmentally Protected Areas around Southern Chotogram and Cox Bazar Region

As shown in this figure, there are following two (2) important ECAs (Ecologically Critical Area) such as Sonadia Island ECA (approximately 17km to the south from the Project site) and Cox's Bazar-Teknaf Peninsula ECA around the study site. Besides, there are several National Parks (NPs), Wildlife Sanctuaries (WS), Game Reserves (GRs) and small-scale Reserved Forests (RFs, green-coloured areas in Figure 5.2-1).

Those NPs, WS and GRs are supervised by Department of Environment (DoE), the Ministry of Environment and Forest (MoEF) as well as RFs are by Department of Forest (DoF) of MoEF.

Within RFs areas, the traditional use of forest products is permitted for nearby local communities therein (note that regional office of DoF has the latest information of those RFs). It was informed that World Bank-funded mangrove plantation project was implemented at the channel between Matarbari and Maheskhali Islands (to be completed by June 2015)[6].

Figure 5.2-2 shows the satellite image map of Sonadia Island ECA while showing the conservation status therein. It is noted that a bold blue-coloured line shows the boundary of Sonadia Island ECA and a bold red-coloured line shows the boundary of this ECA's buffer zone on where traditional social activities of local communities are granted. As mentioned earlier, Figure 5.2-3 shows sea-turtle nesting habitat and migratory shorebird habitat identified around the project site.



Note: bold blue-coloured line shows the boundary of Sonadia Island ECA and bold red-coloured line shows the boundary of this ECA's buffer zone.
Source: DoE

Figure 5.2-2 Sonadia Island ECA

[6] Based on interview with DoF, conducted within JICA-financed "Data Collection Survey on Integrated Development for Southern Chittagong Region in the Republic of Bangladesh (2016)

Source: The Environmental monitoring report on Units 1/2 Construction Work (May – July, 2018)

Figure 5.2-3 Habitat of Sea-turtle nesting and migratory shorebird around the Project site

5.2.2 Environmental Monitoring of Phase 1 construction project

(1) Outline of Environmental Monitoring Activities

L/A of Matarbari Ultra Super Critical Coal-Fired Power Project (Phase 1) was signed in June, 2014, and then, its construction activities and relevant environmental and social management program (environmental monitoring included) were initiated eventually (note: it is still on-going as of Year 2021). Comprehensive baseline natural and social environmental information were collected and summarized within the F/S Report of Phase 1 project. Since the study site of Phase 2 project is located within the site of Phase 1 construction project, it is highly likely that the surrounding bio-physical environment would be affected continuously by on-going construction activities of Phase 1 construction project to some extents. So that, it is essential to scrutinize survey results of the environmental monitoring process of Phase 1 construction project and analyze those impacts qualitatively and quantitatively.

In this section, impacts of Phase 1 construction activities on the surrounding local environment is analyzed, based on environmental monitoring results, summarized within both monthly and quarterly reports of environmental monitoring activities of Phase 1 construction project (September 2017 - August 2020), regarding the temporal variation of five (5) ecosystem-related parameter such as benthos, phytoplankton, zooplankton, sea turtle, local fish catch at both the Kohelia Channel and the Bay of Bengal as well as four (4) water quality parameter such as pH, DO (dissolved oxygen), COD (chemical oxygen demand), TSS (total suspended solid). Table 5.2-1 and Figure 5.2-4 summarize the outline and key sampling points of environmental monitoring activities, developed for Phase 1 construction project (excerpt). Figure 5.2-5 shows the survey area of the fish catch survey, conducted at both the Kohelia Channel and the Bay of Bengal.

Within the environmental monitoring activities of Phase 1 construction project, the water quality analysis of both the Kohelia Channel and the Bay of Bengal is conducted once a month, the counting of both phytoplankton/zooplankton and benthos are conducted at the Kohelia Channel every half year as well as quarterly at the Bay of Bengal. Counting of the sea turtle along the shoreline of the Bay of Bengal is conducted once a year. Fish catch survey at both the Kohelia Channel and the Bay of Bengal is conducted twice a year. Those monitoring survey results have been started to be summarized within either of monthly and/or quarterly monitoring reports since September 2017.

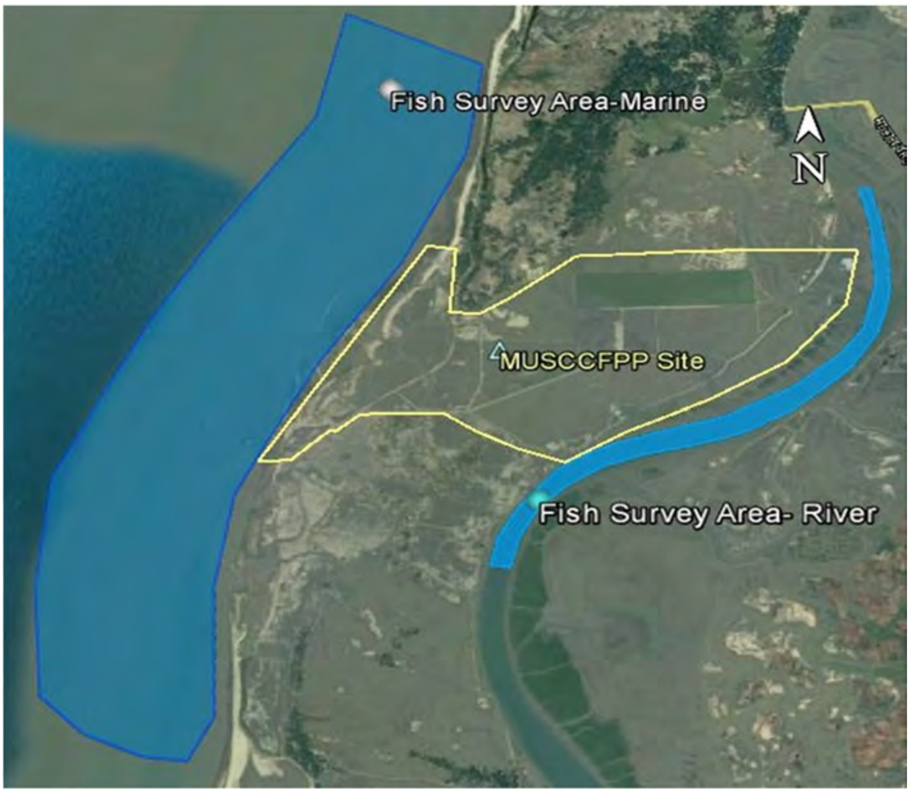
Table 5.2-1 Outline of Environmental and Social Monitoring Activities of Construction of Matarbari Ultra Super Critical Coal-Fired Power Plant Development Project Phase 1 in Bangladesh (excerpt)

Sampling Location ID	Monitoring Activities
RB1, RB2, RB3	Water and sediment samplings are conducted at 3 points along the Kohelia Channel for the water quality, the benthos, the phytoplankton and zooplankton analyses.
MB1, MB2, MB3, MDF	Water and sediment samplings are conducted at 4 points across the Bay of Bengal for the benthos, the phytoplankton and the zooplankton analyses.
SW1, SW2, SW3, SW4, SW5, SW6	Water samplings are conducted at 6 points across the Bay of Bengal for the water quality analysis.
TL-LN1, TL-LN2, TL-LN3, TL-LN4	Counting sea turtles for nesting and spawning at 4 lines.

Source: Study Team

Source: Study Team

Figure 5.2-4 Sampling Points Location of Environmental Monitoring Activities



Source: The Environmental monitoring report on Units 1/2 Construction Work (Feb – Apr, 2018)

Figure 5.2-5 Fish Catch Survey Area at both the Kohelia Channel and Bay of Bengal

(2) Discussions

Figure 5.2-6 shows the temporal variation of the benthos counting, conducted at both the Kohelia Channel and the Bay of Bengal (October 2017 – January 2021). From this figure, it can be seen that the counting number of the benthos individual is increased since the survey started in 2017 (+54%～+91% and +117%～+285% of individual count increases at the Kohelia Channel and the Bay of Bengal, respectively). From the comparison of the same monitoring month (i.e., monitoring results of January 2019 and January 2020), +44%～+51% and +49%～+109% of individual count increases are observed at the Kohelia Channel and the Bay of Bengal, respectively, although monitoring data is limited.

Figure 5.2-7 and Figure 5.2-8 show the temporal variation of the phytoplankton counting, conducted at both the Kohelia Channel and the Bay of Bengal (October 2017 – January 2021), respectively. As shown in these figures, it can be seen that the number of the counting around the water surface is the largest, and those numbers tend to be decreased as the sampling position becomes deeper. Also, it can be seen that entire counting numbers of the phytoplankton seem to be decreased since the counting started in 2017 although there is a sudden increase in July 2020. It is noted that the collection and accumulation of more additional survey data would be essential in order to evaluate this long-term fish catch tendency more precisely. From the comparison of the same monitoring month, -92%～+11% (August 2018 and August 2019: the Kohelia Channel), -66%～+1,025% (January 2019 and January 2020: the Kohelia Channel), +14%～+1,400% (August 2018 and August 2019: the Bay of Bengal) and -11%～+900% (January 2018 and January 2020: the Bay of Bengal) of variations of the individual counts are observed, respectively, although monitoring data is limited.

Figure 5.2-9 and Figure 5.2-10 show the temporal variation of the zooplankton counting, conducted at both the Kohelia Channel and the Bay of Bengal (October 2017 – January 2021), respectively. Similar to the observation made for the phytoplankton, mentioned above, it can be seen that the number of counting around the water surface is the largest, and those numbers tend to be decreased as the sampling position becomes deeper. Also, it can be seen that entire counting numbers of the zooplankton seem to be decreased since the counting started in 2017. From the comparison of the same monitoring month, -21%～-40% (August 2018 and August 2019: the Kohelia Channel), -65%～-44% (January 2018 and January 2020: the Kohelia Channel), -43%～+107% (August 2018 and August 2019: the Bay of Bengal) and -68%～+85% (January 2018 and

January 2020: the Bay of Bengal) of variations of the individual counts are observed, respectively, although monitoring data is limited.

Figure 5.2-11 shows the temporal variation of the spawning-and-nesting-purpose sea turtle counting, conducted along the shoreline of the Bay of Bengal (2018 – 2020). From this figure, it can be seen that no significant variation such as the decrease of the nesting occur.

Figure 5.2-12 shows the temporal variation of the fish catch survey results, conducted at both the Kohelia Channel and the Bay of Bengal (January 2018 – January 2021 (see Table 5.2.10 – Table 5.2.15 of Appendix-5.2 for more detailed information)). It is noted that no further detailed information that would classify fish catch survey results by site (i.e., the Kohelia Channel and the Bay of Bengal) is available. Also, no information regarding the exact location of fish gears nor the survey schedule of this survey is available, neither. So that, it would be difficult to have a detailed discussion regarding the temporal/spatial variation of local fish stocks, but would be beneficial to have a preliminary one for the future study that would be able to compile more survey results, leading to more precise analysis of this survey. It is also noted that no fish catch survey was conducted by relevant organization before Year 2017, so that no quantitative information regarding the fish diversity and fish catch existed around that period. So, a preliminary interview-based fishery survey (see Section 5.3 of this chapter) was conducted within this Phase 2 Study. From this figure, it can be seen that the amount of the fish catch, conducted within this survey, seem to be decreased although there was a sudden increase in August 2020 while around 30 fish species are observed within the survey period. It is noted that more additional survey data would be essential in order to evaluate this long-term fish catch tendency more precisely.

Figure 5.2-13 shows the temporal variation of the water quality parameter (pH) of the Kohelia Channel, conducted between October 2017 and January 2021. From this figure, it can be seen that pH values varies between 7.0 and 8.1 within this survey. Also, it can be said that no significant correlation with those of the benthos, the phytoplankton and the zooplankton of the Kohelia Channel seem not to be observed within this study, either.

Figure 5.2-14 shows the temporal variation of the water quality parameter (DO) of the Kohelia Channel, conducted between October 2017 and January 2021. From this figure, it can be seen that there is no significant decrease in DO value while varying between 5.0 mg/L and 7.5 mg/L within this survey. Also, similar to pH results, mentioned above, it can be said that no significant correlation with those of the benthos, the phytoplankton and the zooplankton of the Kohelia Channel seem not to be observed within this study, either.

Figure 5.2-15 shows the temporal variation of the water quality parameter (COD) of the Kohelia Channel, conducted between October 2017 and January 2021. From this figure, it can be seen that there is one unusual value (1,200 mg/L), detected in January 2018, but COD value is varying between 200 mg/L and 400 mg/L, and then, seem to start to decline since January 2019 within this survey. Similar tendency may be found within the temporal variation pattern of both the phytoplankton and the zooplankton of the Kohelia Channel.

Figure 5.2-16 shows the temporal variation of the water quality parameter (TSS) of the Kohelia Channel, conducted between October 2017 and January 2021. From this figure, it can be seen that there is no significant decrease in DO value while varying between 5.0 mg/L and 7.5 mg/L within this survey. As shown in this figure, no significant long-term variation pattern is observed within this survey.

Figure 5.2-17 - Figure 5.2-19 show the temporal variation of the water quality parameter (pH) of the coastal area of the Bay of Bengal, conducted between October 2017 and January 2021. As mentioned earlier, monthly-based water quality analysis is conducted across the Bay of Bengal, so that its survey result visualization is made, using three graphs. As shown in these figures, pH value is varying between 7.5 and 8.6 within this survey. Also, it can be said that no significant correlation with those of the benthos, the phytoplankton and the zooplankton of the Bay of Bengal seem not to be observed within this study, either. There is a decline in pH value in July 2019, and a similar tendency is observed within that of the Kohelia Channel. It is noted that overall pH values of the Bay of Bengal seem to be higher than those of the Kohelia Channel, so that it can be said that a complete mixing of water mass between the Kohelia Channel and the Bay of Bengal seem not to occur within this survey period.

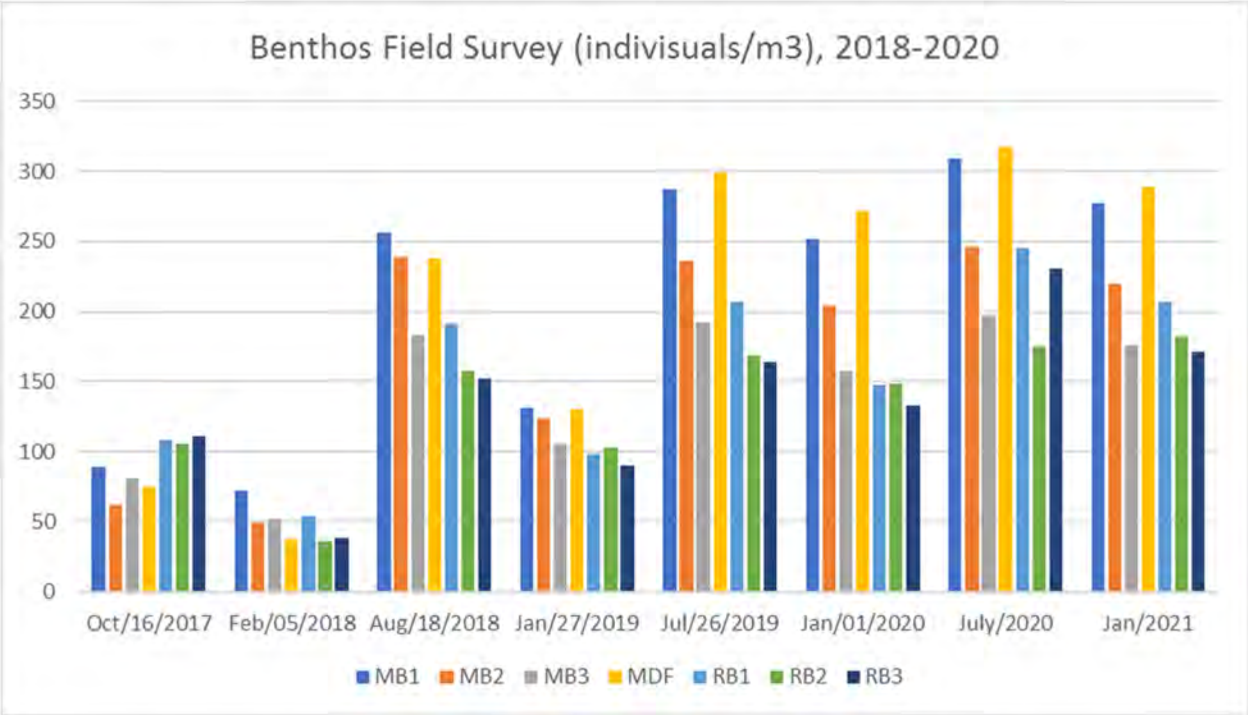
Figure 5.2-20 - Figure 5.2-22 show the temporal variation of the water quality parameter (DO) of the coastal area of the Bay of Bengal, conducted between October 2017 and January 2021. As mentioned earlier, monthly-based water quality analysis is conducted across the Bay of Bengal, so that its survey result visualization is made, using three graphs. As shown in these figures, pH value is varying between 7.5 and 8.6 within this survey. Also, it can be seen that there is no significant decline of DO values, and DO values of Year 2020 seem to be stable while varying between 5.0 mg/L and 8.0 mg/L. No strong correlation among temporal variation of DO and those of the benthos, the phytoplankton and the zooplankton, observed within the coastal area of the Bay of Bengal.

Figure 5.2-23 - Figure 5.2-25 show the temporal variation of the water quality parameter (COD) of the coastal area of the Bay of Bengal, conducted between October 2017 and January 2021. From these figures, it can be said that relatively high COD values, reaching around 1,000 mg/L during January 2018 to March 2018, then, started to decline, but jumped to 800 mg/L in December 2018, and then, again, started to decline. Similar declining tendency can be observed within those of both the phytoplankton and the zooplankton of the coastal area of the Bay of Bengal.

Figure 5.2-26 - Figure 5.2-28 show the temporal variation of the water quality parameter (TSS) of the coastal area of the Bay of Bengal, conducted between October 2017 and January 2021. From these figures, it can be seen that TSS values jumped to around 4,700 mg/L in September 2018, and then, started to decline. TSS values switched to increase gradually after February 2019 while varying around 200 mg/L, and show several peak values after that (1,000 mg/L in September, 2019 and 800 mg/L in August 2020. Similar variation patterns cannot be observed within those of the benthos, the phytoplankton nor the zooplankton of the Bay of Bengal, so that the influence of TSS parameter on the local ecosystem would be relatively small, compared with that of COD within this survey. It is noted that it is possible to obtain new findings and/or remarks within the continuous database development of an on-going environmental monitoring survey of Phase 1 Project, and periodical and punctual monitoring result inspection would be essential for continuous and reliable monitoring activities.

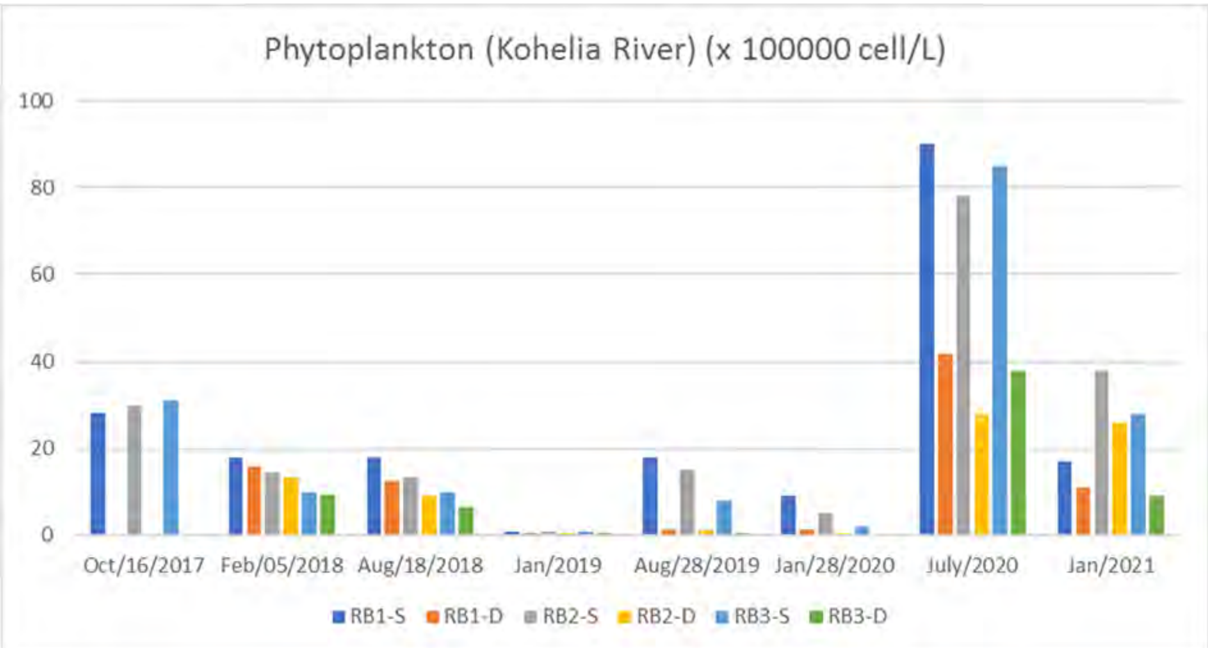
(3) Future Tasks

As mentioned earlier, the project site of Phase 2 is located within the same site of Phase 1, so that relevant environmental and social studies shall be conducted while establishing the integrity with on-going continuous monitoring activities of Phase 1 in order to develop a comprehensive monitoring database. Environmental monitoring activities of Phase 1 was initiated in Year 2017, and its data accumulation seems to start to provide interesting survey results such as a long-term variation of several environmental factors. For more precise and reliable evaluation and analysis of those survey results, continuous monitoring activities as well as periodical and timely inspection of those survey results that may provide some useful feedback to on-going monitoring activities of Phase 1 project would be essential. Also, it would be beneficial to compare monitoring results of the same monitoring month in order to check long-term variation of site-specific floral/faunal situation once suitable database accumulation for certain period (e.g., 5 years or so would be long enough) is established.



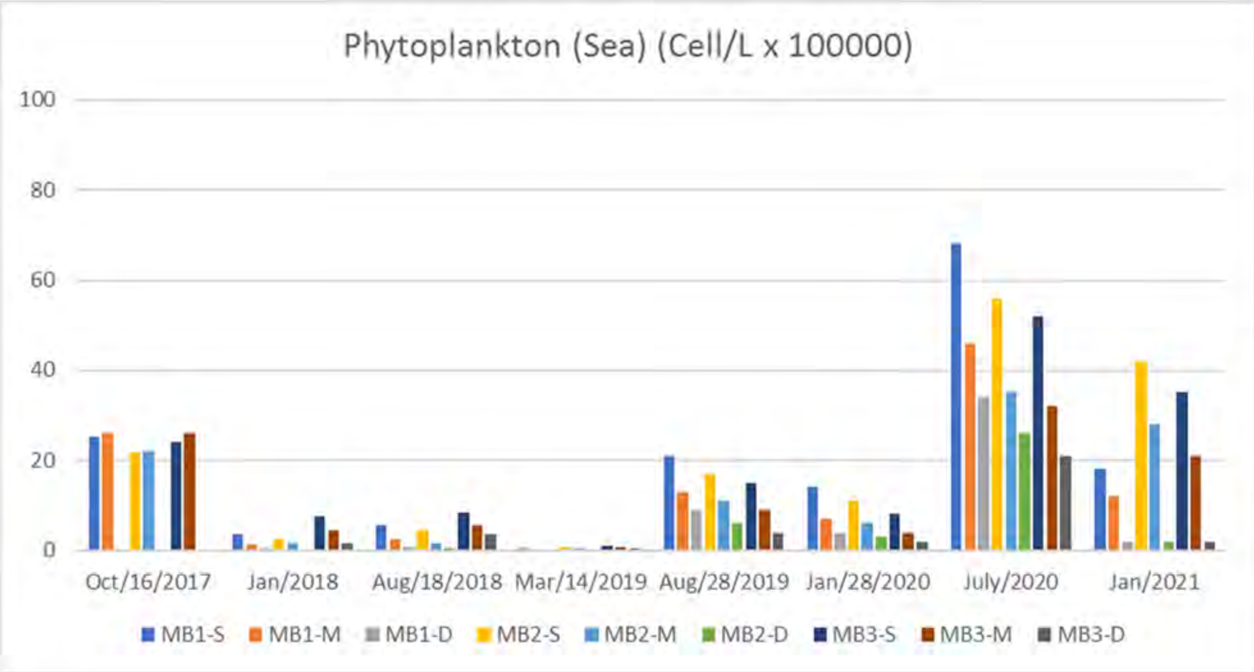
Note: "MB1", "MB2", "MB3", "MDF" and "RB1", "RB2", "RB3" indicate the sampling point IDs of both the Bay of Bengal and the Kohelia Channel, respectively.
Sediment sample of macro benthic faunal communities was collected using Ekman grab from an area of 15×15×15 cm at respective sampling point. The samples were sieved through a 0.5 mm mesh and preserved with 10% formalin in sampling bottle.
Source: Study Team

Figure 5.2-6 Environmental Monitoring (Benthos, October 2017 - January 2021)



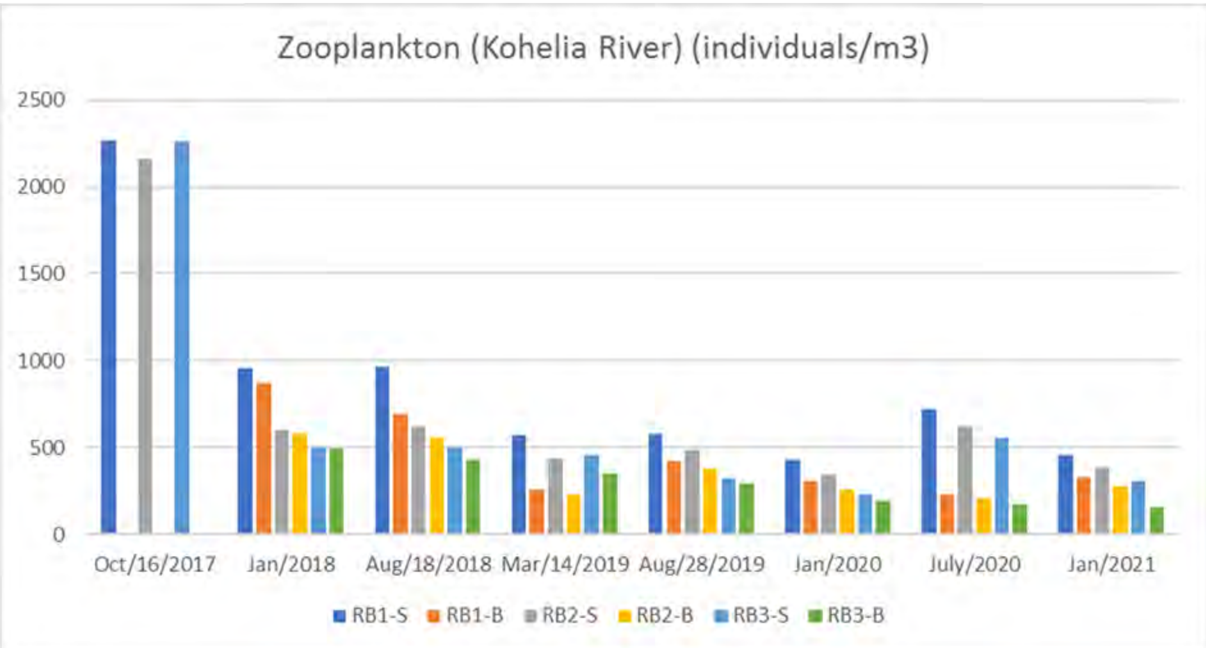
Note: "RB1-S", "RB2-S", "RB3-S" and "RB1-D", "RB2-D", "RB3-D" indicate the Kohelia Channel shallow and deep sampling points, respectively.
Phytoplankton water sample was collected using Van Dorn water sampler. Approximately 10 – 15 litres of water sample were filtered through plankton net of 30µm mesh size and preserved with 4% formalin in properly rinsed bottle.
Source: Study Team

Figure 5.2-7 Environmental Monitoring (Phytoplankton, Kohelia Channel, October 2017 - January 2021)



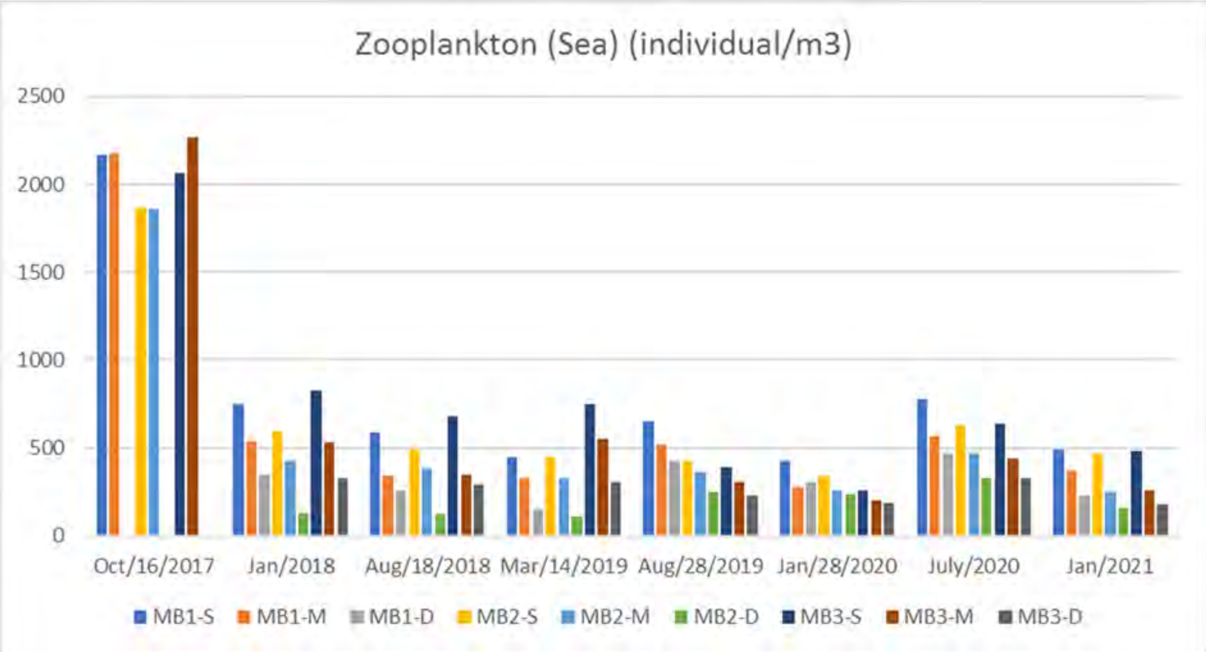
Note: “MB1-S”, “MB2-S”, “MB3-S” and “MB1-D”, “MB2-D”, “MB3-D” indicate the Bay of Bengal shallow and deep sampling points, respectively. “MB1-M”, “MB2-M” and “MB3-M” indicate the sampling points located between those two sampling points, mentioned above.
Phytoplankton water sample was collected using Van Dorn water sampler. Approximately 10 – 15 litres of water sample were filtered through plankton net of 30µm mesh size and preserved with 4% formalin in properly rinsed bottle.
Source: Study Team

Figure 5.2-8 Environmental Monitoring (Phytoplankton, Bay of Bengal, October 2017 - January 2021)



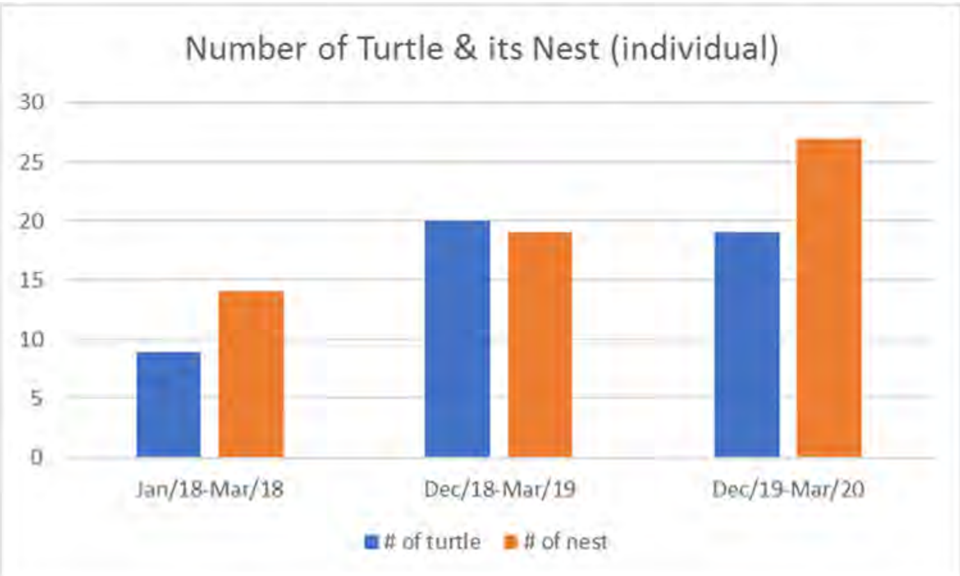
Note: “RB1-S”, “RB2-S”, “RB3-S” and “RB1-D”, “RB2-D”, and “RB3-D” indicate the Kohelia Channel shallow and deep sampling points, respectively. It is also noted that there is no data of deep sampling points in October 2017.
Zooplankton water sample was collected using a Zooplankton net with mesh size of 300µm and metallic circular frame with a 25cm mouth opening. The sample was preserved in 4% formalin.
Source: Study Team

Figure 5.2-9 Environmental Monitoring (Zooplankton, Kohelia Channel, October 2017 - January 2021)



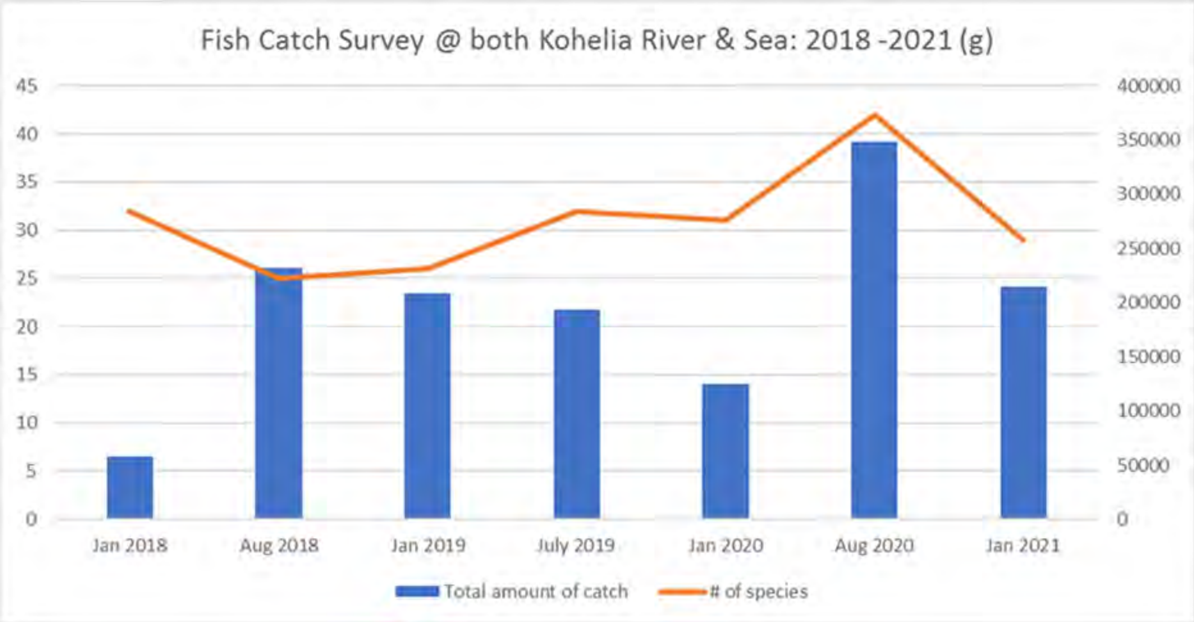
Note: “MB1-S”, “MB2-S”, “MB3-S” and “MB1-D”, “MB2-D”, “MB3-D” indicate the Bay of Bengal shallow and deep sampling points, respectively. “MB1-M”, “MB2-M” and “MB3-M” indicate the sampling points located between those two sampling points, mentioned above. It is also noted that there is no data of deep sampling points in October 2017.
Zooplankton water sample was collected using a Zooplankton net with mesh size of 300μm and metallic circular frame with a 25cm mouth opening. The sample was preserved in 4% formalin.
Source: Study Team

Figure 5.2-10 Environmental Monitoring (Zooplankton, Bay of Bengal, October 2017 - January 2021)



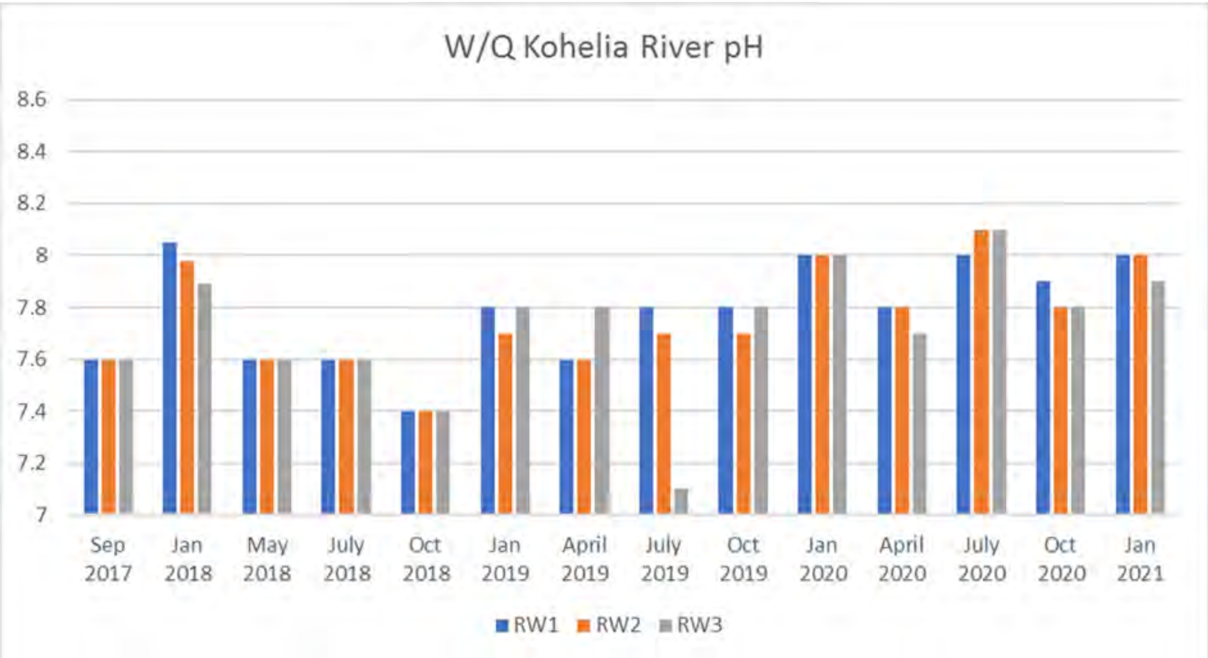
Source: Study Team

Figure 5.2-11 Environmental Monitoring (Counting of Sea Turtle Nesting along Shoreline of the Bay of Bengal, 2018 – 2020)



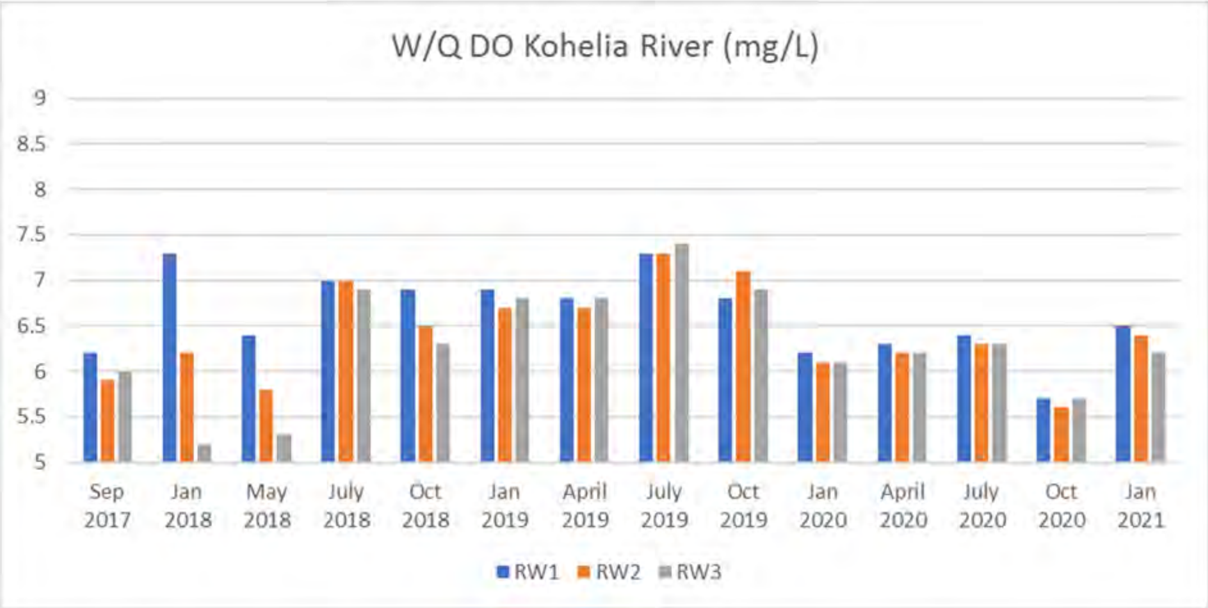
Source: Study Team

Figure 5.2-12 Environmental Monitoring (On-spot Fish Catch Effort Survey at the Kohelia Channel and the Bay of Bengal, 2018 – 2021)



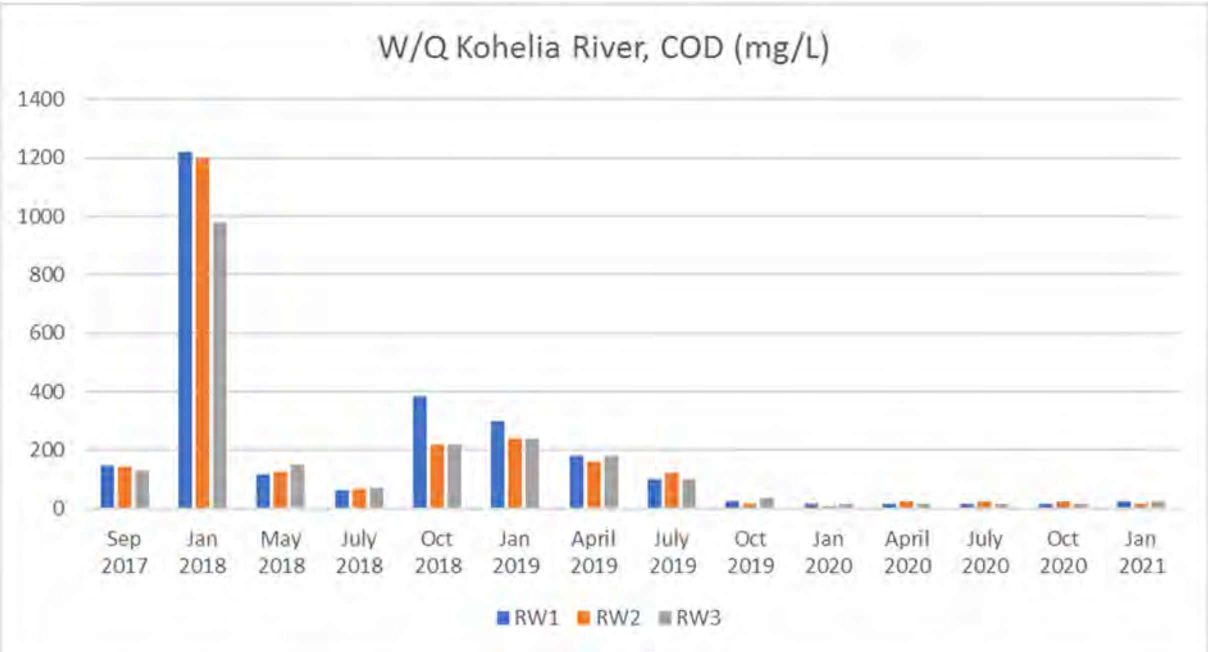
Source: Study Team

Figure 5.2-13 Environmental Monitoring (Water Quality pH, Kohelia Channel, October 2017 – January 2021)



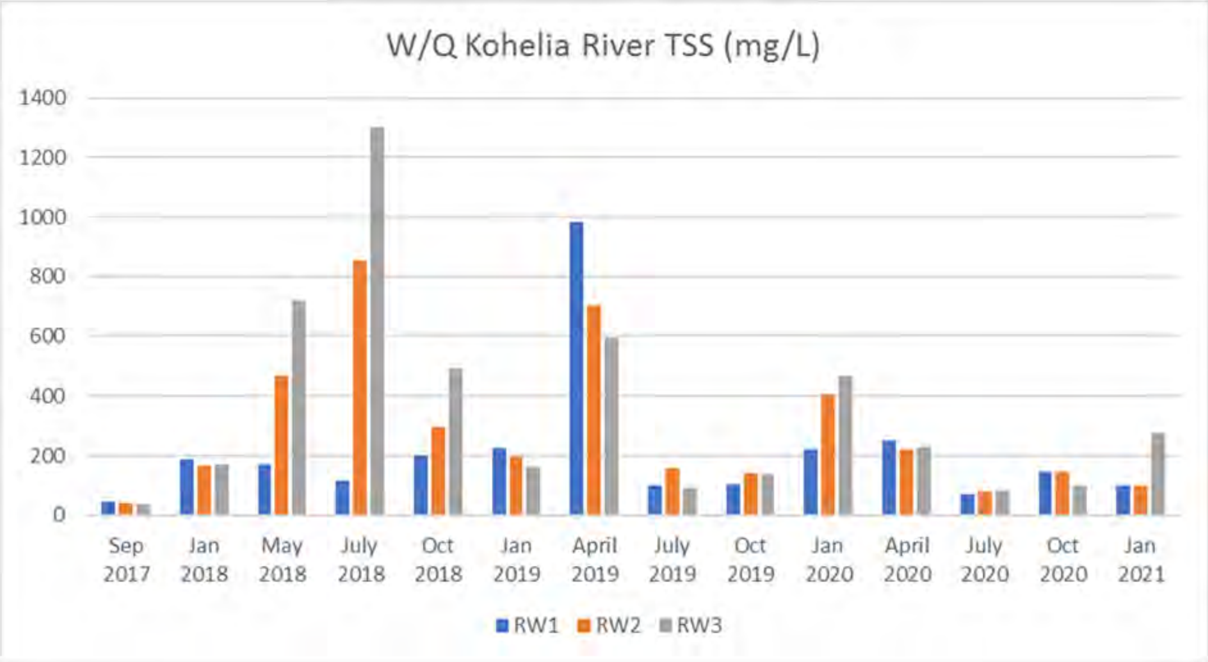
Source: Study Team

Figure 5.2-14 Environmental Monitoring (Water Quality DO, Kohelia Channel, October 2017 – January 2021)



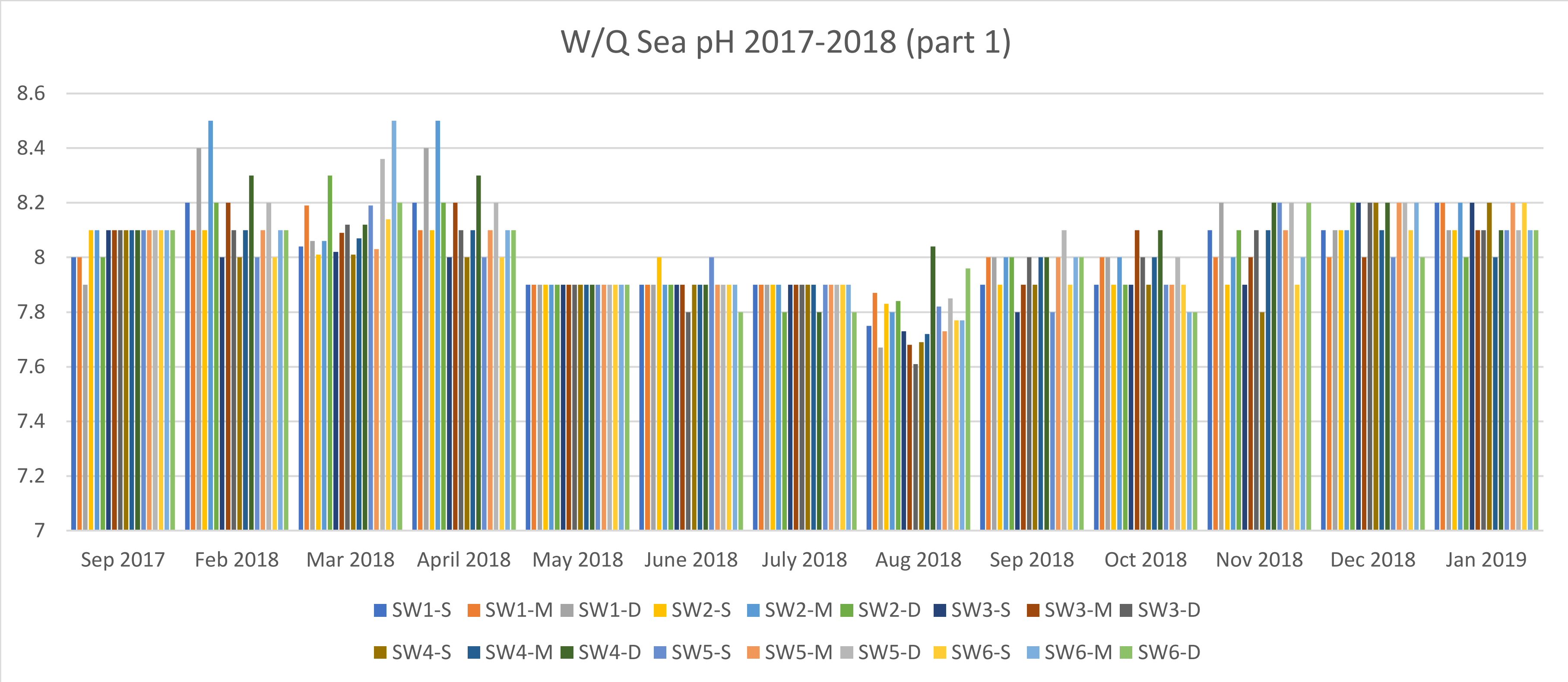
Source: Study Team

Figure 5.2-15 Environmental Monitoring (Water Quality COD, Kohelia Channel, October 2017 - January 2021)



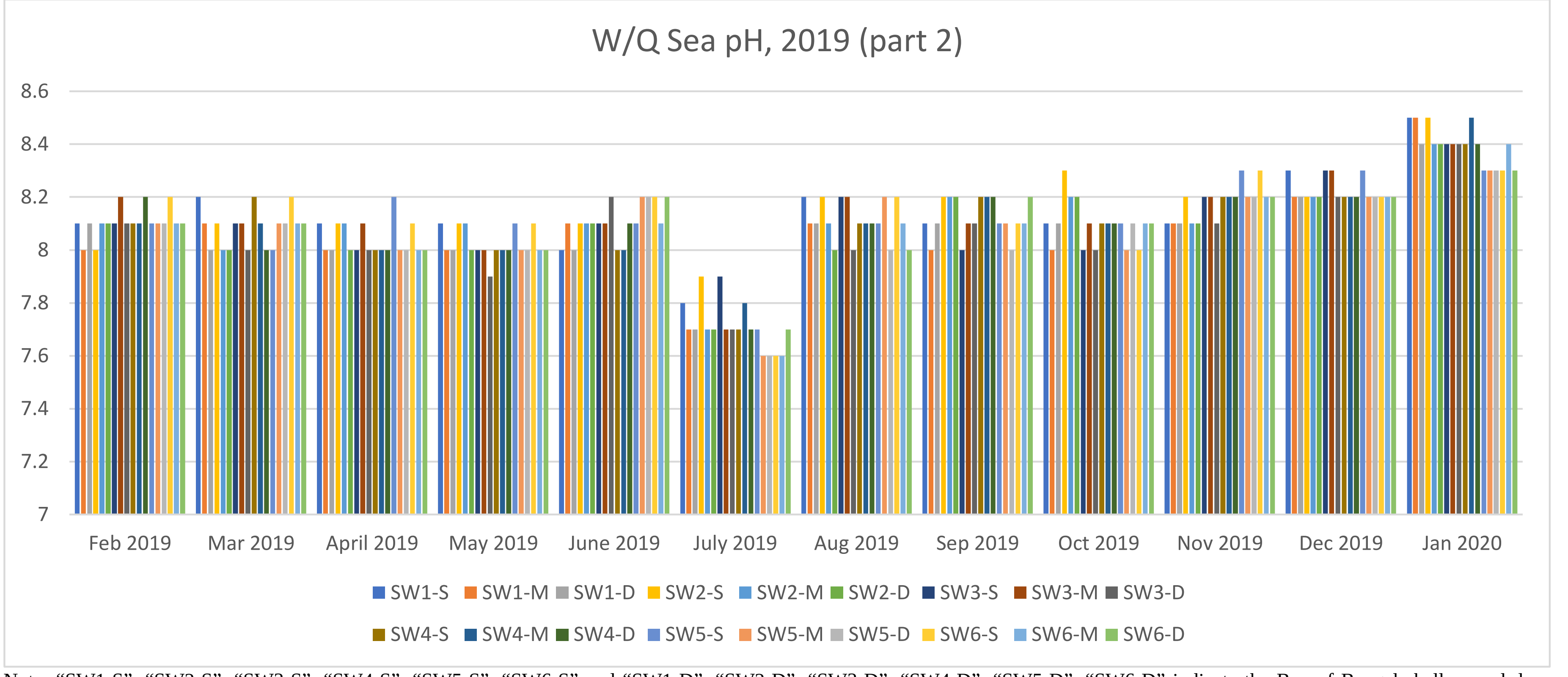
Source: Study Team

Figure 5.2-16 Environmental Monitoring (Water Quality TSS, Kohelia Channel, October 2017 – January 2021)



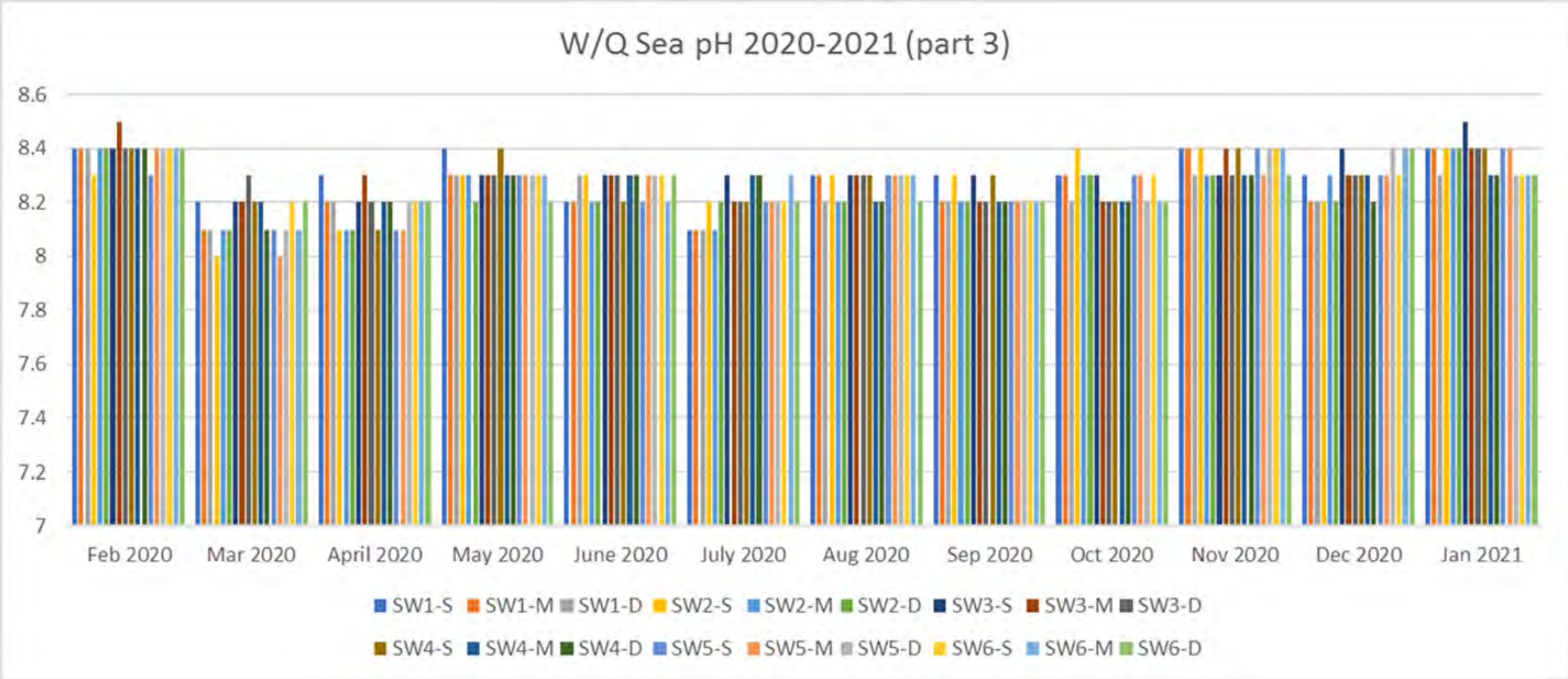
Note: "SW1-S", "SW2-S", "SW3-S", "SW4-S", "SW5-S", "SW6-S" and "SW1-D", "SW2-D", "SW3-D", "SW4-D", "SW5-D", "SW6-D" indicate the Bay of Bengal shallow and deep sampling points, respectively. "SW1-M", "SW2-M", "SW3-M", "SW4-M", "SW5-M" and "SW6-M" indicate the sampling points located between those two sampling points, mentioned above.
Source: Study Team

Figure 5.2-17 Environmental Monitoring (Water Quality pH, Coastal Area of the Bay of Bengal, October 2017 - January 2019, part 1)



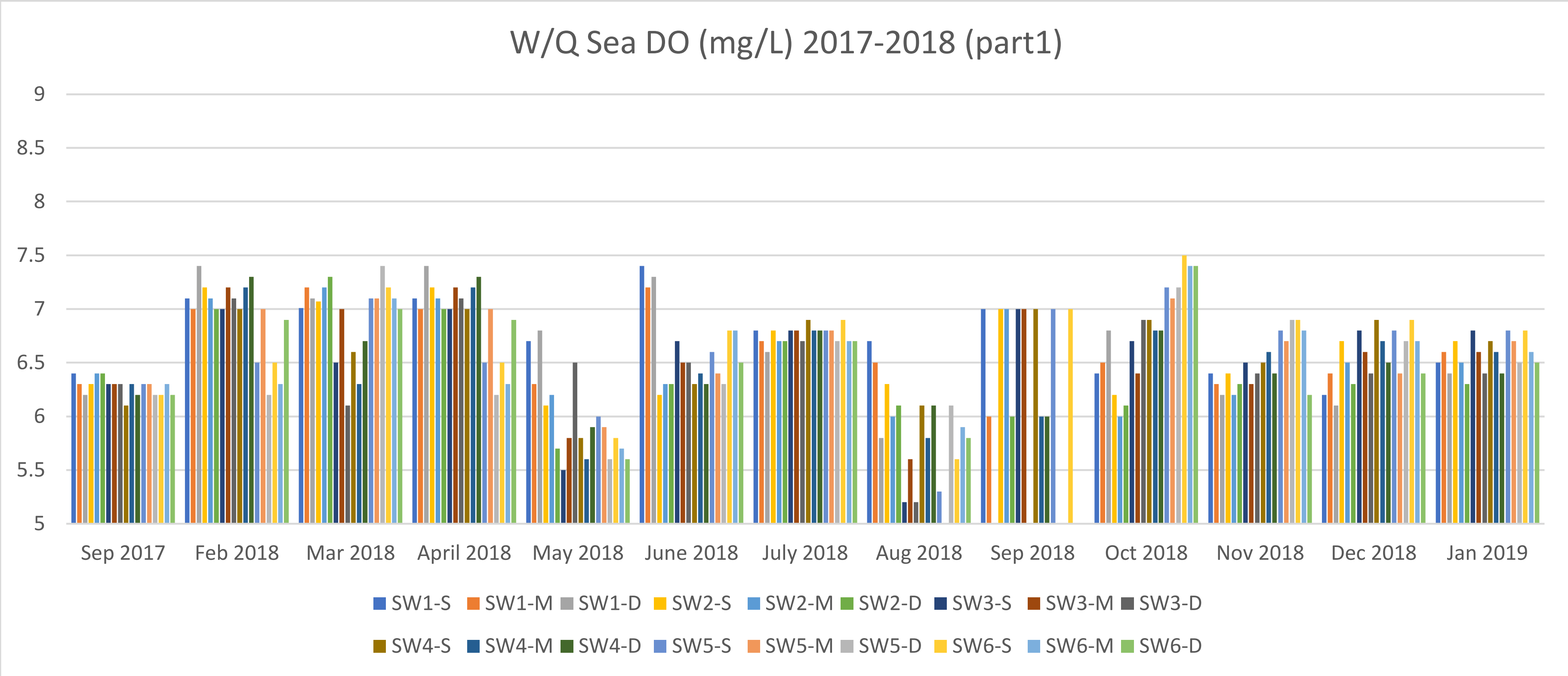
Note: "SW1-S", "SW2-S", "SW3-S", "SW4-S", "SW5-S", "SW6-S" and "SW1-D", "SW2-D", "SW3-D", "SW4-D", "SW5-D", "SW6-D" indicate the Bay of Bengal shallow and deep sampling points, respectively. "SW1-M", "SW2-M", "SW3-M", "SW4-M", "SW5-M" and "SW6-M" indicate the sampling points located between those two sampling points, mentioned above.
Source: Study Team

Figure 5.2-18 Environmental Monitoring (Water Quality pH, Coastal Area of the Bay of Bengal, February 2019 - January 2020, part 2)



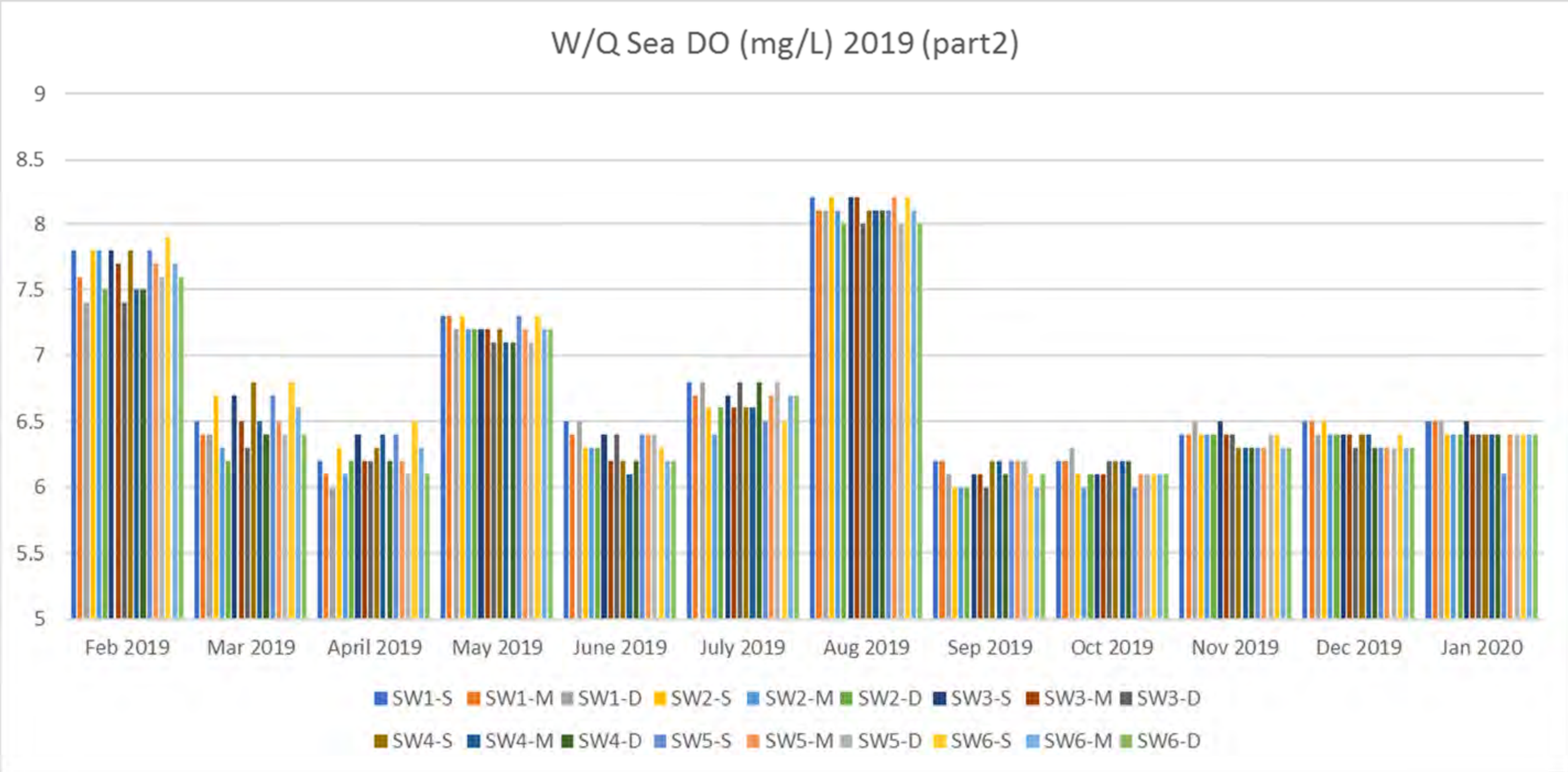
Note: "SW1-S", "SW2-S", "SW3-S", "SW4-S", "SW5-S", "SW6-S" and "SW1-D", "SW2-D", "SW3-D", "SW4-D", "SW5-D", "SW6-D" indicate the Bay of Bengal shallow and deep sampling points, respectively. "SW1-M", "SW2-M", "SW3-M", "SW4-M", "SW5-M" and "SW6-M" indicate the sampling points located between those two sampling points, mentioned above.
Source: Study Team

Figure 5.2-19 Environmental Monitoring (Water Quality pH, Coastal Area of the Bay of Bengal, February 2020 – January 2021, part 3)



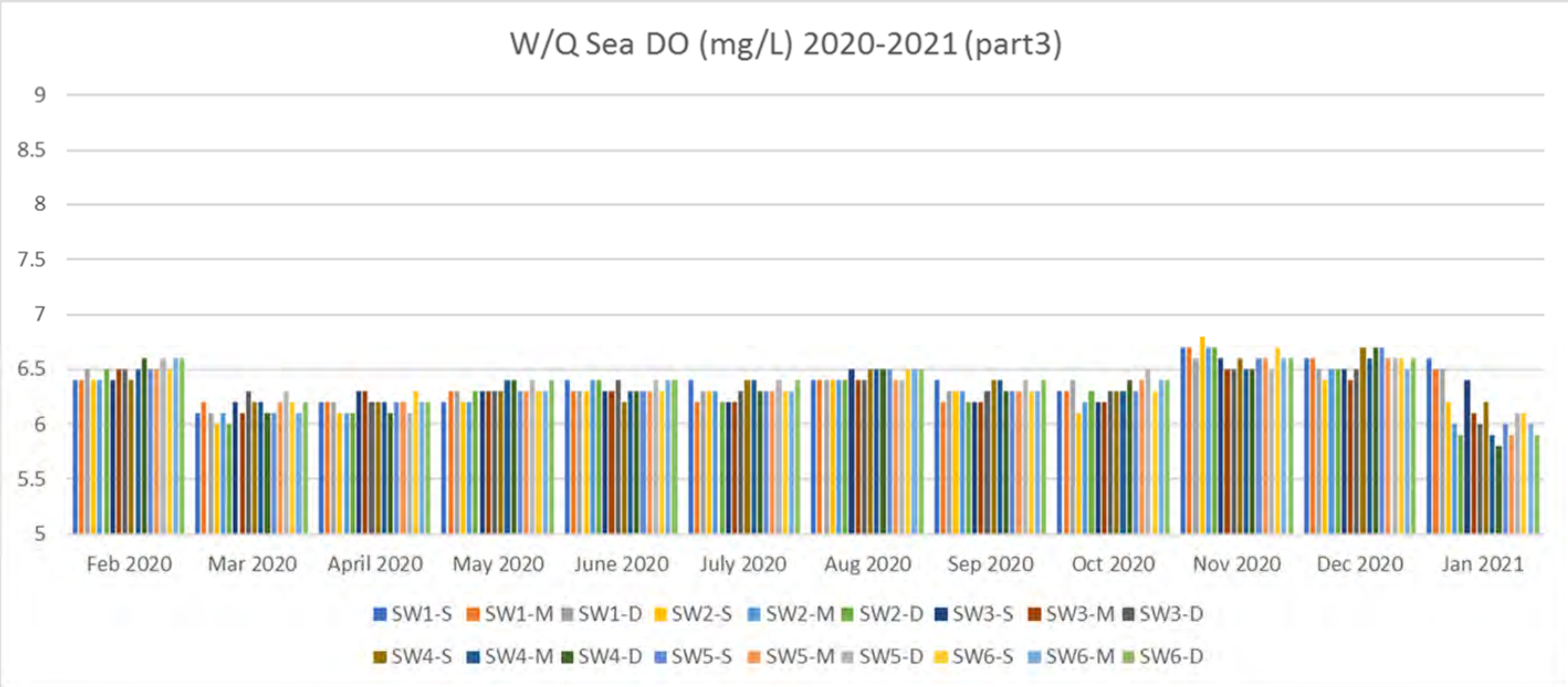
Note: "SW1-S", "SW2-S", "SW3-S", "SW4-S", "SW5-S", "SW6-S" and "SW1-D", "SW2-D", "SW3-D", "SW4-D", "SW5-D", "SW6-D" indicate the Bay of Bengal shallow and deep sampling points, respectively. "SW1-M", "SW2-M", "SW3-M", "SW4-M", "SW5-M" and "SW6-M" indicate the sampling points located between those two sampling points, mentioned above.
Source: Study Team

Figure 5.2-20 Environmental Monitoring (Water Quality DO, Coastal Area of the Bay of Bengal, October 2017 - January 2019, part 1)



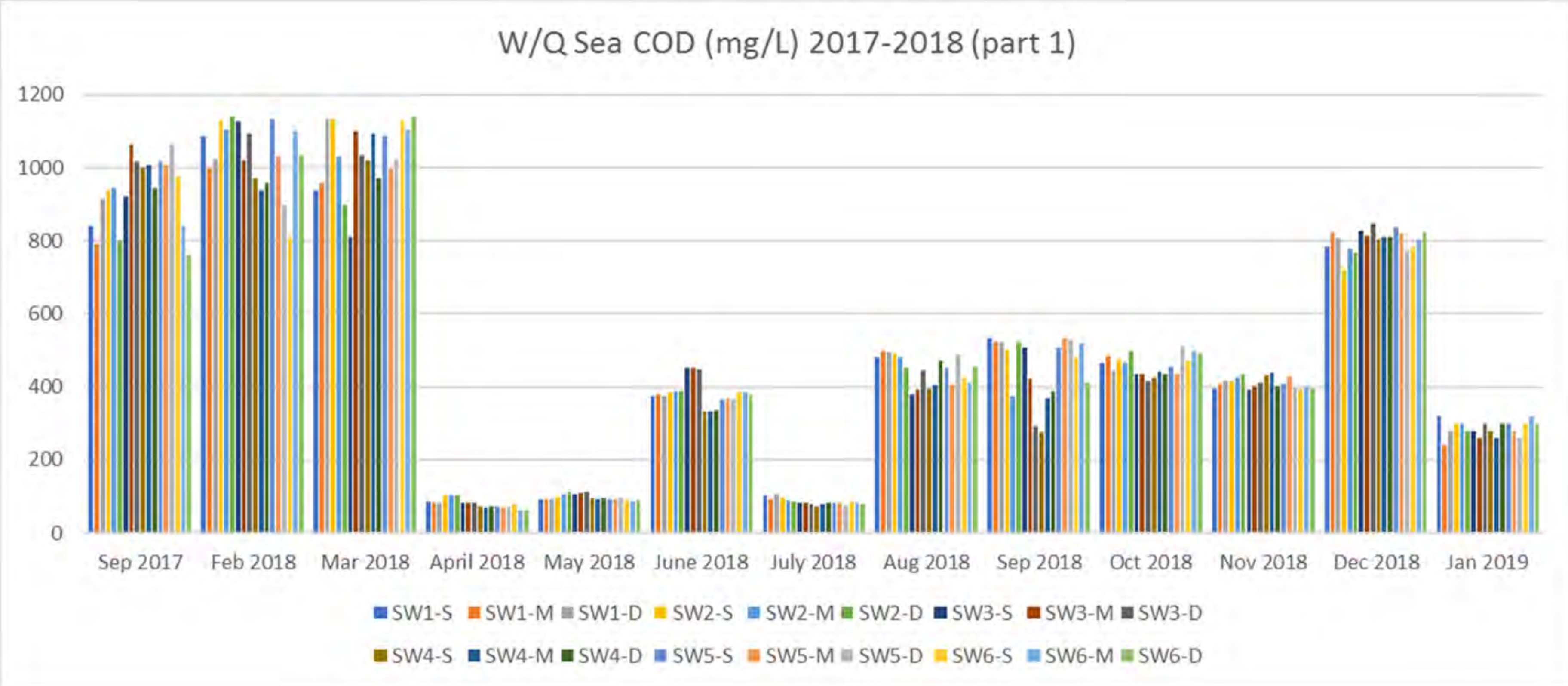
Note: "SW1-S", "SW2-S", "SW3-S", "SW4-S", "SW5-S", "SW6-S" and "SW1-D", "SW2-D", "SW3-D", "SW4-D", "SW5-D", "SW6-D" indicate the Bay of Bengal shallow and deep sampling points, respectively. "SW1-M", "SW2-M", "SW3-M", "SW4-M", "SW5-M" and "SW6-M" indicate the sampling points located between those two sampling points, mentioned above.
Source: Study Team

Figure 5.2-21 Environmental Monitoring (Water Quality DO, Coastal Area of the Bay of Bengal, February 2019 - January 2020, part 2)



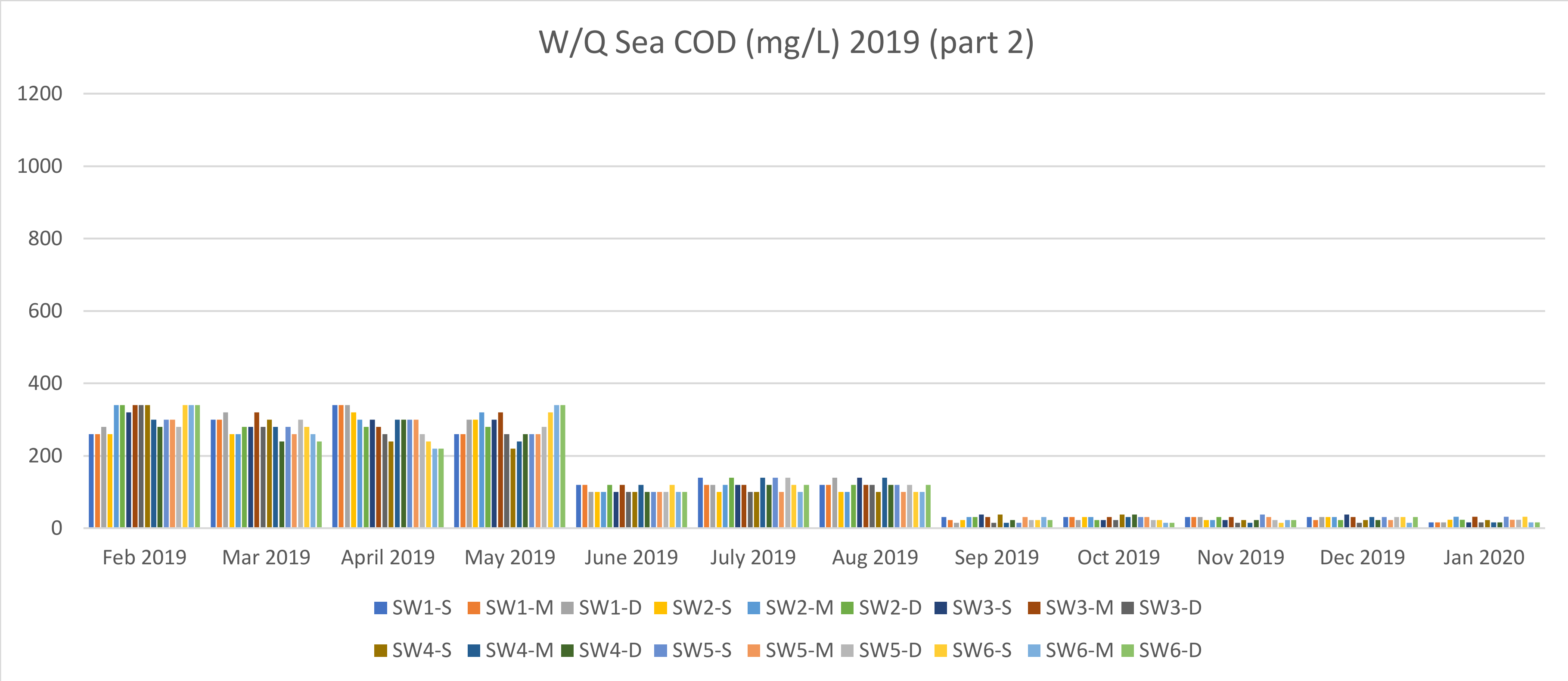
Note: "SW1-S", "SW2-S", "SW3-S", "SW4-S", "SW5-S", "SW6-S" and "SW1-D", "SW2-D", "SW3-D", "SW4-D", "SW5-D", "SW6-D" indicate the Bay of Bengal shallow and deep sampling points, respectively. "SW1-M", "SW2-M", "SW3-M", "SW4-M", "SW5-M" and "SW6-M" indicate the sampling points located between those two sampling points, mentioned above.
Source: Study Team

Figure 5.2-22 Environmental Monitoring (Water Quality DO, Coastal Area of the Bay of Bengal, February 2020 – January 2021, part 3)



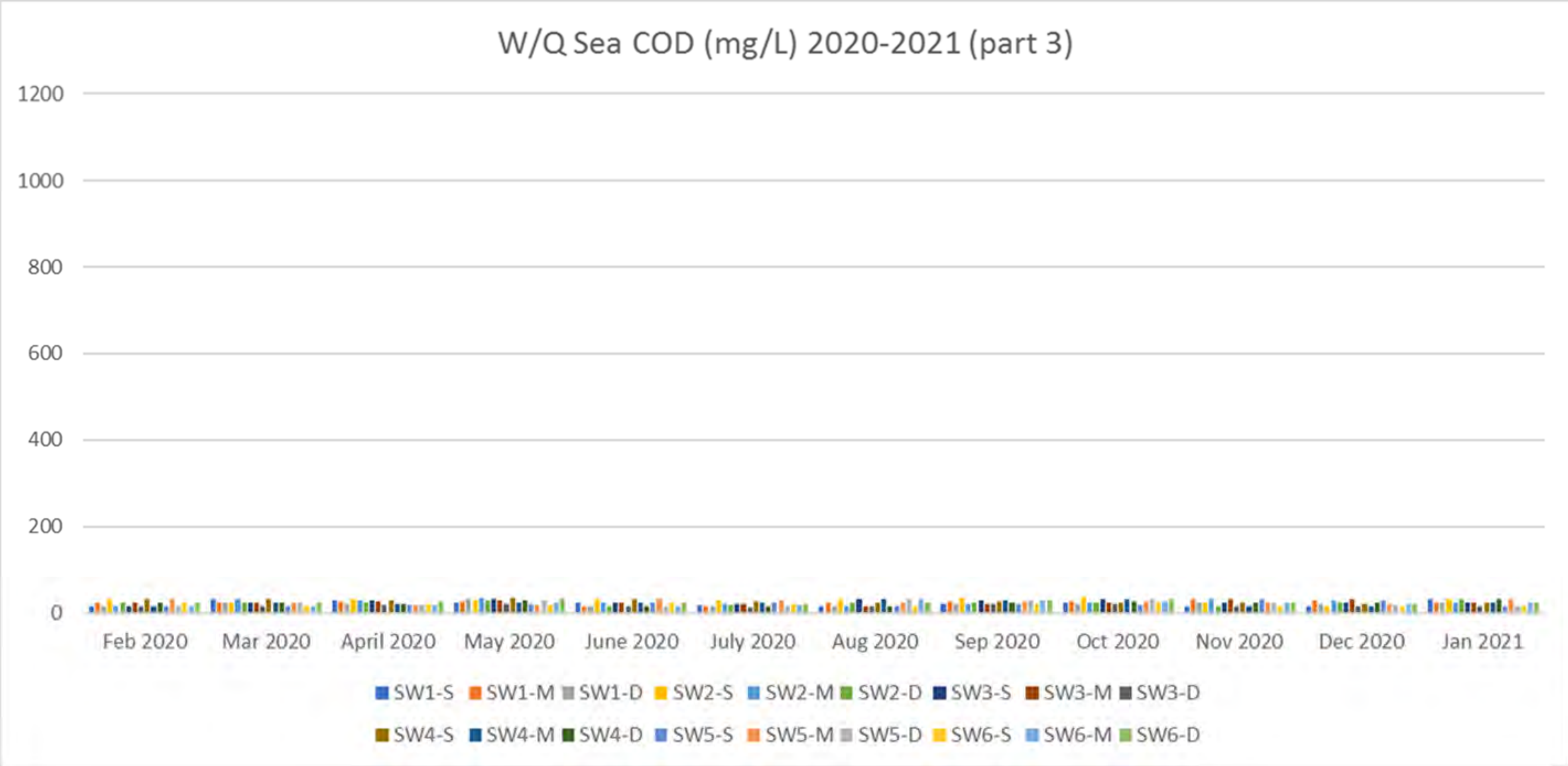
Note: "SW1-S", "SW2-S", "SW3-S", "SW4-S", "SW5-S", "SW6-S" and "SW1-D", "SW2-D", "SW3-D", "SW4-D", "SW5-D", "SW6-D" indicate the Bay of Bengal shallow and deep sampling points, respectively. "SW1-M", "SW2-M", "SW3-M", "SW4-M", "SW5-M" and "SW6-M" indicate the sampling points located between those two sampling points, mentioned above.
Source: Study Team

Figure 5.2-23 Environmental Monitoring (Water Quality COD, Coastal Area of the Bay of Bengal, October 2017 - January 2019, part 1)



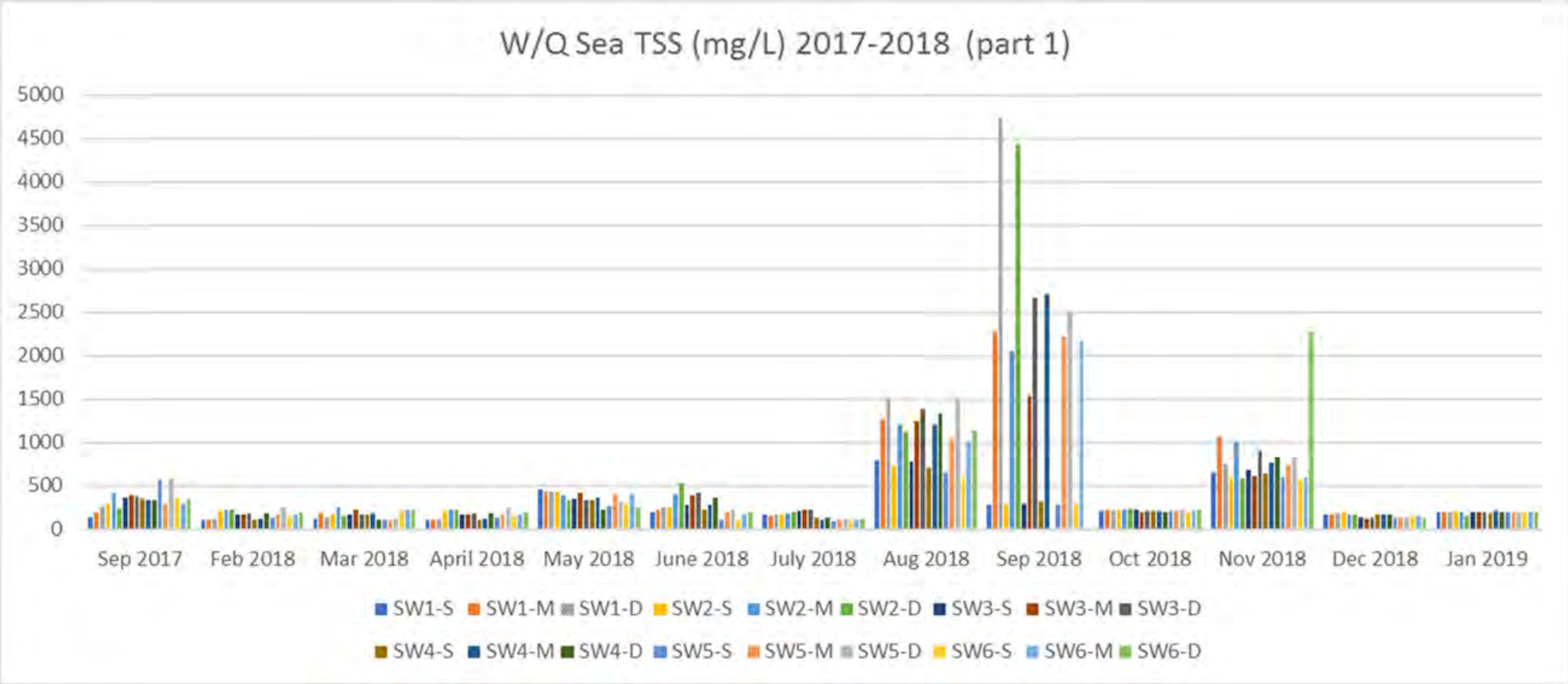
Note: “SW1-S”, “SW2-S”, “SW3-S”, “SW4-S”, “SW5-S”, “SW6-S” and “SW1-D”, “SW2-D”, “SW3-D”, “SW4-D”, “SW5-D”, “SW6-D” indicate the Bay of Bengal shallow and deep sampling points, respectively. “SW1-M”, “SW2-M”, “SW3-M”, “SW4-M”, “SW5-M” and “SW6-M” indicate the sampling points located between those two sampling points, mentioned above.
Source: Study Team

Figure 5.2-24 Environmental Monitoring (Water Quality COD, Coastal Area of the Bay of Bengal, February 2019 - January 2020, part 2)



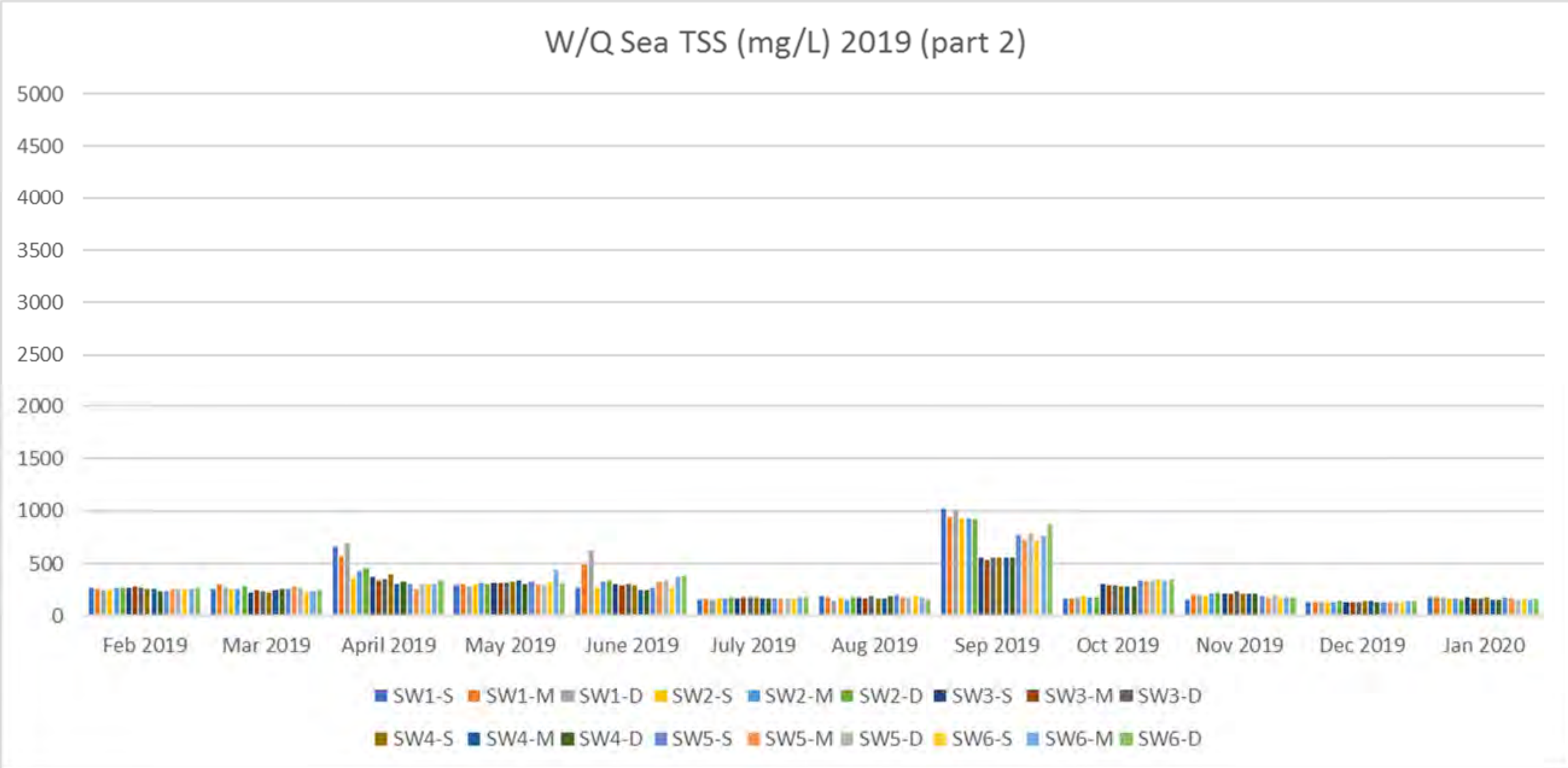
Note: "SW1-S", "SW2-S", "SW3-S", "SW4-S", "SW5-S", "SW6-S" and "SW1-D", "SW2-D", "SW3-D", "SW4-D", "SW5-D", "SW6-D" indicate the Bay of Bengal shallow and deep sampling points, respectively. "SW1-M", "SW2-M", "SW3-M", "SW4-M", "SW5-M" and "SW6-M" indicate the sampling points located between those two sampling points, mentioned above.
Source: Study Team

Figure 5.2-25 Environmental Monitoring (Water Quality COD, Coastal Area of the Bay of Bengal, February 2020 – January 2021, part 3)



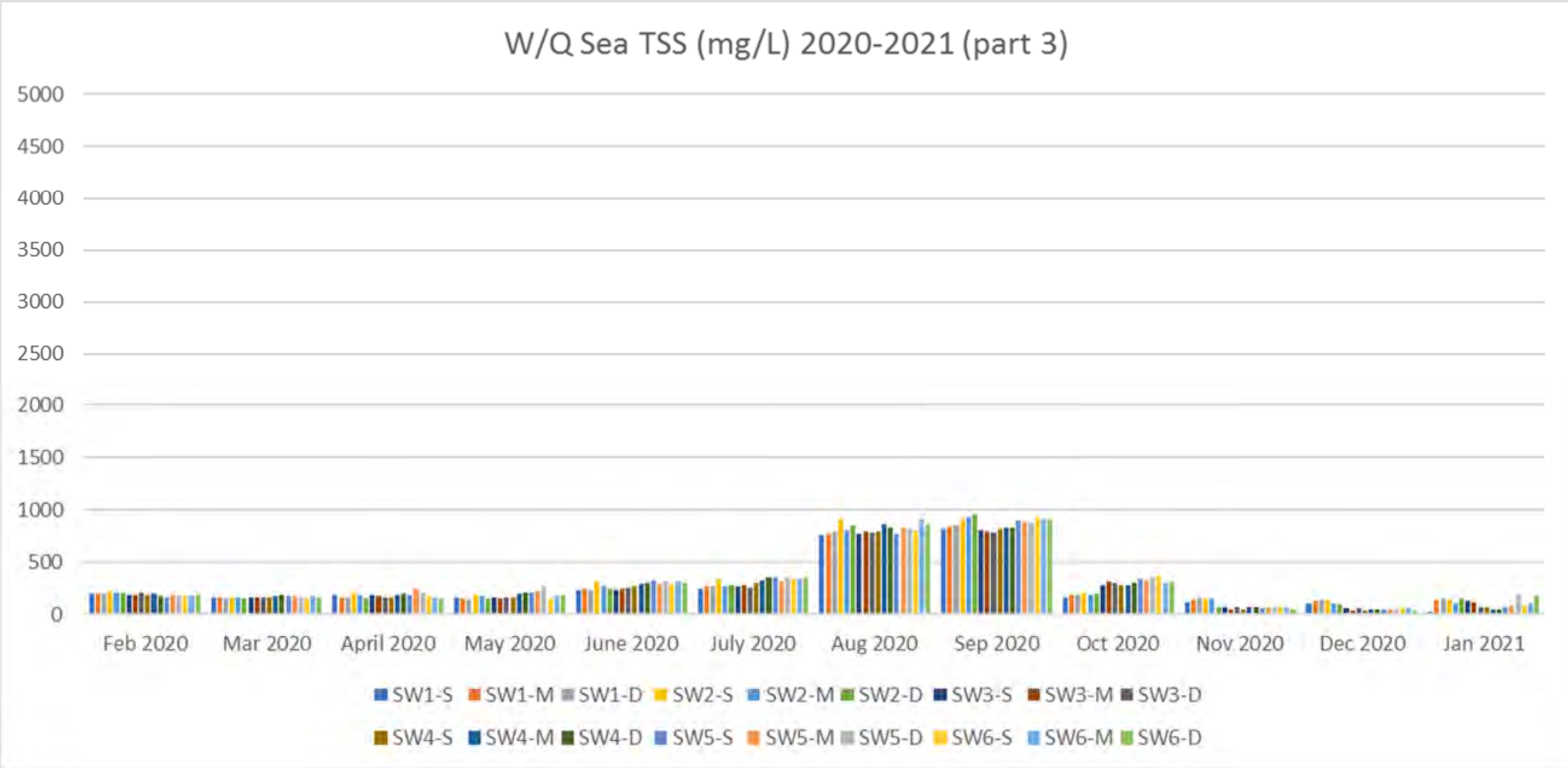
Note: “SW1-S”, “SW2-S”, “SW3-S”, “SW4-S”, “SW5-S”, “SW6-S” and “SW1-D”, “SW2-D”, “SW3-D”, “SW4-D”, “SW5-D”, “SW6-D” indicate the Bay of Bengal shallow and deep sampling points, respectively. “SW1-M”, “SW2-M”, “SW3-M”, “SW4-M”, “SW5-M” and “SW6-M” indicate the sampling points located between those two sampling points, mentioned above.
Source: Study Team

Figure 5.2-26 Environmental Monitoring (Water Quality TSS, Coastal Area of the Bay of Bengal, October 2017 - January 2019, part 1)



Note: "SW1-S", "SW2-S", "SW3-S", "SW4-S", "SW5-S", "SW6-S" and "SW1-D", "SW2-D", "SW3-D", "SW4-D", "SW5-D", "SW6-D" indicate the Bay of Bengal shallow and deep sampling points, respectively. "SW1-M", "SW2-M", "SW3-M", "SW4-M", "SW5-M" and "SW6-M" indicate the sampling points located between those two sampling points, mentioned above.
Source: Study Team

Figure 5.2-27 Environmental Monitoring (Water Quality TSS, Coastal Area of the Bay of Bengal, February 2019 - January 2020, part 2)



Note: "SW1-S", "SW2-S", "SW3-S", "SW4-S", "SW5-S", "SW6-S" and "SW1-D", "SW2-D", "SW3-D", "SW4-D", "SW5-D", "SW6-D" indicate the Bay of Bengal shallow and deep sampling points, respectively. "SW1-M", "SW2-M", "SW3-M", "SW4-M", "SW5-M" and "SW6-M" indicate the sampling points located between those two sampling points, mentioned above.
Source: Study Team

Figure 5.2-28 Environmental Monitoring (Water Quality TSS, Coastal Area of the Bay of Bengal, February 2020 – January 2021, part 3)

5.2.3 Flora and Fauna Survey

(1) Background and Objective

The main objective of this flora and fauna survey is to support the data collection of the latest floral and faunal information around the study site, to be used for the preparation of EIA Report and relevant ECC (Environmental Clearance Certificate) approval process of Units 3/4 Project, based on JICA Guidelines for Environmental and Social Considerations (2010).

EIA report of Units 1/2 Project was approved in October 2013, and then, relevant construction activities have been initiated in February 2016. More than seven (7) years have passed since its ECC approval. So that it is essential to review contents of both FS and EIA Reports of Units 1/2 Project, and then, update relevant information of the latest EIA-related legal framework (e.g., structure of DoE), codes and process as well as the conservation status and its policy in Bangladesh while updating the baseline natural environmental information since it is highly likely that local natural environment around the study site is affected due to its construction activities to some extents.

Throughout this review and updating process, it is also possible to develop more meaningful environmental management program and its monitoring plan for Units 3/4 Project. As mentioned earlier, construction of Units 1/2 Project have been started already, and relevant environmental management and monitoring activities of the terrestrial and aquatic flora/fauna have been initiated also. It is highly likely that similar environmental safeguard procedures are to be taken within Units 3/4 Project reflecting pros and cons of actual practices of EMP of Units 1/2 Project. Thus, in order to develop meaningful EMP and EMoP of Units 3/4 Project, it is important to incorporate the latest environmental baseline information while incorporating review results of both EMP and EMoP-related issues of Units 1/2 therein.

(2) Flora and Faunal Survey of Units 3/4 Project

Terrestrial and aquatic floral and faunal survey of Units 3/4 Project was conducted across Matarbari and Moheshkhali Islands around the study site while reviewing relevant data of current studies. Field surveys were conducted once in the dry season (January – February 2021) and once in the rainy season (to be conducted in July 2021).

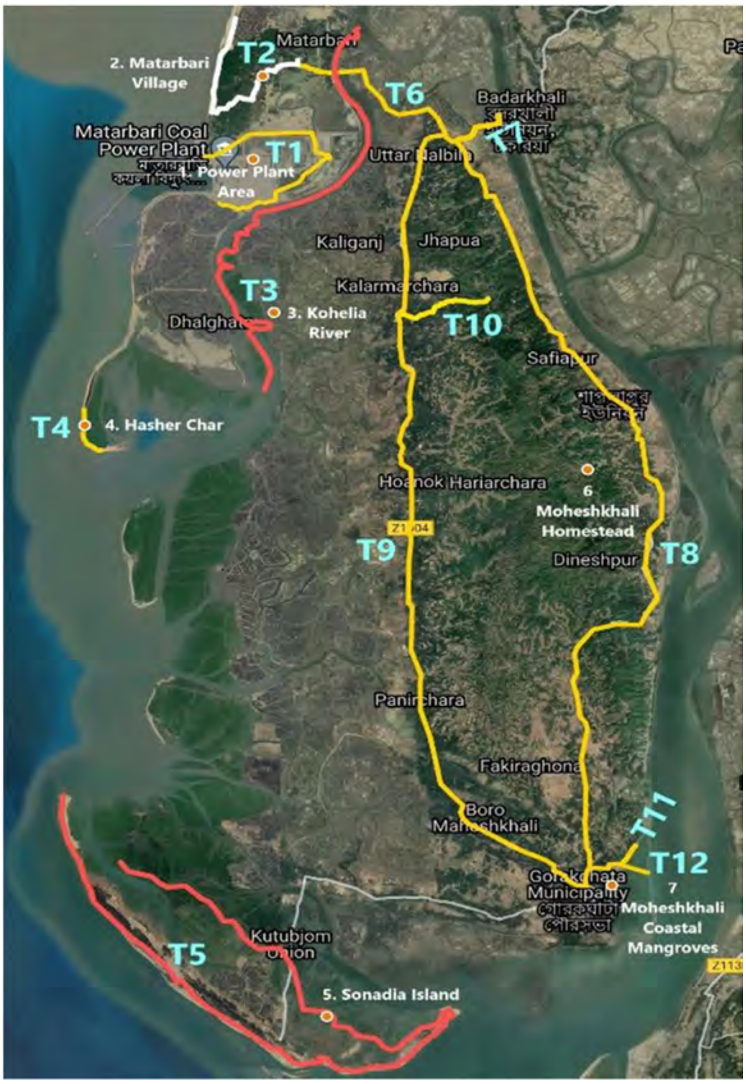
Table 5.2-2 and Figure 5.2-29 show twelve (12) transect lines, set for the floral survey of Units 3/4 Project. Table 5.2-3, Figure 5.2-30 and Figure 5.2-31 show eighteen (18) transect lines, set for the faunal survey of Units 3/4 Project. Table 5.2-4 and Figure 5.2-32 show the outline of bird observation activities. Bird observation was conducted at following two (2) points, i.e., one (1) at Hansher Char and the other one (1) at Sonadia Island

Table 5.2-2 Transect Lines of Floral Survey

Transect ID	Outline	Length (m)
T1 (Project Site)	Gate No. of Powerplant to Gate No.12, mud filling and salt field at the left (Roadside)	7,032
T2 (Matarbari Area)	Matarbari High School to Shaitpara to Jetty sea beach through embankment (Homestead)	5,763
T3 (Kohelia Channel)	Kohelia Channel (Mangrove)	15,442
T4 (Hasher Char)	Hasher Char western side (Sandy beach & Mangroves)	1,440
T5 (Sonadia Island)	Sonadia sea beach and the island (Sandy beach & Mangrove)	24,241
T6 (Residential Area of Moheshkhali Island)	Matarbari High School to Saliatali Bazar (Roadside)	4,500
T7 (Same as above)	Saliatali Bazar to Moheshkhali Bridge (Roadside)	1,521
T8 (Same as above)	Saliatali Bazar to Gorakghata via Shaplapur (Roadside, Small Hills, Homestead)	24,033
T9 (Same as above)	Gorakghata to Saliatali Bazar via Kalarmarchara (Roadside)	24,500
T10 (Same as above)	Kalarmarchara to East side of the Moheshkhali via local narrow village roads upto hill barrier (Homestead)	2,057
T11 (Coastal Mangrove Vegetation of Moheshkhali Island)	Beside Adinath Temple (Mangrove, Hillside)	660
T12 (Same as above)	From Gorakghata Bazar to Moheshkhali Terminal (Roadside, Mangrove)	1,620

Transect ID	Outline	Length (m)
Total		112,809

Note that the width of all transect lines are of 10m.
Source: Study Team



Source: Study Team
Figure 5.2-29 Location of Transect Line for Floral Survey

Table 5.2-3 Transect Lines of Faunal Survey

Transect ID	Habitat Outline	Length (m)	Width (m)	Survey Area (m^2)
T1	From 1st gate of powerplant to Swankhali. Left side mudflat, dry salt field (mud filling area)	2,919	100	291,900
T2	From the corner of Swankhali lagoon to diversion corner of the road_mud filling area	1,000	50	50,000
T3	From the diversion corner of the road to Gate No. 12_ left side mud filling area, right side project area, salt field	3,378	60	202,680
T4	From the Shaitpara beach to Jetty Sea beach with some mudflats	1,198	100	119,800
T5	From the corner of Rajghat bridge to the mature mangrove patch, east side salt field and west side riverbank with growing mangrove	909	120	109,080
T6	From the Gate 1 to Shaitpara through the embankment	1,208	50	60,400
T7	Hasher char eastern side	3,033	100	303,300

T8	Hasher Char western side	2,795	100	279,500
T9	Kohelia channel	9,436	50	471,800
T10	Moheshkali point, Paddy field, hill, human settlement	1,688	30	50,640
T11	Moheskhali point, Paddyfield, hill, human settlement	1,453	30	43,590
T12	Beside Adinath temple/Mangrove, Hill	1,189	20	23,780
T13	Moheskhali point, bettle leaf garden, hill area, agricultural field, homestead	657	40	26,280
T14	Homestead	2,303	20	46,060
T15	Swankhali lagoon/Salt bed and wild grass vegetation and lagoon in the right side	697	50	34,850
T16	Badarkhali bridge /riverside/salt-bed	2,879	40	115,160
T17	Sonadia Island/mangrove forest	3,809	40	152,360
T18	Sonadia sea beach	3,568	50	178,400
Total		44,119		2,559,580

Source: Study Team

Source: Study Team
Figure 5.2-30　Transect Line of Faunal Survey (around the Project site)

Source: Study Team
Figure 5.2-31　Transect Line of Faunal Survey (around Sonadia Island ECA)

Table 5.2-4　Outline of Bird Survey (e.g., Spoon-billed Sandpiper)

Date and Time		Observation Point	
		Hansher Char (21°38.935'N, 91°50.864'E)	Sonadia Island (21°28.892'N, 91°52.908'E)
27-01-2021	08:00 – 12:00	0	-

	16:00 – 17:00	0	-
28-01-2021	07:00 – 11:00	0	-
	15:00 – 17:00	0	-
30-01-2021	08:00 -12:00	-	0
	14:00 -16:00	-	0
01-02-2021	08:00 -12:00	-	0
	14:00 -17:00	-	0
03-02-2021	09:00 -12:00	0	-
	15:00 -17:00	0	-
04-02-2021	11:00 – 13:00	0	-
	16:00 – 17:00	0	-
05-02-2021	08:00 -11:00	-	0
	14:00 – 16:00	-	0

Source: Study Team

Source: Study Team

Figure 5.2-32 Bird (e.g., Spoon-billed Sandpiper) Observation Points

(3) Survey Results

(a) Flora

1) Dry Season (January – February 2021)

The survey recorded 254 flora species under 80 families across the survey area (see Figure 5.2.1a and Table 5.2.1a of Appedix-5.2 for more detailed information). Species abundance in each family showed variations; 44% species represented by 10 families and 56% represented by 70 families in the study site. The most dominant family is the Poaceae, followed by Euphorbiaceae, Verbenaceae, Asteraceae, Convovulaceae, Mimosacceae, Moraceae, Malvaceeae and Cucurbitaceae. It is noted that IUCN (International Union for Conservation of Nature and Natural Resources) Bangladesh has started the data processing of Red List - related plant assessment in 2021 and is not completed yet. Figure below shows the vegetation map of entire Matarbari-Moheshkhali survey area.

Source: Study Team

Figure 5.2-33 Vegetation of Matarbari - Moheshkhali Survey Area

2) Rainy Season (late June 2021)

The survey recorded a total of 299 flora species under 81 families from the survey area (see Figures 5.2.1b and Table 5.2.1b of Appedix-5.2 for more detailed information). Species abundance in each family showed variations; 48 % species represented by 10 families and 52% represented by 71 families in the study area. The most dominant family is the Fabceae followed by Poaceae, Euphorbiaceae, Malvaceeae, Verbenaceae, Convovulaceae, Lamiaceae, Asteraceae and Acanthaceae.

(b) Fauna (Amphibian)

1) Dry Season (January – February 2021)

Eight (8) species of amphibians in two families were recorded during the study period of which one species was toad and the remaining seven species were frogs (see Table 5.2.2a and Figure 5.2.2a of Appendix-5.2 for more detailed information). Amphibians are ectothermic vertebrates that do not regulate their body temperature through internal physiological processes. Their body temperature varies with the environmental temperature; thus, they need to go hibernation during winter months. As the amphibian survey was conducted in a dry winter month (January-February), it was usual not to get all amphibian species of that habitat.

2) Rainy Season (late June 2021)

A total of Twenty (20) species of amphibians in five (5) families were recorded during the study period of which one species was toad and the remaining nineteen (19) species of frogs (see Table 5.2.2b and Figure 5.2.2b of Appendix-5.2 for more detailed information).

(c) Fauna (Reptile)

1) Dry Season (January – February 2021)

During the study period only six (6) species of reptiles were recorded of which three species were snakes, two species of Lizards and one sea-turtle (see Table 5.2.3a and Figure 5.2.3a of Appendix-5.2 for more detailed information). Reptiles are the first group among vertebrates who are adapted to dry places. Their bodies are covered with scales or scute to conserve moisture. Like amphibians they are also cold-blooded vertebrates and cannot generate their own internal heat. That’s why they bask in the sun during the day and seek shelter at night to avoid cold at night. Since, the survey was conducted in the dry winter (January – February) in a degraded habitat with dense human population, it was very practical not to have many reptiles during the study period.

2) Rainy Season (late June 2021)

Twenty two (22) species of reptiles were recorded from eight reptile families of which eleven (11) species each were snakes, lizards and skinks and one species of turtle (see Table 5.2.3b and Figure 5.2.3b of Appendix-5.2 for more detailed information). Reptile family Colubridae possessed the highest number of species (6 species) followed by Gekkonidae (5 species) and Scincidae (4 species).

(d) Fauna (Birds)

1) Dry Season (January – February 2021)

Hundred twenty (120) species of birds were recorded during the study period of which eighty five (85) species were resident and thirty five (35) species were migratory (see Table 5.2.4a and Figure 5.2.4a of Appendix-5.2 for more detailed information).

2) Rainy Season (late June 2021)

Eighty three (83) species of birds were recorded during the study period of which seventy eight (78) species were resident and five (5) species were migratory (see Table 5.2.4b and Figure 5.2.4b of Appendix-5.2 for more detailed information).

(e) Fauna (Mammals)

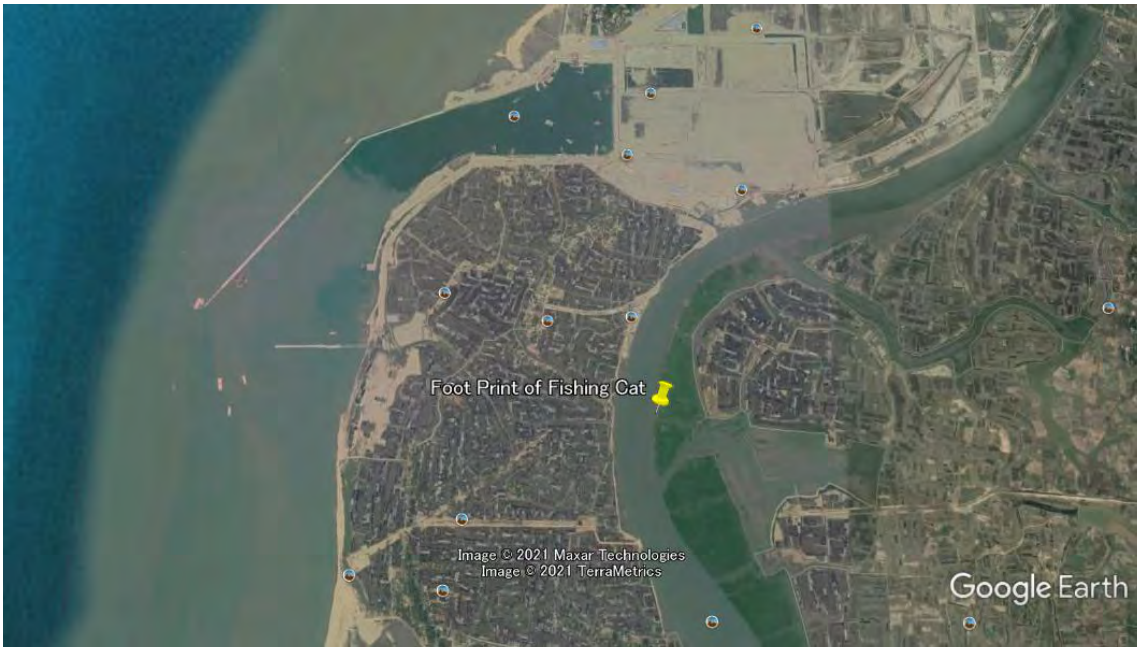
1) Dry Season (January – February 2021)

Nine (9) species of mammals were recorded across the survey area (see Table 5.2.5a and Figure 5.2.5a of Appendix-5.2 for more detailed information). Among the recorded mammals, Lesser Bandicoot Rat (Bandicota bengalensis) was common. Greater Bandicoot Rat (Bandicota indica), Asian House Shrew

(Suncus murinus) were common. Several burrows of Lesser Bandicote Rat were found close to the agricultural fields. House shrew is primarily insectivore but also a scavenger. It was also common at night-time near the households and crop fields. Scat of Golden Jackal was found in the study site. Footprints of Fishing Cat (Prionailurus viverrinus) was found in the mangroves of Kohelia Channel. Fishing Cat is a Nationally Endangered species (EN) (IUCN Bangladesh 2015a) as well as Globally Vulnerable one (VU).

2) Rainy Season (late June 2021)

Sixteen (16) species of mammals were recorded (see Table 5.2.5b and Figure 5.2.5b of Appendix-5.2 for more detailed information) from the survey site during rainy season. Among the recorded mammals, Bandicoot Rats (Bandicota bengalensis and Bandicota indica) were commonly found near the home gardens and freshwater ponds. House mouse was found in the households including in the shops. House shrew was found to scavenge at the night time. Indian Flying Fox (Pteropus giganteus), Lesser Yellow Bat (Scotophilus kuhlii) and Pipistrelle bat (Pipistrellus sp.) were found flying during dusk. Local people confirmed the presence of Large Indian civet (Viverra zibetha), Jungle Cat (Felis chaus), and Fishing Cat (Prionailurus viverrinus) in Moheshkhali hill areas. Foot prints of Fishing Cat was also found in the mangroves of Kohelia Channel (see Figure 5.2-34 and Figure 5.2-35).



Source: Study Team

Figure 5.2-34 Field Observation Point of Footprint of Fishing Cat (EN/VU), part 1

Note: Footprint of Fishing Cat was observed at the eastern side of Moheshkhali Island during the rainy season.
Source: Study Team

Figure 5.2-35 Field Observation Point of Footprint of Fishing Cat (EN/VU), part 2

(f) Fish

1) Dry Season (January – February 2021)

Thirty five (35) fish species, grouped in twenty five (25) families, were documented across the survey area (see Table 5.2.6 of Appendix-5.2 for more detailed information). Fishes in the family Cyprinidae were found to be the most abundant (11%) within this survey, followed by Penaeidae (9%), Mugilidae, Palaemonidae, Oxudencidae, Clupeidae and Sciaenidae (6%). Remaining families constituted 3% each in the total fish population.

2) Rainy Season (July – August 2021)

Thirty-nine (39) fish species were documented within the rainy season survey. In total forty-nine (49) fish species, grouped in thirty three (33) families, were documented within both dry and rainy season surveys across the study area (see Table 5.2.6 of Appendix-5.2 for more detailed information)). Fishes in the family Cyprinidae were found to be the most abundant (18%), followed by Channidae, Engraulidae, Penaeidae, Mugilidae and Sciaenidae (4%). Remaining families constituted 2% each in the total fish population.

(g) Benthic Species, Phytoplankton and Zooplankton

1) Dry Season (January – February 2021)

Fourteen (14) benthic species, twenty eight (28) phytoplankton species and six (6) zooplankton species were recorded across the survey area (see Tables 5.2.7, 5.2.8a - 5.2.9a and Figures 5.2.6 - 5.2.9 of Appendix-5.2 for more detailed information). It is noted that 1st benthic survey, originally, scheduled to be conducted around the January 2021, was postponed to June 2021 (pre-monsoon) due to some technical difficulties. The order of the magnitude of the survey results of both phytoplankton and zooplankton seem to be reasonable, compared with those of environmental monitoring survey results of Phase I (the latest one was conducted in January 2021, see Figures 5.2.7 - 5.2.10) although survey results of the Kohelia Channel are little bit higher than those of the Bay of Bengal.

2) Rainy Season (July -August 2021)

Seventeen (17) benthic species, forty (40) phytoplankton species and fifteen (15) zooplankton species were recorded across the survey area (see Tables 5.2.7, 5.2.8b - 5.2.9b and Figures 5.2.6 - 5.2.9 of Appendix-5.2 for more detailed information).

(h) Findings of Precious and Rare Species 1 (Spoon-billed Sandpiper, Sandpiper, Spotted Greenshank, Great Knot other migratory birds)

1) Dry Season (January – February 2021)

During the survey period, none of the Spoon-billed Sandpiper was recorded. However, two (2) individuals of Spoon-billed Sandpiper were found in Sonadia Island during last week of January 2021 (Personal communication; MMH Khan, Department of Zoology, Jahangirnagar University). The previous Spoon-billed Sandpiper site at the mouth of the Kohelia Channel, mentioned in the Phase-I report of Matarbari Power Plant, does not exist.

2) Rainy Season (late June 2021)

During the survey period, none of the Spoon-billed Sandpiper was recorded. Since, the survey was conducted in non-migratory bird season, it was not expected to have any migratory species. However, several numbers of the migratory birds such as Eurasian Curlew (Numenius arquata), Whimbrel (Numenius phaeopus), Common Redshank (Tringa tetanus), Pacific Golden Plover (Tringa tetanus) did not return to their breeding ground and stayed in Sonadia Island. None of the individuals of Red Knot and Great Knot was found in the survey sites.

(i) Findings of Precious and Rare Species 2 (Sea Turtle)

1) Dry Season (January – February 2021)

Within this survey, two (2) probable sea turtle nesting habitats were identified; one along the coastline of Hansher Char and another was at Sonadia Island. One dead Olive Ridley Turtle, Vulnerable species (VU) in both Bangladesh and international standard (IUCN Bangladesh 2015b), was observed at Sonadia Island.

2) Rainy Season (late June 2021)

None of sea turtle (dead body included) or any sign was detected during the rainy season study period. This is due to the fact that this rainy-season survey was conducted in non-breeding season of sea turtles.

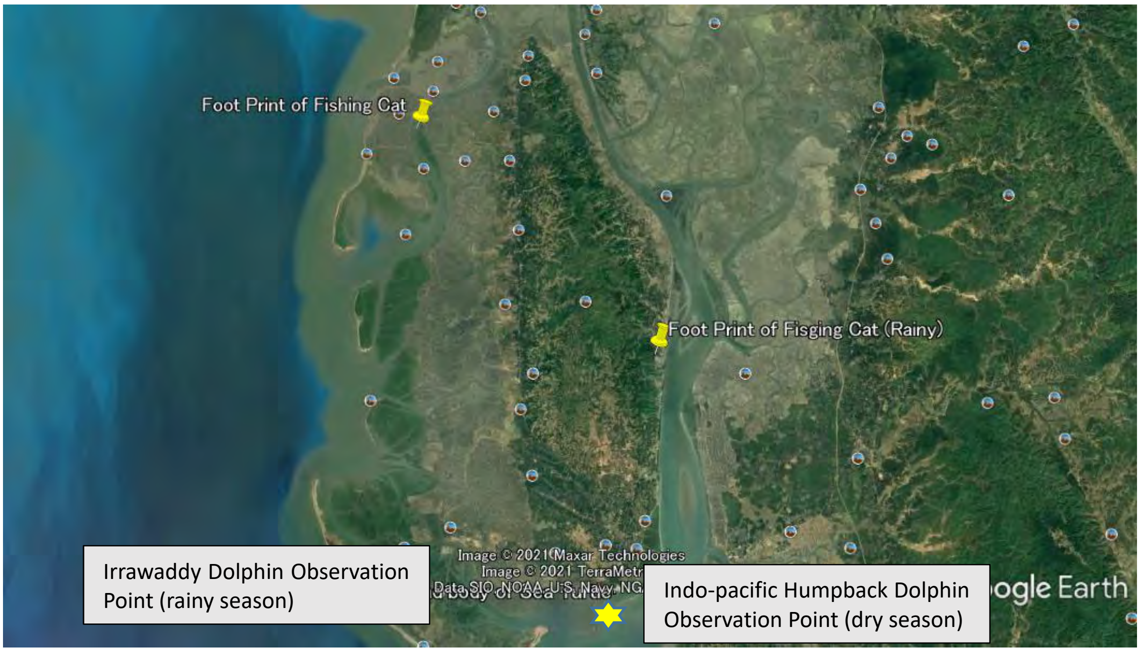
(j) Findings of Precious and Rare Species 3 (Dolphin)

1) Dry Season (January – February 2021)

None of the dolphin was sighted near the project area. Indo-pacific Humpback Dolphin was sighted near Sonadia Island.

2) Rainy Season (late June 2021)

One (1) individual of Irrawaddy Dolphin (Orcaelia brevirostris) was sighted near Sonadia Island (see Figure 5.2-36). None of the dolphin was sighted near the project area.



Source: Study Team

Figure 5.2-36 Field Observation Point of Irrawaddy Dolphin (EN) and Indo-pacific Humpback Dolphin (VU)

(k) Summary of Rare Species, identified within This Study

Table below summarizes the rare species, identified within this flora/fauna survey, conducted within this 3/4 Construction Project.

Table 5.2-5 Summary of Rare Species, identified within This Study

	Species IUCN Conservation Status	Season		Remarks
		Dry	Rainy	
1	Olive Ridley Turtle VU (Bangladesh) VU (International)	○		One dead body was observed at Sonadia ECA. The olive ridley turtle has a circumtropical distribution, living in tropical and warm waters of the Pacific and Indian Oceans.
2	Fishing Cat EN (Bangladesh) VU (International)	○	○	Footprints of fishing cat were observed at several sites within this survey. Also, its occurrence is confirmed through interview with local people. In 2012, West Bengal, India, declared that the fishing cat as the state symbolic animal. In Orrisa State, India, conservation activity is popular by environmental conservation NGOs. "The Fishing Cat Project" was initiated in 2010, and the public awareness and concerns of the fishing cat is gradually raised therein. The fishing cat is broadly but discontinuously distributed in South and Southeast Asia. It is strongly associated with wetlands, inhabiting swamps and marshy areas around oxbow lakes, reed beds, tidal creeks and mangrove forests; it seems less abundant around smaller, fast-moving watercourses. Most records are from lowland areas. The fishing cat is threatened by destruction of wetlands, which are increasingly being polluted and converted for agricultural use and human settlements. The conversion of mangrove forests to commercial aquaculture ponds is a major threat in Andhra Pradesh, where the targeted killing of fishing cats is also prevalent where there is human/animal conflict.

3	Irrawaddy Dolphin NT (Bangladesh) EN (International)		○	Observed at the coastal area of Sonadia Island ECA. An euryhaline species of oceanic dolphin found in discontinuous subpopulations near sea coasts and in estuaries and rivers in parts of the Bay of Bengal and Southeast Asia.

Note: Information of IUCN Conservation Status (International) is referred from https://www.iucnredlist.org/ja/search?taxonomies.
Source: Study Team

5.3 Outline of Social Environment

5.3.1 Socio-Economic Information

(1) Local Administrative Structure

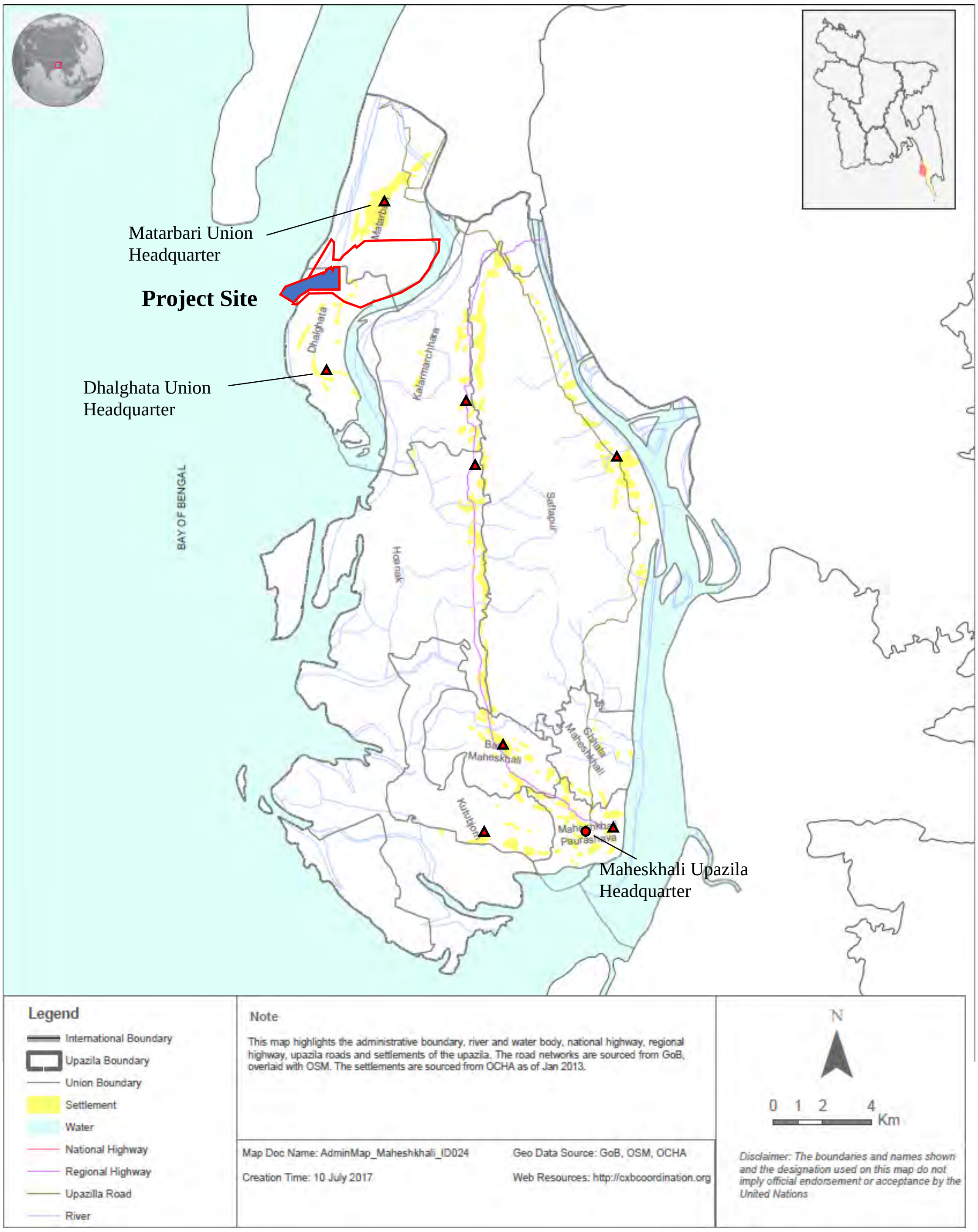
The local top administrative division is called Division, followed by District / Zilla / Zila, Sub-district / Upazilla / Thana), and in rural areas Unions consisting of several Mouza/Village.

Local administration is executed with the Divisional Commissioner in each division, the Deputy Commissioner in each District, and the Upazila Nirbahi Officer (UNO: Upazila Executive Officer) in each Upazila.

Each union has one Union Parishad consisting of 10 to 15 villages, which consists one elected Union Leader (Chairman), nine members from 9 wards (every union is divided into 9 wards), and three female members elected from every three wards. (Awatsu, 2014)[7]

The project implementation area is located in Matarbari Union and Dhalghata Union of Maheskhali Upazila, Chittagong Division, Cox's Bazar District (see Figure 5.3-1).

[7] Takuro Awatsu (2014): Research on basic legislation in Bangladesh. International Cooperation Department, Legal Research Institute (*in Japanese)*



Source: Study Team from Web Resources (http://cxbcoordination.org)

Figure 5.3-1 Administrative areas of Maheskhali Upazila

(2) Socio-economic Environment before the land acquisition for Units 1/2 Project

Based on the 2011 Census [8, 9], the socio-economic indicators of the Matarbari Union and Dhalghata Union on Matarbari Island, where this project site is located, are shown in Table 5.3-1. The 2011 Census results were before the land acquisition and resettlement for the Unit 1/2 project, but the census is conducted every 10 years, the situation after land acquisition and resettlement of residents was estimated based on the number of voters above 18 years in April 2021 provided by the union parishad and the children/adult ratio obtained from interview surveys. The current population are estimated as 50,098 in Matarbari and 15,276 in Dhalghata.

Table 5.3-1 Socio-economic indicators of the Matarbari Union and Dhalghata Union on Matarbari Island before the land acquisition for Units 1/2 Project

Union	Matarbari Union	Dhalghata Union
Area*1	27.04 km^2 (2,704ha)	6.05 km^2 (605ha) *1
Mouza	21	14
Household	8,168	2,250
Population	44,937 (Male: 22,801; Female:22,136)	12,877 (Male: 6,688; Female: 6,189)

*1: The area of Dhalghata Union is shown as 6.05 km^2 based on the National version of the 2011 Census Report, but 494 acres in the Community Version of the 2011.
Source: Study Team from 2011 Census Report (Community Version and National Version Volume 2: Union)

(3) Land Use and the land acquisition for Units 1/2 Project

Figure 5.3-2 shows the land use of around the site within 15km radius before the land acquisition for the Units 1/2 project based on satellite image. Most part of the Matarbari and Dhalghata Union were salt fields and shrimp ponds, which are seasonal land use that is used as salt fields in dry season and as shrimp ponds in the rainy season. In the Matarbari Union, the residential area is relatively cohesive on the north side of the power plant site, but in the Dhalghata Union, it is scattered in small areas on the south side of the power plant and the southeastern part of the union. Agricultural land is rarely found in the Dhalghata Union, and in the Matarbari Union, upland rice farmland such as Aman can be seen on the north side of the power plant.

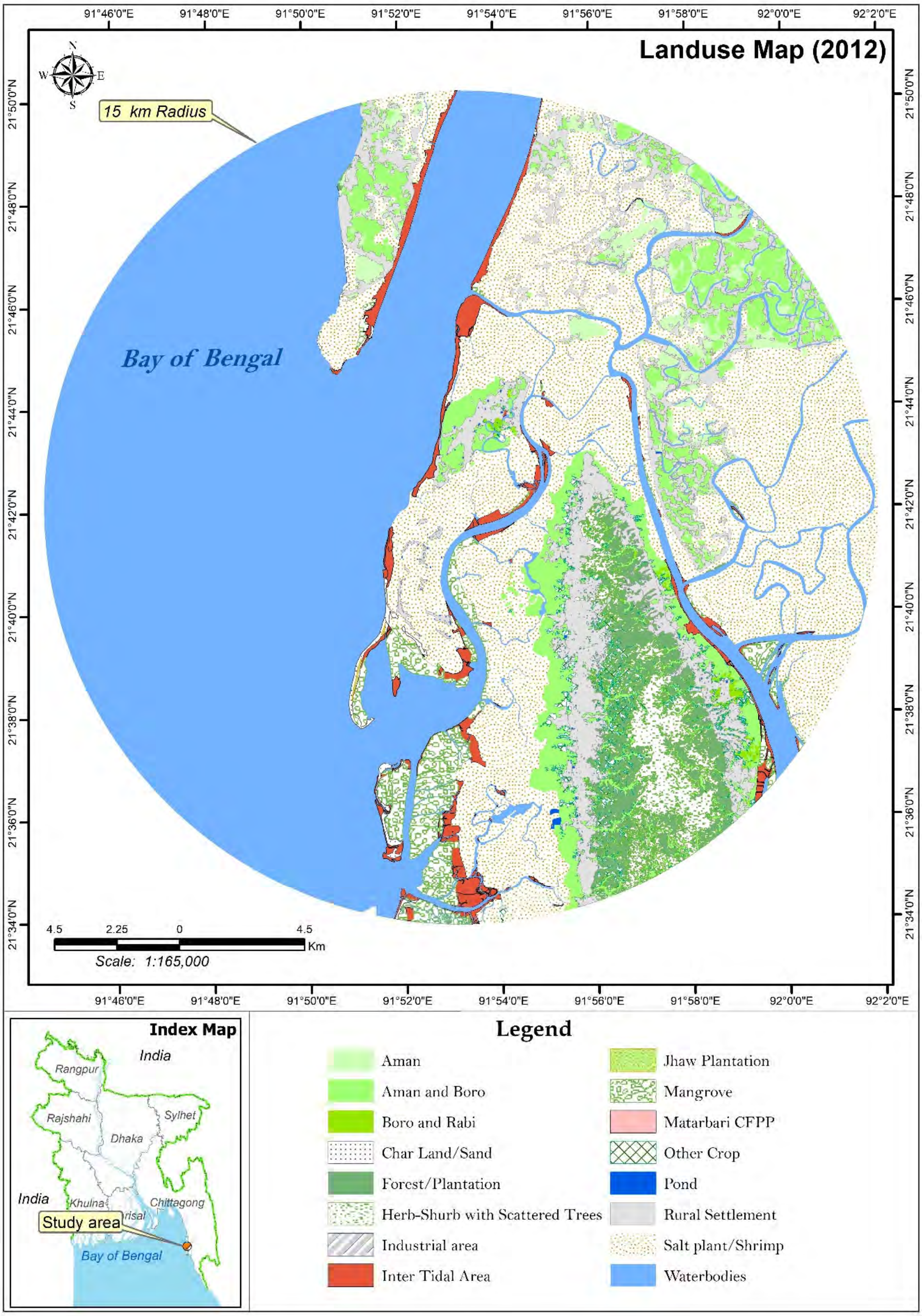
The acquired land area is shown in Table 5.3-2. The acquired land was 651ha, with 383ha in the Matarbari Union accounting for about 60%, about 30% in the Dhalghata Union, and the rest was owned by BWDB. On the Matarbari Union side, 4ha of the acquired land is used for the construction of housing for squatters. Therefore, the project site is 647 ha, and the project area is 709 ha including the sea area of 62 ha which is permitted to use as a port by Ministry of Shipping.

Table 5.3-2 Land acquired in the project area

Category of area	Quantity of land	
	(acre)	(ha)
Matarbari Union subtotal	946	383
Dhalghata Union subtotal	483	195
Matarbari & Dhalghata Union (BWDB Land)	179	72
Total acquired land	1,608	651
Sea area (taken permission from Shipping Ministry)	+153	+62
Resettlement area (Housing facilities for squatters)	-10	-4
Total acquired project area	1,598 (1,608-10)	647 (651-4)
Total project area	1,751	709

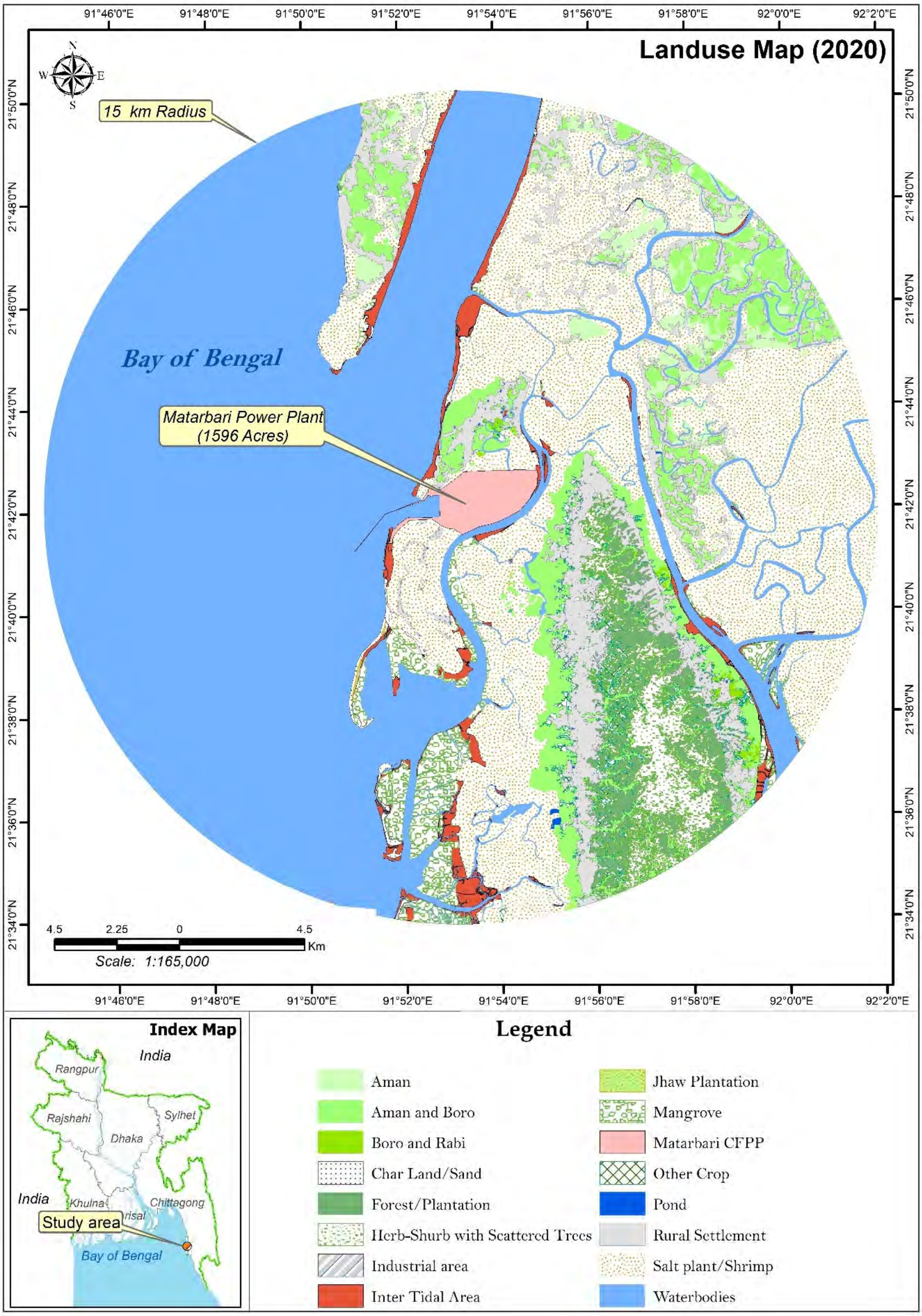
Source: Study Team

8 Bangladesh Bureau of Statistics（2014）：Population & Housing Census-2011, Community Report: Cox's Bazar
9 Bangladesh Bureau of Statistics（2014）：Population & Housing Census-2011, National Report　Volume-2: Union Statistics (2014)



Source: Study Team

Figure 5.3-2 Land Use of around the site within 15km radius before the land acquisition for Units 1/2 Project



Source: Study Team

Figure 5.3-3 Current land use within 15km radius around the project site

(4) Fisheries

According to Year Book of Fisheries Statistics of Bangladesh 2017-2018[10], the national catch of the country is about 1.22 million tons on the inland water, about 2.41 million tons for inland aquaculture, and about 0.65 million tons for the marine fishery (of which about 0.12 million tons are large-scale (‘Industrial’), about 0.53 million tons are small scale (‘Artisanal’). Inland aquaculture and inland water catch in Cox's Bazar District about 25,000 tons, of which shrimp farming is about 23,000 tons. Hilsa (*Clupeidae*) is the main fish species of the marine catch, accounting for about 43% of the national marine catch, and even in Cox's Bazar District, the catch is about 37,000 tons, which exceeds the inland catch. Figure 5.3-4 shows zones of fishing ground within EEZ of Bangladesh. Marine fishing is effectively limited to continental shelf region, i.e. a depth <200 m, but the majority fishing boats and vessels operate in the coastal areas within 40 m depth. The fishing grounds could be divided into five distinct zones (A-E), of which the nearest two zones (A and B) are subject to active fishing and the remaining zones (C, D and E) have the potential to provide new business opportunities. Starting from the coastline, up to a depth of 40 m and distance of 120 km is used by the artisanal fishers. The fishing zones extending up to 80 m depth and 170 km distance are for trawling. All other zones are either lightly fished or unexploited at present. （Hossain et al., 2017)

Figure 5.3-5 shows the fishing ground map of the Bay of Bengal. Close to the planned site is a fishing ground called South Patch, which is a relatively shallow body of water with a depth of 50 m or less that extends 30-80 km south of the project site. The area has a state-owned landing site in downtown Cox's Bazar and a private landing site in the city of Moheshkari Upazila.

Most of the coastal fisheries are carried out by using small powered or unpowered boats with a total length of 6 to 12 m, and by using push nets (rowing nets), gill nets, seine nets, etc.

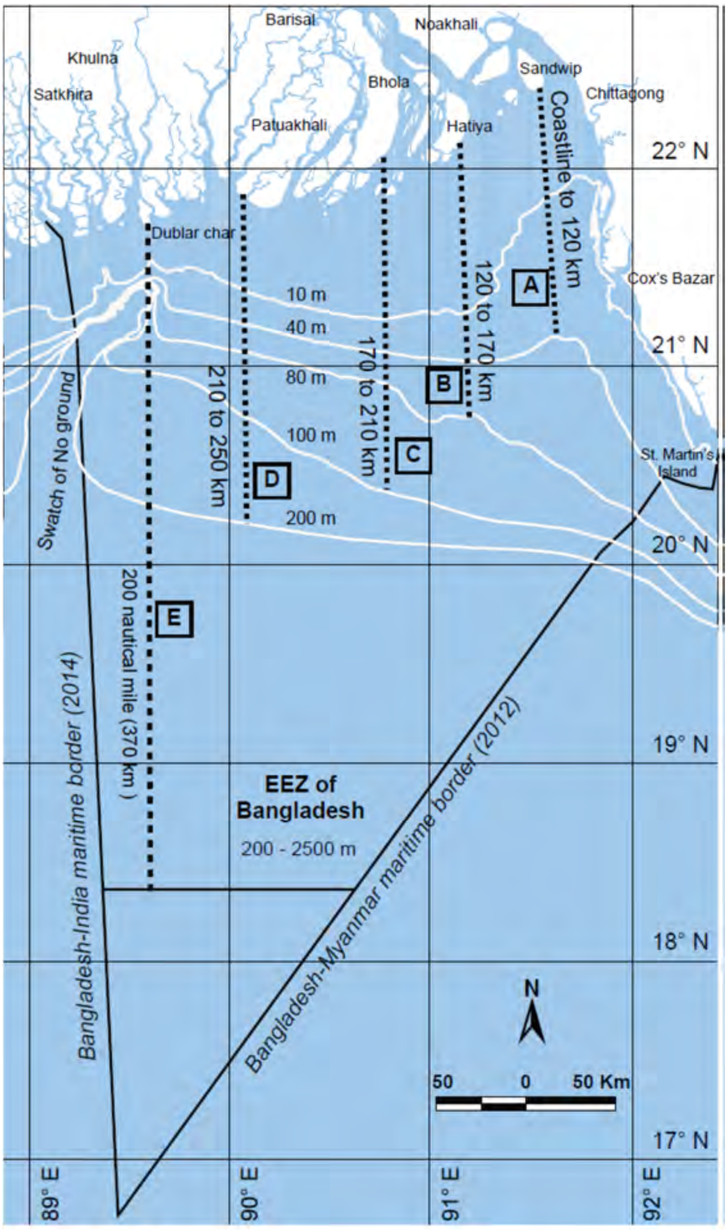
According to the field survey including fish catching, visiting fish markets and interviewing fishermen, the major fishing fields near the project site are limited along the coast and Kohelia channel as shown in Figure 5.3-6. The coastal fishermen use mainly three type gears, marine set bag nets (MSBN), seine net and gill net, in contrast, fishermen of Kohelia channel use seine net, cast net, drag net and long line. The number of fisherman’s households is estimated to be 3,000 to 4,000, and the average monthly income by fishing activities is about 10,000 to 15,000 BDT per household.

(5) Other industries

The major industries in Matarbari Union and Dhalghata Union are salt farming in the dry season (salt pans) and shrimp farming in the rainy season using low-altitude land, and most of them Dhalghata Union is salt pan/shrimp pond as shown in Figure 5.3-3.

Agriculture is mainly upland rice cultivation such as Aman in the relatively high-altitude area on the north side of the power plant in Matarbari Union, and there is almost no agriculture in Dhalghata Union.

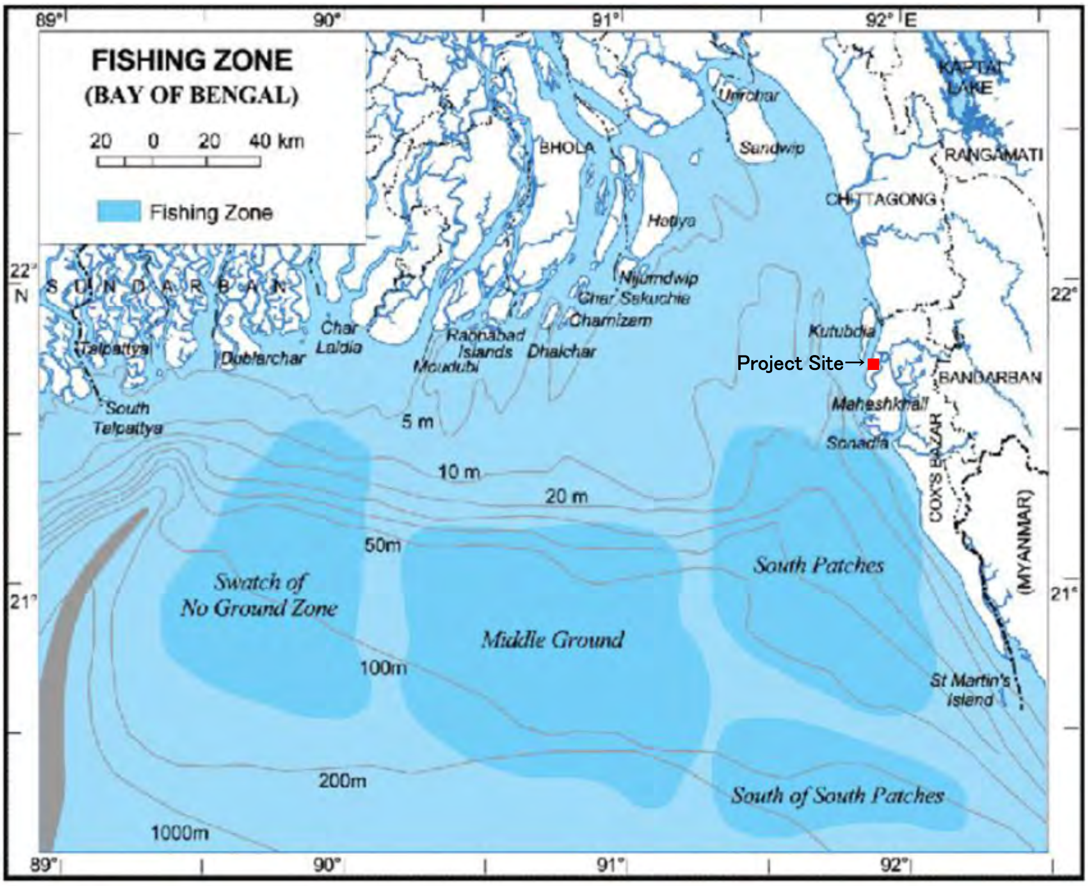
[10] Department of Fisheries Bangladesh, Ministry of Fisheries and Livestock(2018): Year Book of Fisheries Statistics of Bangladesh 2017-2018



Note: A (depth: 0-40 m; distance: coastline to 120 km; artisanal fishing), B (depth: 40-80 m; distance: 120-170 km; trawl fishing), C (depth: 80-100 m; distance: 170-210 km; lightly fished zone), D (depth: 100-200 m; distance: 210-250 km; no fishing), and E (depth: >200 m; distance: >250 km; no fishing).
Source: Hossain et al. (2017)[11]

Figure 5.3-4 Zone of fishing ground within EEZ of Bangladesh

[11] Hossain MS, Chowdhury SR, Sharifuzzaman SM. 2017. Blue EconomicDevelopment in Bangladesh: A policy guide for marine fisheries and aquaculture. Institute of Marine Sciences and Fisheries, University of Chittagong, Bangladesh, 32 pp.



Source: Barual et al. (2014)[12]

Figure 5.3-5 Fishing zones in the Bay of Bengal

Source: Study Team

Figure 5.3-6 Fishing fields near the project site

[12] Suman Barua1, Ehsanul Karim and Nasiruddin Md. Humayun (2014): present status and species composition of commercially important finfish in landed trawl catch From Bangladesh marine waters. international Journal of Pure and Applied Zoology Volume 2, Issue 2, pp: 150-159, 2014

5.3.2 Current status of socio-economic environment

(1) Social environment status based on the monitoring results of Units 1/2 Project

(a) Compensation for the land acquisition of Units 1/2 Project

The number of entitled persons of compensation for the land acquisition of Units 1/2 Project is shown in Table 5.3-3. According to CPGCBL, the number of certified entitled persons is 2,272 persons (as of August 2021), and it is confirmed that the compensation for entitled persons is almost completed.

The process of compensation payment is under the full responsibility of CPGCBL as an executive body under the Land Acquisition and Relocation Action Plan (LARAP) prepared by the non-profit organization, namely BBCS. The land acquisition procedure is led by the Deputy Commissioner Office based on the relevant national laws and regulations, and the work related to further resettlement based on the JICA Guidelines is proceeded in cooperation with the consultant and NGO under the Joint Valuation Team (JVT) consisting of Executive Engineer of CPGCBL, DC Office, Union Chairman, NGO, Property Valuation Advisory Team (PVAT) consisting Sub-divisional Engineer of CPGCBL, DC Office, Secretary of RAP implementation agency and Union Chairman, and Grievance Redness Committee (GRC) consisting of Sub-divisional Engineer, Union Chairman, PAP and Head master of local high school/primary school which have been established based on the gazette of the Ministry of Electricity, Energy and Mineral Resources (MOPERMR).

The reason why it takes time to pay compensation is that it takes time to confirm the eligibility of each applicant. In the feasibility study of Unit 1/2 project, the number of affected landowners was 343 and the number of wage workers was 1,441. After the precise survey conducted by joint venture of Shushilan[13] and BBCS[14], the number of landowners is 821, and the number of wage workers is 1,249 (2,070 in total), and based on the examination by JVT it is 2,272 (as of August 2021). Applications from people are aggregated monthly and the documents are checked, but there are cases where duplicate applications are found, cases where documents are put on hold due to incompleteness, cases where the amount of compensation is dissatisfied and a proceeding is filed. As a result, the number of entitled persons for compensation will increase or decrease, which makes it difficult to determine. With the support of NGOs, CPGCBL continues to inform the affected persons, and in December 2019, January and February 2020, promoted the identification of affected persons and the notification of procedures called the ‘resettlement fair, for implementing appropriate compensation procedures.

In addition, since the whereabouts of 58 wage workers who were initially applied for as affected residents were not contacted, a list of total labors including traceless PAPs was hung during September 2018, and the NGO conducted door to door survey in Matarbari and Dhalghata, and in February 2019 a list of total labors including persons who didn't submit their file was handed over to the chairman/ villagers during February 2019, but no response from PAPs, the chairman/other representatives and villagers. After that, the consultant team went to the address at the time of application, but could not confirm it, and in August 2020, the list of traceless persons was published on the CPGCBL website, and also posted in local and national newspapers. The situation has not changed, although efforts are being made to find the traceless persons.

As a part of the monitoring survey of Units 1/2 project, consulting meetings with people in Matarbari and Dhalghata have been held almost regularly in the villages around the project site. It was held 7 times in 2018, 13 times in 2019, and 6 times in 2020 under COVID-19 situation Although a complaint from informal resident about the delay of compensation was raised in the meeting held in May 2018, no similar complaints were raised during the period until November 2020 with the provision of residents, one-time payment and relocation payment, and any complaint from such PAPs has not been raised. In addition, any complaint of compensation has not been to the GRC. Also, in the focus group discussion of this study, there were opinions that the leasing fee of salt field/ shrimp pond has been rising, but according to the result of the interview survey of this study, the current leasing fee for one season per acer is 35,000 to 50,000 BDT for salt field and

[13] Shushilan: A national non-Government development organization established in 1991 is working almost all over in Bangladesh. As part of their mission to build a Congenial Society for Economic and Socio-Cultural Development we are moving forward to tackle poverty and vulnerability in the country and support to change the lives of most disadvantaged for good, help people to claim their rights to economic opportunities and empowering women to participate in family and social development. (https://shushilan.org/#)

[14] BBCS (Brampton Bangladeshi Community Service): Brampton Bangladeshi Community Service (BBCS) is a non-profit organization for the Bangladeshis & Bengalis in the region. They support all that is good for the community, free from bias and regardless of any differences. (https://www.bbcs-canada.com/about-us/)

25,000 to 30,000 BDT for shrimp pond, which is an increase of 10 to 15 points compared to 2013 before land acquisition for 8 years. This is a smaller increase than the increase at the average consumer price escalation rate which is around 6% (World Bank Database[15]).

Table 5.3-3 The number of entitled persons of compensation for the land acquisition of Units 1/2 Project

Category	Type of loss/ Entitled Persons	Number of Entitled Person
Land Owner	Loss of private land/ Legal owners/ of land Permanent loss of means of livelihoods/ source of income/ Lessor (land owners who rent their land will lose income from land lease contract) Loss of residential/ commercial structures/ Legal titleholders Owners of structures Loss of standing crops at home gardens shrimp, and fish/ Land owners Bargadar Lessee and, Unauthorized occupant of land Loss of limber and fruit bearing trees/ Legal owner. of land Socially recognized owner Non-titled user of land	904
Temporary and Permanent Wage Labor	Permanent loss of means of livelihoods/ source of income/ Permanent, laborers. Temporary minimum wage rates. Laborers, Sharecroppers	962
Lessor/Lose tenants right/Lose occupancy of govt. land	Loss of private land/ Tenants and./ leaseholders Loss of Government land including khas land/ Tenants and lessee Loss of Government land including Khas land/ Occupants without legal tenure, Permanent loss of means of livelihoods/ source of income/ Businessmen, employers of salt farms, shrimp farms and fishing sites, self-employed people Permanent loss of means of livelihoods/ source of income/ Businessmen, employers of salt farms, shrimp farms and fishing sites, self-employed people Temporary loss of livelihood/ source of income during construction/ Business owners, tenants leaseholders, employees, vendors	362
Socially recognized owners/ unauthorized occupants (Squatters)	Loss of residential, commercial structures, Temporary Structure/ Socially recognized owners/ unauthorized occupants Temporary Structure/ Unauthorized Occupants	44
Total		2,272

Source: CPGCBL' information

(b) Compensation for poor people

According to CPGCBL, among the project affected persons (PAPs), squatters were deemed as 'poor people', and CPGCBL provided all of them houses, transfer grants and sifting allowances.

In addition, temporary and permanent wage labors losing their means of livelihood have received one-time assistance for lost income based on monthly income for three years at minimum wage rates.

(c) Livelihood

1) Employment in Units 1/2 construction works

According to CPGCBL, the total number of employees in the Units 1/2 construction project is 4,396,

15 World Bank Database: https://data.worldbank.org/indicator/FP.CPI.TOTL.ZG?locations=BD (accessed on 2 November 2021)

and 1,126 persons of which Matarbari, Dhalghata and Badalkari Unions are employed as technicians and non-skilled workers (As of November 2020).

2) Vocational and Technical Training

The vocational and technical training program conducted is shown in Table 5.3-4. According to CPGCBL, as of July 2021, 339 affected persons have participated in the training program, and it is confirmed that 128 persons have engaged jobs by subsequent follow-up. In order to promote vocational training in future, it is desirable that CPGCBL systematically track such as the effectiveness and requests for improvement.

Table 5.3-4 Vocational and technical training program conducted

(as of July 2021)

Training program	Land owner	Squatters	Businessmen, share cropper, Tenants and leaseholders	Wage labor/ Earner/ Employee	Total (engaged person)
Computer	21	0	0	0	21 (1)
Livestock and Poultry	24	1	0	0	25 (25)
Dress Making	122	9	1	0	132 (80)
Electric & Electronics	48	0	0	7	55 (12)
Fish Cultivation	30	1	0	3	34 (5)
Refrigeration/ Air Conditioning (AC)	6	0	1	5	12
Electricians	34			1	35 (5)
Welding	25				25
Number of the participated persons	310	11	2	16	**339 (128)**

Source: Study Team

(d) People's opinions about Units 1/2 project collected thorough community consultations

Community consultation meetings have been held in several villages in Matarbari union and Dhalghata union in turn as part of monitoring activities quarterly (excluding the locked-down period). According to CPGCBL, major concerns raised from community's people and follow-up taken by CPGCBL are as follows;

1) Opinion on employment

The major issues on employment raised from people were the less number of employment than the expected, employment from out of Matarbari, limited employment in less wage, etc.

CPGCBL has recommended the EPC contractor to employ local people, and implemented vocational training program.

2) Opinion from fishermen

There have been many complaints from fishermen on the construction works, such as disturbance of landing by installation of dredging pipeline, damaging fishing gear by security patrol, restriction of fishing field by designated construction area, threat of safety, etc.

CPGCBL including the EPC contractor and sub-contractors have sincerely responded to the issues one by one.

3) Opinion on infrastructure

Dhalghata people have complained that the community road between Dhalghata and Matarbari was closed by the project site and the tentative detour route is not convenient.

CPGCBL have urged to complete the alternate community road, but it has been delay because of Covid-19, and as the other alternative roots are difficult because of security reason. CPGCBL has provide mini-bus transportation services.

4) Opinion on inundation

During 2017 monsoon, villagers of middle and north Shairar Dail experienced sever suffering due to unexpected inundation of homesteads, village roads, fish culture ponds and agricultural land areas caused by internal flooding.
CPGCBL informed BWDB and UP authority to take necessary action, and BWDB initiated a drainage management project to resolve this problem, and UP chairman dug a channel to drainage out the submerged water under the cooperation of CPGCBL.

(e) Results of other monitoring survey items

The environmental monitoring survey on the social issues have been conducted through observation and interview. The results of the monitoring survey are summarized as follows.

1) Road traffic in Matarbari
Increase of traffic volume and occurrence of traffic jam has been observed on Matarbari road and the road conditions have been worse. CPGCBL has implemented repairment works several times.
2) Children's right
No children working in the project site has been observed.
3) Infectious Diseases such as HIV/AIDS
Awareness program preventing infectious diseases have been conducted properly. And awareness advertisement on Covid-19 is conducted properly.
4) Work environment (including work safety)
Basically, the work environment has been kept safe and healthy, even though there have been sometime observed inadequate management, those were improved.
5) Accidents
There were an injury accident and a fatal accident in the site. The treatments were conducted properly, and safety training program was conducted.

Table 5.3-5 Series of consultation meeting for the monitoring survey of Units 1/2 project

Sl	Date	Target area		Target Classification	Number of Participants
		Union	Village, Ward		
	2018				
1	Mar.25	Dhalghata	Nasir Mohammod Dail and Shaitpara	General inhabitant	44
2	May 29	Matarbari	South Shairar Dail and Mogdail	General inhabitant	42
3	May 30	Matarbari	North Sairar Dail	General inhabitant	31
4	May 30	Dhalghata	Muhorighona and Panir Chara	General inhabitant	50
5	Aug 17	Matarbari	Ward No-4~9	Members of Motsho Shomobay Shomiti	34
6	Aug. 30	Matarbari	Shairar Dail and Mog Dail	Fishermen	33
7	Aug. 30	Dhalghata	Shaitpara and Nasir Mohammod Dail	General inhabitant	44
	2019				
8	Jan. 28	Matarbari	South Mog Dail, Ward No-8	General inhabitant	43
9	Jan. 29	Matarbari	Jele Para, Shairar Dail, Ward No-9	General inhabitant	42
10	Feb 26	Dhalghata	Nasir Mohammod Dail, Ward No-1	General inhabitant	26
11	Apr.17	Matarbari	South Shairar Dail, Ward No-9	General inhabitant	40
12	Apr.18	Dhalghata	Shaitpara, Ward-3	General inhabitant	34
13	May 6	Dhalghata	Mohori Guna and Panir Sara, Ward-2	General inhabitant	33
14	Jun.18	Dhalghata	Mohori Guna and Panir Sara, Bon Jamira Ward-2	General inhabitant	33
15	Jun.19	Matarbari	South Mog Dail, Ward No-8	General inhabitant	51
16	Jul.27	Dhalghata	Shapmarar Dail	Fishermen	19
17	Oct.17	Matarbari	South Shairar Dail, Ward No-9	General inhabitant	33

Sl	Date	Target area		Target Classification	Number of Participants
		Union	Village, Ward		
18	Oct.17	Matarbari	middle Shairar Dail and middle Mog Dail, Ward No-9 and 8	General inhabitant	31
19	Oct.18	Dhalghata	Banjamira, Ward No-3	General inhabitant	25
20	Nov.23	Matarbari	Vula khali, South Shairar Dail, WardNo-9	General inhabitant	45
	2020				
21	Jan.1	Matarbari	South Shairar Dail, Ward No-9	General inhabitant	24
22	Jan.2	Matarbari	South Shairar Dail Ward No-9	General inhabitant	43
23	Jan.2	Dhalghata	Shait Para, Ward No-3	General inhabitant	35
24	Mar.3	Dhalghata	Mohori Guna, Ward No-2	General inhabitant	28
25	Nov.17	Matarbari	South Mog Dail, Ward No-8	General inhabitant	24
26	Nov.18	Dhalghata	Shait Para, Word No-3	General inhabitant	24

Source: Study Team

Table 5.3-6 Summary of opinions in the consultation meeting of Units 1/2 project and response of CPGCBL

SI	Date and Location (M):Matarbari (D):Dhalghata	Summary of people's opinion	Response/Follow-up of CPGCBL
Opinion on Compensation			
1	(1)25th March 2018: Nasir Mohammod Dail and Shaitpara (D) (2)29th May 2018: South Shairar Dail and Mogdail (M) (3)30th May 2018: Muhorighona and Panir Chara(D) (4)30th May 2018: North Sairardail (M)	**Informal residents (squatters)** Delay in compensation disbursement (land acquisition) make project affected people frustrated, especially non-title- PAPs.	Initially, it had been happened but gradually PAPs have got all compensation and especially non-title PAPs like squatters have also got all compensation including housing facilities.
Opinion from Fishermen			
2	(1)25th March 2018: Nasir Mohammod Dail and Shaitpara **(D)** (2)29th May 2018: South Shairar Dail and Mogdail **(M)** (3)30th May 2018: Muhorighona and Panir Chara **(D)** (4)30th May 2018: North Sairardail **(M)**	**Fishermen - Dhalghata** Fishermen community expressed their concern with mentioning that installation of floating pipeline to transport dredging material at site shall create obstacle for fishing boat to access the Dhalghata beach, which is a fish landing spot.	EPC contractor immediately canceled the floating pipeline system to avoid obstacle for fishing boat to access the Dhalghata beach.
3		**Fisherman** Villagers-especially fishermen community complain included misbehavior of river security patrol team members, damage of fishing gear, cutting of fishing gears by sand carriers, etc.	Within two or three days, all fishing gears were returned to fisherman. EPC contractor arranged the training/workshop to river security patrol team members to develop knowledge and behavior.
4	(1)17th August 2018: Motsho Shomobay Shomiti (residents of Ward No-4, 5, 6, 7, 8, & 9 of Matarbari Union **(M)**	Fisherman Fishermen community complain included misbehavior of Coastal and Contractor security patrol team members, damage of fishing gear, cutting of fishing gears by sand carriers, etc.	(Same as above)
5	(2)30th August 2018:)Shairar Dail and Mog Dail Villages	Fisherman Both CPGCBL and EPC contractor should conduct workshop for security	(Same as above)

SI	Date and Location (M):Matarbari (D):Dhalghata	Summary of people's opinion	Response/Follow-up of CPGCBL
	(M) (3)31st August 2018: Shaitpara and Nasir Mohammod Dail **(D)**	staffs to develop their knowledge and behavior. They should know legal rights of villagers, their stake with project and consequence of community unrest situation.	
6		Fishermen Contractors working area at marine and Kohelia channel must be demarcated so that fishermen can catch fish without any fear of damage to the fishing gears. EMU should discuss this issue with responsible subcontractor.	Restricted area of marine and Kohelia channel were not demarcated but supervision was fostered in the restricted area to avoid collision of fishing boat with project vessels.
7		Fisherman's wife Female participants made request to the project authority to stop harassing their household earning member while fishing. Otherwise, employ them in construction project.	CPGCBL and EPC contractor had heard the request, but there was no specific fact to harass household earning members (men including husband) while fishing in out of restricted area.
8	(1)17th April 2019: South Shairar Dail, Ward No-9, **(M)** (2)8th April 2019: Shaitpara, Ward-3 **(D).** (3)6th May 2019: : Mohori Guna and Panir Sara, Ward-2**.(D)**	Fisherman Following complaint of fishermen community of Shaitpara village has noted during meeting: Fishermen do not understand/ agree with the basis/reason (safety risk /threat) considerations by the project authority in declaring fishing restriction along the shallow shoreline, which is located outside the North-west boundary of power plant site. -Suggestion made by fishermen If fishing at shallow foreshore area remains restricted, project authority must pay compensation/day for loss of income during upcoming monsoon season. Suggestion for EMU to take immediate action: -Respective contractor must assess this issue and findings must feedback to the fishermen community.	CPGCBL and EPC contractor had responded this issue, and EPC contractor revoked their restriction in May 2019 and solved the problems.
9	(1)18th June 2019: Mohori Guna and Panir Sara, and Bon Jamira Ward-2 (D). (2)19th June 2019: South Mog Dail, Ward No-8,**(M)** (3)27th July 2019: Fishermen of Shapmarar Dail village of Dhalghata union.**(D)**	Fisherman Fishermen mentioned that day by day, fishing spots at Kohelia channel are shrinking for which their income livelihood is now in threat. Following constrains have been recorded as major concerns of Dhalghata fishermen community: From Rajghat bridge to 10 no. ghat (passenger terminal of CPGCBL), water level remains too low (even during monsoon high tide) to catch fish with fishing gears i.e., Set bag net, Ber jal, Gill net, and Chat jal.	CPGCBL and the responsible contractor had responded this issue. But the project is not liable to degradation of navigation of Kohelia channel which is stated in the consultant observation. Noted that, many factors are liable to silted up the channel bed such as sediment load run off from nearby hill areas, water flow degradation due to establish dam in upstream area in India etc. ***-Consultant observations:*** *Fishermen community of Dhalghata Union perceives that Kohelia channel is being filled due to discharge of excess dredging water.* *But the fact is, hydrological network linked in between Kohelia Channel, Matamuhuri River and Maheshkhali*

SI	Date and Location (M):Matarbari (D):Dhalghata	Summary of people's opinion	Response/Follow-up of CPGCBL
			Channel is also suffering from this problem, which obviously not caused by the project discharges.
10		Fisherman Fishermen complained that due to navigation of large numbers of project vessel's (sand carriers) and anchoring of empty sand carriers from south-west corner of project boundary to Shapmamrar Dail jetty area, they are unable to set their gears at deepen part of the Kohelia channel. Because they are afraid of damage and loss of fishing assets	EPC contractor responded that they would instruct all subcontractors that all vessels should leave the Kohelia channel after such vessels complete their works. They would also instruct their subcontractor to coordinate with the fishermen to establish good faith and trustworthy relationship. According to instructions, all the vessels have been shifted from Shapmamrar Dail jetty area within one month from the time of request raise.
11		Fisherman Fishermen also made complaint for anchoring the floating accommodation and empty material barges (21°39'28.39"N, 91°53'15.67"E) at down-stream of Shapmamrar Dail jetty, which is a potential spot for fishing with estuarine set bag net. They made request to remove the empty material barge 100 meter ahead of floating accommodation barges.	(Same as above)
12	(1)17th November 2020: South Mog Dail, Ward No-8, Matarbari Union (M) (2) 18th November 2020: Shait Para, Ward No-3, Dhalghata Union **(D)**	Fisherman Participants mentioned that during last week of October 2020, project's security patrol team ceased two marine set bag nets but there was no fishing restriction.	Some bodies in the name of security patrol team took the two marine set bag nets but CPGCBL and EPC contractor did not identify the men those who captured the nets. If they can identify the main culprit, of course, they would take action against the stealer/robber.
Opinion on Inundation			
13	(1)25th March 2018: Nasir Mohammod Dail and Shaitpara **(D)** (2)29th May 2018: South Shairar Dail and Mogdail **(M)** (3)30th May 2018: Muhorighona and Panir Chara(D) (4)30th May 2018: North Sairardail （**M**）	Villager Villagers of middle and north Shairar Dail experienced sever suffering due to unexpected inundation of homesteads, village roads, fish culture ponds and agricultural land areas caused by internal flooding. Based on which, villagers have expressed their concern and drawn attention of project authority to take immediate action to resolve the problem.	EPC contractor in association of UP (Union Parishad) authority conducted some measures against the issue. In the month of August 2018, EPC contractor in association of UP (Union Parishad) dug the canal to discharge the stagnant water from the villages. It was happened only one time, May to August 2018. -Project authority is well aware about this issue and already informed Bangladesh Water Development Board (BWDB) & UP(Union Parishad)authority to take necessary action. It can be mentioned that BWDB has initiated a drainage management project to resolve this problem and UP (Union Parishad) chairman has to be dug a channel to drainage out the submerged water. Now (August, '18), the problem is about to solved
14		Villager-Matabari During last monsoon, villagers of middle and north Shairar Dail experienced sever suffering due to unexpected inundation of homesteads, village roads, fish culture ponds and agricultural land areas caused by internal flooding. Based on which, villagers have expressed their concern and drawn attention of project authority to take immediate action to resolve the problem.	
Opinion on Employment			
15	(1)25th March 2018:	The Project Affected household	EPC contractor recruited skill and non-

SI	Date and Location (M):Matarbari (D):Dhalghata	Summary of people's opinion	Response/Follow-up of CPGCBL
	Nasir Mohammod Dail and Shaitpara **(D)** (2)29th May 2018: South Shairar Dail and Mogdail **(M)** (3)30th May 2018: Muhorighona and Panir Chara(D) (4)30th May 2018: North Sairardail (**M**)	members and villagers Very few among the project affected household members and villagers of Dhalghata and Shairar Dail areas have been employed in construction project.	skilled labor through labor supply organization. It is tough to maintain or supply the equal distribution of labor force from village to village. However, CPGCBL requested to EPC contractor to maintain equal labor force distribution among the APs of affected villages.
16	(1)28th January 2019: South Mog Dail, Ward No-8, Matarbari Union **(M)** (2) 29th January 2019: Jele Para, Shairar Dail, Ward No-9 (3) 26th February 2019: Nasir Mohammod Dail, Ward No-1**,(M)** Dhalghata Union**.(D)**	PAP PAP has not been employed in construction work yet.	Here, mentioned as PAP is for 44 squatters' vulnerable people those who are recruited from June'19. They all were engaged as employee of construction contractor.
17	(1)28th January 2019: South Mog Dail, Ward No-8, Matarbari Union **(M)** (2) 29th January 2019: Jele Para, Shairar Dail, Ward No-9, Matarbari Union **(M)** (3) 26th February 2019: Nasir Mohammod Dail, Ward No-1, Dhalghata Union **(D)**	Villagers They mentioned that contractor / subcontractors of power plant construction project are sourcing local unskilled labor from several labor supply organizations/ individual agents and these organizations/ agents are recruiting local villagers as their employee mostly daily wage basis. Large numbers among employed villagers had to pay job-cost or made commitment to fulfill personal interest of individual agent.	CPGCBL requested to EPC contractor to maintain equal labor force distribution among the APs of affected villages. CPGCBL also requested to EPC contractor to control the labor organization/ individual agents for shunning from personal interest of individual agent.
18		Villagers It was also mentioned that few local subcontractors do not employ any local villager. EPC contractor/ subcontractors must recruit local people directly with announcement of vacancy.	As per contract, CPGCBL requested to EPC contractor verbally to control subcontractors for ensuring the employment of local APs in affected villages, but it is not achieved yet.
20		Villagers During recruitment, project affected daily wage labor must employ priority basis then other residents of Shairar Dail and Mog Dail villages.	EPC contractor recruited skill and non-skilled labor through labor supply organization. It is tough to maintain or supply the equal distribution of labor force from village to village. However, CPGCBL requested to STIC to maintain equal labor force distribution among the APs of affected villages including Shairar Dail and Mog Dail villages.
21	(1)17th April 2019: South hairar Dail, Ward No-9, Matarbari Union **(M)** (2)18th April 2019: Shaitpara, Ward-3, Dhalghata Union**.(D)** (3)6th May 2019: Villagers of Mohori	Villagers Meeting discussions reflected following complaint regarding employment of local villagers in construction project: Appointed labor supply organization/ individual agent of contractor/ subcontractors are recruiting local villagers as unskilled labor	EPC contractor recruited skill and non-skilled labor through labor supply organization. It is tough to maintain or supply the equal distribution of labor force from village to village. However, CPGCBL requested to EPC contractor to maintain equal labor force distribution among the APs of affected villages.

SI	Date and Location (M):Matarbari (D):Dhalghata	Summary of people's opinion	Response/Follow-up of CPGCBL
	Guna and Panir Sara, Ward-2, Dhalghata Union.**(D)**	(daily/monthly salary basis) upon fulfill their personal interest.	
22		Villagers Few local subcontractors do not employ any local villager.	
23	(1)17th October 2019: South Shairar Dail, Ward No-9, Matarbari Union **(M)** (2)17th October 2019: Middle Shairar Dail and middle Mog Dail,Ward No-9 and 8, Matarbari Union **(M)** (3)18th October 2019: Banjamira, Ward No-3, Dhalghata Union （**D**） (4)23rd November 2019:)Vula khali, South Shairar Dail, Ward No-9, Matarbari Union **(M)**	Villagers-Matabari Maximum participants of meetings no. 1, 2, & 4 (villagers of Matarbari Union) have been agreed with the employment statistics by raising following question regarding beneficiaries: -Why residents of Badarkhali union are employed in construction project while thousands of projects affected daily wage labor of Shairar Dail and Mog Dail villages are still unemployed. Construction workers, who are being recruited from Matarbari Union never had any stake with the project in lieu of loss of income livelihood. They asked project authority to disclose the list of workers those are employed as villagers of Matarbari Union.	Project authority requested to EPC contractor verbally to disclose the list of workers those who are employed from different village. It will be improved soon.
24		Villagers Contractor/ subcontractors must recruit local people with circulation of notice/announcement of vacancy. During recruitment, project affected daily wage labor residing in Ward no-7, 8 & 9 of Matarbari Union should consider as priority candidates. Daily Wage labor of Banjamira village had not been directly affected due to land acquisition.	EPC contractor recruited skill and non-skilled labor through labor supply organization. It is tough to maintain or supply the equal distribution of labor force from village to village. However, CPGCBL requested to EPC contractor to maintain equal labor force distribution among the APs of affected villages.
25	(1)1st January 2020: South Shairar Dail, Ward No-9, **(M)** (2)2nd January 2020: Villagers of South Shairar Dail, Ward No-9, **(M)** (3)2nd January 2020: Shait Para, Ward No-3, **(D)**	Villagers Why residents of Badarkhali union are employed in construction project while thousands of project's affected daily wage labor of Shairar Dail and Mog Dail villages are still unemployed. -Construction workers, who are being recruited from Matarbari Union never had any stake with the project in lieu of loss of income livelihood. They asked project authority to disclose the list of workers those are employed as villagers of Matarbari Union. -Participants said that contractor must employ the local residents of Ward no. 7, 8, and 9 of Matarbari union priority basis. d) Contractor should make proper announcement of unskilled labor recruitment and should follow acceptable transparent process.	CPGCBL requested to EPC contractor to maintain equal labor force distribution among the APs of affected villages including Shairar Dail and Mog Dail villages. Project authority also requested to EPC contractor to disclose the list of workers those who are employed from different village.
26	3rd March 2020: Mohori Guna, Ward No-2, Dhalghata Union **(D)**	Villagers-Dhalghata Meeting- participants have been repeated following suggestion regarding employment of local	CPGCBL requested to EPC contractor to maintain equal labor force distribution among the APs of affected villages. Project authority also requested to EPC

SI	Date and Location (M):Matarbari (D):Dhalghata	Summary of people's opinion	Response/Follow-up of CPGCBL
		villagers: -Among the local residents of Dhalghata and Matarbari Union's those were lost their income livelihood due to land acquisition by the Coal Power Project must employ priority basis. -Contractor should make proper announcement of unskilled labor recruitment and should follow acceptable transparent process.	contractor to disclose the list of workers those who are employed from different village.
27	(1)17th November 2020: South Mog Dail, Ward No-8, **(M)** (2)18th November 2020: Shait Para, Ward No-3, **(D)**	Villagers-Matabari -Thousands of migrant labors are being employed by the construction contractor whereas we have lost our entire income livelihood due to the land acquisition of Matarbari Coal Power plant Project but unfortunately - in last three years, only two residents of our village were fortunate enough to get job in construction project employ priority basis.	CPGCBL requested to EPC contractor to maintain equal labor force distribution among the APs of affected villages including Mog Dail villages.
28		Villagers A group of young female participants expressed their interest to work in construction project.	CPGCBL requested to EPC contractor verbally to take issue sincerely.
29		Villagers Participants made following urges to the project authorities: With consideration of local economy that shattered by the COVID-19 Pandemic situation, project owner and construction contractor should fill the maximum number of positions of skilled and unskilled labor with local villagers residing at Mog Dail village of Matarbari union. During recruitment, project affected daily wage labor should employ priority basis.	EPC contractor recruited skill and non-skilled labor through labor supply organization. It is tough to maintain or supply the equal distribution of labor force from village to village. However, CPGCBL requested to EPC contractor to maintain equal labor force distribution among the APs of affected villages.
30		Villager Dhalghata Employment Four (4) participants informed that they have been employed by the subcontractor of Port Work construction project in October 2019. But, at the beginning of the COVID-19 pandemic, they have been terminated showing cause of 'health risks of exposure to the COVID-19 infection and community transmission. But they wonder that in last two months, other subcontractors have hired thousands of migrant labors, but they did not hear or received any call for rejoining. They made request for kind action by EPC contractor.	Already deployed the persons in January'21.
31		Villager Respective participants were employed under the 'Income	44 squatters were employed (in January'21) under income restoration program/ given as vulnerable people.

SI	Date and Location (M):Matarbari (D):Dhalghata	Summary of people's opinion	Response/Follow-up of CPGCBL
		restoration program' set for the 'Project Affected (physically displaced) household members.	
Opinion on Infrastructure			
32	(1)25th March 2018: Nasir Mohammod Dail and Shaitpara **(D)** (2)29th May 2018: South Shairar Dail and Mogdail **(M)** (3)30th May 2018: Muhorighona and Panir Chara(D) (4)30th May 2018: North Sairardail （**M**）	Villager Existing Community Road that ran over the construction site have been closed with opening a new diversion road.	Regarding the roads that were closed, the opening of alternative roads, etc., CPGCBL recognized this issue. Existing community road that was ran over the construction site have been closed due to security purposes, but CPGCBL opened the new diversion road for their communication.
33		Villagers-Dhalghata Villagers of Dhalghata union are not happy with this sudden change due to increase of travel time and cost and thus demanded to let them allow to pass over the site till completion of community road fully.	CPGCBL recognized this issue in that time and allowed to pass over the site till completion of community road fully.
34	(1)17th April 2019: South Shairar Dail, Ward No-9, **(M)** (2)8th April 2019: Shaitpara, Ward-3 **(D).** (3)6th May 2019: : Mohori Guna and Panir Sara, Ward-2**.(D)**	Villagers -Dhalghata Employment: -Decision regarding rerouting of alternate community (Dhalghata-Matarbari Union) road over the construction site have been highly appreciated by the meeting participants. villagers urged to keep this route open until construction of union road completes. -On behalf of Mohori Guna, Panir Sara, Bon Jamira, and Shaitpara villagers, Member (Ward Counselor) of Dhalghata Union described their sufferings regarding road communication and community transport facility. Therefore, meeting participants urged for the following improvement of community transport arrangement: -Relocation of 'community transport stand' from 'junction point' to 'Nasir Dail Village', which shall reduce around 400 meters walking distance. -Establishment of a small 'passenger waiting shed (roof-top only)' with a jar of 'drinking water', which shall comfort and protect the female, children, and elderly travelers from summer heat and monsoon rain; and -Installation of a mobile toilet (only urinary) facility.	Relocation of 'community transport stand' from 'junction point' to 'Nasir Dail Village' is somewhat problems due to security purpose. Establishment of passenger waiting shed with drinking water facility, installation of mobile toilet will be established soon.
35	(1)17th October 2019: South Shairar Dail, Ward No-9, Matarbari Union **(M)** (2)17th October 2019: Middle Shairar Dail and middle Mog Dail,Ward No-9 and 8, Matarbari Union **(M)** (3)18th October 2019:	Villagers -Dhalghata Disturbance to the Existing Social Infrastructure (Alternate community road)- Dhalghata Union In Meeting no. 3, following complain, requirement, suggestion, etc. have been noted regarding alternate community road: Principal of Mohori Guna Madrasa informed that teachers who are living	EPC contractor had taken necessary action to resolve respective issue. Priority to go through internal road for teachers/students had been allowed. Noted that, schools all over the Bangladesh are closed from last 15 months for COVID 19 outbreak. Relocation of 'community transport stand' from 'junction point' to 'Nasir Dail

SI	Date and Location (M):Matarbari (D):Dhalghata	Summary of people's opinion	Response/Follow-up of CPGCBL
	Banjamira, Ward No-3, Dhalghata Union (**D**) (4)23rd November 2019:)Vula khali, South Shairar Dail, Ward No-9, Matarbari Union **(M)**	outside of Dhalghata union often struggle/fail to arrive at madrasa in due time. He made request to allow those teachers to use the internal access road (for pedestrian) over the construction site. Participants have been described their sufferings regarding communication through alternate community road and community transport facility. They urged for the following improvement of community transport arrangement (same as mentioned in 7th QEMR): Relocation of 'community transport stand' from 'junction point' to 'Nasir Dail Village', which shall reduce around 400-meter walking distance. Establishment of a small 'passenger waiting shed (roof-top only)' with a jar of 'drinking water' that shall comfort and protect children, female, and elderly travelers from summer heat and monsoon rain; and Installation of a mobile toilet (only urinary) facility.	Village' is somewhat problems due to security purpose. Establishment of passenger waiting shed with drinking water facility, installation of mobile toilet will be established soon.
36	(1)1st January 2020: South Shairar Dail, Ward No-9, **(M)** (2)2nd January 2020: Villagers of South Shairar Dail, Ward No-9, **(M)** (3)2nd January 2020: Shait Para, Ward No-3, **(D)**	Villagers - Dhalghata Disturbance to the existing social Infrastructure (alternate community road)- Dhalghata Union Participants of meeting-3 (villagers of Matarbari Union) have been described their sufferings to travel through the alternate community road that included bad condition of road surface and quality of community transport. They urged to extend the passenger transfer point up to South Beach Camp (former).	CPGCBL instructed to EPC contractor to improve alternate community road and transport. Consequently, EPC contractor conducted improvement of bad condition of road surface and quality of community transport.
37	3rd March 2020: ohori Guna, Ward No-2,**(D)**	Villagers - Dhalghata Disturbance to the existing social Infrastructure (alternate community road/Dhalghata Union road) Participants addressed their frustration regarding project authority's negligence in completing the Dhalghata Union (alternate community) road. They made query and asked for feedback immediately. Query - **When does construction of Dhalghata Union road shall be completed?** They also made complaint regarding quality of community transport and request to improve the community transport service facility by introducing passenger shed, drinking water and sanitary facility.	CPGCBL instructed to EPC contractor to improve alternate community road and transport. Consequently, EPC contractor conducted improvement of road surface and quality of community transportation condition.
38	(1)17th November 2020: South Mog Dail, Ward No-8, **(M)**	Villagers-Dhalghata Alternate community road and community transport	CPGCBL instructed to EPC contractor to improve alternate community road and transport. Consequently, EPC contractor

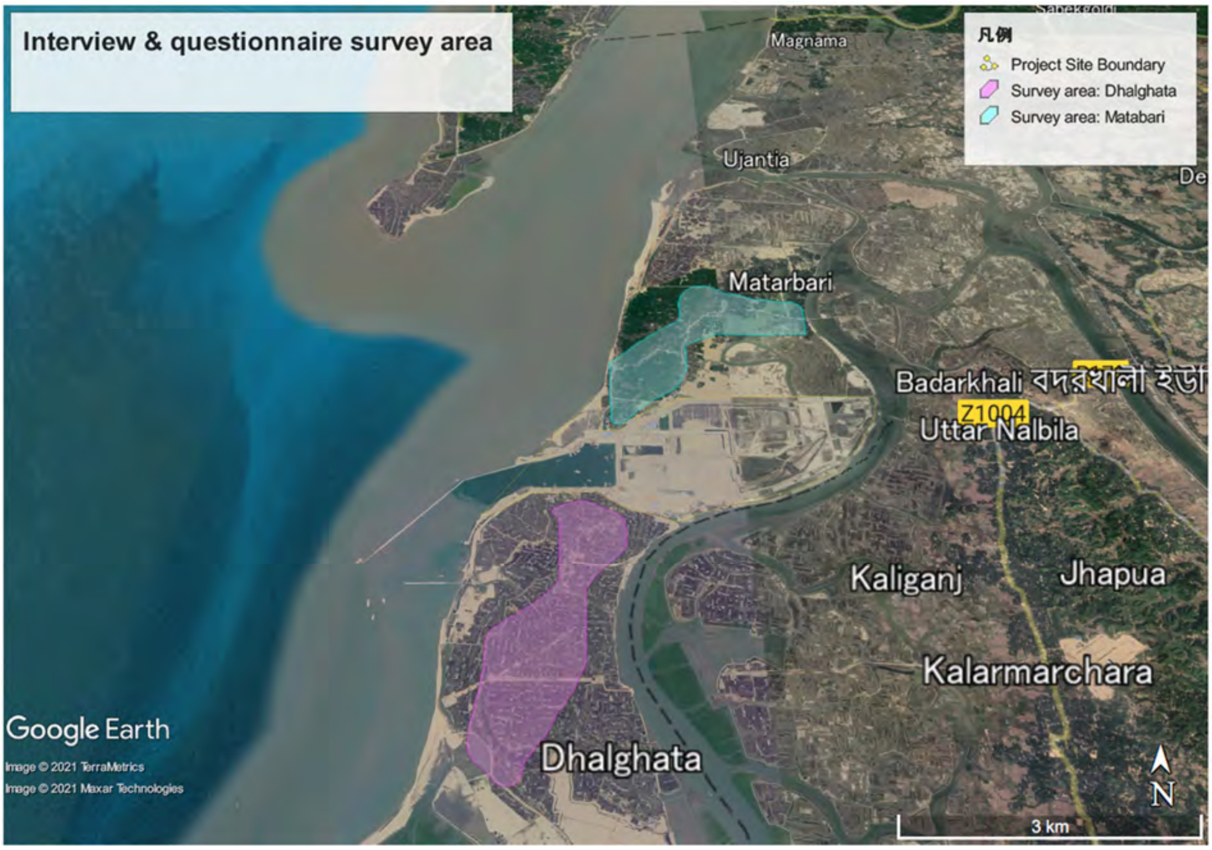
SI	Date and Location (M):Matarbari (D):Dhalghata	Summary of people's opinion	Response/Follow-up of CPGCBL
	(2)18th November 2020: Shait Para, Ward No-3, **(D)**	Meeting Participants have expressed frustration while described their following sufferings and complaints in relation to the road connectivity with Shait Para village, community transport service, non-cooperation during emergency situation, and no access to the project authority to address complaint/concern: Due to the poor condition of community road and inadequate number of community service transport, increase of travel time became intolerable. From September 2020, it takes minimum two and half hours to travel from Shait para to Gate No-2 through alternate community road. For which, students and service holders are often failed to reach their destination in due time. Also due to the noisy and poor quality of vehicle, travel for the elderly and sick persons became very difficult and painful. They made query and asked for feedback on – 'When construction of Dhalghata Union road shall be completed?'	have conducted improvement of bad condition of road surface and quality of community transport.
39		Villagers For avoiding discomfort and time-consuming travel through the alternate community road, project must allow villagers to cross over the construction site on foot/ by transport until construction of alternate road completes. Improvement of community transport (vehicle) quality; and Extension of community transport service route up to the 'Shait Para Village', which shall reduce 1.5km walking distance. Deploy one vehicle to provide transport service to the villagers of Shait Para exclusively.	EPC contractor has to consider about security problems to do extension of community transport service route up to the 'Shait Para Village.
Opinion on Transportation			
40	(1)17th November 2020: South Mog Dail, Ward No-8, **(M)** (2)18th November 2020: Shait Para, Ward No-3, **(D)**	Villagers From September 2020, total seventeen (17) of which, ten (10) units of community transport has been excluded. For this reason, villagers often wait for long hour to avail transport service. In February 2019, EPC contractor has deployed an emergency (for 24x7) transport for particular travelers' i.e., students, elderly villagers, and sick person. This emergency transport service has also been closed from September 2020.	CPGCBL instructed to EPC contractor to increase the community transport and to give emergency support.
Opinion on Conflict			
41	During August 2020	Head-teachers of local madrasa and	Project authority requested to EPC

SI	Date and Location (M):Matarbari (D):Dhalghata	Summary of people's opinion	Response/Follow-up of CPGCBL
	＊Key Informant Interviews (KII)	primary school and 'non formal' meetings with local residents and fishermen communities During interviews interviewees/ participants observed and perceived that local people has warmly welcome all outside worker, but at the same time, they expressed their preference for employing the local people on priority basis.	contractor to disclose the list of workers those who are employed from different village and requested to employ local people on priority basis.
CSR activity			
43	Jun-Aug 2020: Matarbari **(M)** and Dhalghata **(D)** unions		Measures undertaken to encounter COVID-19 In coordination with CPGCBL, consultant and EPC contractor of Unit 1/2 project, COVID-19 safeguard guideline has been developed on 12th August 2020,
44			EPC contractor and its associate subcontractors undertake Corporate Social Responsibility (CSR) activity to build up good relationship with the local community people. From the beginning of the project to till now EPC contractor and its associate subcontractors have been undertaken many of the CSR activities in and outside of the project areas like Matarbari and Dhalghata villages. The undertaken CSR activities included local road repairing, school building repairing, Madrasha building repairing, recreation visit of the school/Madrasha students, community development activities including humanitarian and medical support with assistance to meet and cope with the COVID-19 Pandemic crisis etc.
Opinion on Environmental impact			
45	(1)17th November 2020: South Mog Dail, Ward No-8, **(M)** (2)18th November 2020: Shait Para, Ward No-3, **(D)**	Villagers Following responses from 19 participants have drawn on environment and social impact issues that are recently encountered/ witnessed by them: In last year, they observed dust occurrences only during southerly high windy days. During late night, they heard 'hammering type (pile drive)' noise but occasionally.	December 2020, EPC contractor has been taken initiative to stop dust occurrences and such noise pollution. Now, it is solved the issue.

Source: Study Team

(2) Results of questionnaire and interview survey for the affected persons conducted in 2021

In February 2021, a questionnaire and interview survey was conducted by randomly selecting 267 households out of 870 households including informal residents among the affected persons. The outline of the survey results is shown below, and the outline of survey is shown in Appendix-5.3.



Source: Study Team

Figure 5.3-7 Affected household randomly selected for questionnaire/interview survey (Matarbari)

(a) Income source

Table 5.3-7 shows the aggregated results regarding income sources. Of the 267 households, 66 households had the largest number of services in general, followed by 48 households with day laborers and 46 households with office workers, accounting for about 50% of the total. There were three unemployed households, but not for land acquisition but for personal reasons.

Table 5.3-7 Sources of income of affected household

No	Occupation	Number of Household	%
1	General Service	66	24.7
2	Day Labourer (Salt/Agriculture/Shrimp/Coal Power/ Others)	48	18.0
3	Businessman (other)	46	17.2
4	Foreign Worker	29	10.9
5	Agriculture	23	8.6
6	Teacher	17	6.4
7	Fish Businessman	7	2.6
8	Salt Cultivator	6	2.2
9	Salt business	5	1.9
10	Grocery Shop Owner	5	1.9
11	Master Tailor	4	1.5
12	Tea Stall	3	1.1
13	Unemployed	3	1.1
14	Shrimp business	2	0.7
15	Quack	1	0.4
16	Carpenter	1	0.4
17	Carpenter	1	0.4
Total		267.00	

Source: Study Team

(b) Household income

The monthly household income from 2021 survey is shown in Table 5.3-8. There is almost no difference in the number of households with monthly income of 50,000 BDT or more between 2021 and 2013, but in 2021, the number of households in each category of less than 30,000 BDT will decrease, and the number of households in the 30,000 to 50,000 BDT category will increase. It can be seen that the number is increasing.

Table 5.3-8 Household income (BDT) per month in 2021 and 2013

Monthly income (BDT)	No of Household (2021)	No of Household (2013)
<5,000	-	-
5,000≤ <10,000	-	6
10,000≤ <20,000	43	79
20,000≤ <30,000	85	92
30,000≤ <40,000	88	44
40,000≤ <50,000	28	24
50,000 or more	N/A	22
50,000≤ <60,000	13	N/A
60,000≤ <80,000	9	N/A
80,000 or more	1	N/A
(Total)	267	267

Source: Study Team

(c) House structure

A comparison of the 2021 housing structure of 267 affected residents and the housing structure at the time of the 2011 census is shown below.

Table 5.3-9 A comparison of house structure in 2021 and 2011

No.	Type of house structure	2021 (Study Team)		2011 Census	
		Household	%	Matarbari	Dhalghata
1	Pucca	61	22.8	4.4	0.5
2	Semi-Pucca	85	31.8	4.8	0.8
3	Kacha	121	45.3	71.7	16.0
4	Jhupro	0	0	19.1	82.7

Note. Pucca: Permanent house with a useful life of over 25 years. Made of brick walls and concrete roof.
Semi-Pucca: Semi-permanent house with some walls made of brick, floors cemented, and roofs made of galvanized iron.
Kacha: Temporary house built from mud, bamboo, grass, reeds, stones, thatched roofs, straw, leaves, unburned bricks, crop residues, etc., readily available from local natural environments. Sometimes the roof is made of galvanized iron. It can be modified to make it a more permanent structure.
Jhupri: A small, shabby shelter or hut that is temporarily used as a residence. Made from jute sticks, jute sack, leaves etc.
Source: Study Team

(d) Water

Table 5.3-10 shows the current status of 267 affected households and the status at the time of the 2011 census regarding the source of clean water. The main source of water in this area is tube wells.

Table 5.3-10 A comparison of water source in 2021 and 2011

No.	Water source	2021 (Study Team)		2011 Census	
		Household	%	Matarbari	Dhalghata
1	Tap water	0	0	0.2	0.5
2	Tube well	267	100	95.0	92.3
3	Pond	0	0	-	-
4	Others	0	0	4.8	7.2

Source: Study Team

(e) Sanitation facilities

Table 5.3-11 shows the current status of toilet structure of 267 affected households and the results of a survey conducted by the JICA Survey Team in 2013. At present, the number of Pucca (permanent) toilets has increased compared to 2013, but about 30% of Kacha (temporary) toilets are seen, which is the same level as 2013.

Table 5.3-11 A comparison of toilet structure in 2021 and 2013

No.	Toilet structure	2021 (Study Team)		2013 (JICA)
		Household	%	%
1	Pucca (Permanent) toilet	168	62.9	10.2
2	Slab toilet	20	7.5	51.5
3	Slab/ Kacha toilet	0	0	0.3
4	Kacha (temporary) toilet	79	29.6	37.7
5	(none)	0	0	0.3
Total			267	100

Source: Study Team

(f) Electrification

Table 5.3-12 shows the status of electrification in a comparison of the current status of 267 affected households and the results of the 2011 census. The electrification rate of the affected residents is 100%.

Table 5.3-12 A comparison of electrification in 2021 and 2011

No.	Electrification	2021 (Study Team)		2011 Census	
		Household	%	Matarbari	Dhalghata
1	Electrification	267	100	27.9	18.4
2	Non-electrification	0	0	72.1	81.6

Source: Study Team

(3) Other baseline information collected in 2021

(a) Ethnic minorities and indigenous peoples

With reference to the 2011 National Census results and the Units 1/2 Project Preparatory Survey Report (2013), it was confirmed that there are no minority ethnic groups or indigenous peoples in and around the project implementation area in the survey results at that time. In addition, in the field survey in February 2021, it was confirmed that there are still no ethnic minorities and indigenous people living in the area.

(b) Cultural heritage

There are no nationally or regionally designated cultural heritage sites within a 15km radius of this survey, and no cultural heritage sites in communities, villages or unions were identified during the interviews with residents on Matarbari Island.

(c) Children’s right

During the questionnaires survey of 267 PAP's, it is seen that all of them have intention to send their children in either school (Bengali Education system - National curriculum) or madrasah (Arabic, National curriculum). FGD of Woman with children on educational issues, every woman is positive and tries to send their children in the school / madrasah. With a few exceptions, the woman told that there could be a probability to drop-out their children from the school due to economic stress of their family.

(d) Accident

The CNG and auto rickshaw driver complains about the present road condition of Matarbari. Sometimes, accidents happen due to the bad conditions of the road.

During an interview with the boat driver, they mentioned that, in normal movement conditions, no accidents happen in the sea or Kohelia channel. But lots of accidents happen in bad weather conditions. The boat driver mentioned that there was a Ghat/ boat landing station in the Matarbari area which was located inside the coal power project which is no longer in use. The fishing-related people (boat driver, fisherman, boat) desire to build a new Ghat/ boat landing station in Matarbari/Dhalghata the area which will save them from accidents in bad weather conditions. Noted that there is no place for parking/landing boats in bad weather conditions.

(4) Socio-economic issues to be specified in the project site and its vicinity

With the implementation of Units 1/2 project, some issues have been raised by the residents around the project area through the consultation meetings of the monitoring survey of Units 1/2 project, the stakeholder meetings and focus group discussions (FGDs) in this study. Information collection and some natural condition baseline surveys were conducted in this study.

(a) Sedimentation in Kohelia Channel

It was pointed out in the stakeholder meeting of this study that there are problems of fishing and boat navigations because of sedimentation/shallowing in Kohelia Channel, and there were opinions that the catch was decreasing in the FGD of the fishermen's group. On the other hand, in Kohelia Channel, there was no sediment discharge or topographical modification work due to the construction of the power plant, and the causal relationship with the work by the Units 1/2 project is unknown. In addition, as shown in 5.1.5 (1) of this chapter, there is almost no seasonal variation from the results of bathymetry surveys during the dry season, normal season, and rainy season in Kohelia Channel.

(b) Inundation

Regarding the inundation on the north side of project site, it is a problem that was strongly desired to be solved through the consultation meetings of the monitoring survey for Units 1/2 project, the stakeholder meeting and FGDs in this study, but it should be noted that it has the following two aspects.

1) Inundation occurring regularly in rainy season every year

Residents are aware that inundation has occurred in this area during the monsoon season (June-September), that is, rainy season, even before the start of Units 1/2 project. A detailed topographical survey of the area was carried out in this study, and a low range of ground height was confirmed (see "5.1.7. Geographical conditions"). Inland waters in rainy season depend on the water level difference from the outside of the bank, that is, Kohelia Channel side, and the inland waters that cannot be completely discharged from low ground height areas. Judging from the results of water level observations in the Rangakhari Channel inside the bank, the Kohelia Cannel outside the bank, and the sea area, the Rangakhari Channel is not affected by the tide level at all, and the water level is a little less than 1 m higher in rainy season than in dry season. It can be regarded as annual phenomenon, but it has not yet been determined that the implementation of Units 1/2 project or the closure of Rangakhali Channel prolonged the period, and the inundation depth was increased. Before the implementation of Units 1/2 project, Rangakhali Channel was directly connected to Kohelia Channel without a gate, and when the water level of Kohelia Channel was higher than the inland water, floods occurred due to backflow from Kohelia Channel, so there was a request from the local community. There is a history that the closure of Rangakhali Channel was due to the construction of the retaining wall on the north side of the project site. However, there was a concern that this would reduce the ability to drain inland waters, so in 2018, with the support of CPGCBL, a waterway and sluice gate were constructed before Kohelia Channel to drain inland waters.

2) Storm surge during the 2017 monsoon period

The heavy inundation in the 2017 monsoon period, which was raised in the consultation meeting, was caused by storm surge caused by the cyclone in the view of BWDB confirmed in this study, and has a different character from the inundation occurring in rainy season every year.

(c) Operation status of salt farm and shrimp farming

The actual situation of the change in the period and degree of inundation before and after the start of Units 1/2 project is still unknown, but there are opinions that the leasing fee for salt farms / shrimp farming ponds is rising in both Matarbari and Dhalghata areas. There is a possibility that changes in the supply and demand balance of leasing due to a decrease in land area and changes in the economic situation in the region such as rising prices have occurred. In addition, some salt farm and shrimp farmers are feeling unfairness between compensated persons due to the land acquisition for Units 1/2 project, and there is also anxiety about their lives due to the difficulty of changing jobs for the elderly.

(5) CSR activities by CPGCBL

CPGCBL is implementing the following CSR activities along with livelihood restoration measures such as diversification of employment.

- 100% of rural electrification in Matarbari and Dhalghata Union
- Local structural development (road, culvert for improved drainage etc.)
- Educational development through establishment of school, college (also can be used as cyclone center)
- Development of health facility
- Increase new business scope for the local people
- Increase property value (house rent etc.)
- SFD fund (3 paisa/per unit of electricity) for local development

(6) Relevant future plan

CPGCBL has been developing an infrastructure development plan, namely ‘Township Plan’ which will be implemented in the east side of the project site where will be the connecting point of the access road.

While the details are under considerations, the conceptual perspective drawing is as shown in Figure 5.3-8, and the population is supposed to be about five thousand.

Source: CPGCBL

Figure 5.3-8 Township Plan at the eastern side of the project site

Chapter 6 Power System Analysis

6.1 Outline

In terms of a connection of units 3/4 at Matarbari PP with the grid, the Study Team conducted essential system analyses, i.e., power flow, fault current and stability ones.

6.1.1 Power flow analyses

In line with “ELECTRICITY GRID CODE 2019” (hereinafter called "the GRID CODE"), Power flow analyses were conducted under not only a normal or N-0 condition but also N-1 conditions, e.g. a single transmission line circuit outage. From a power flow analysis result, a 400kV transmission line between Matarbari PP and Banshkhali PP to connect Matarbari PP with the grid had enough capacity under one circuit outage of the same transmission line section. Although an outage of one 400kV transmission line circuit between Banshkhali PP and Madunaghat SS causes overloading of the remaining another circuit of the same 400kV transmission line section, tripping units of Banshkhali PP can solve the transmission line overloading and the whole power system can maintain synchronous operation. Thus, judging from the results of power flow analyses based on the GRID CODE, there is no problem for power evacuation from Matarbari PP.

6.1.2 Fault current analysis

From a fault current analysis result, fault current at 400kV, 230kV and 132kV buses was less than the maximum fault current levels of corresponding voltage. Thus, there is no problem for the fault current regarding the connection of Matarbari PP phase 2 generators with the grid.

6.1.3 Stability analysis

According to PGCB, fault clearance time for 400kV transmission line is 0.08 second in the stability analysis. From Stability analysis results under this fault clearance condition, a fault at some location on the 400kV transmission line between Matarbari PP and Meghnaghat SS made the system unstable.

However, a differential relay scheme has been already adopted as a protection relay for the said 400kV transmission line and the differential relay scheme can technically clear the fault in 0.07 second. Considering the application of this relay, the system was stable on all study cases with 0.07 second fault clearance time. Thus, judging from the results of stability analyses based on the GRID CODE, there is no problem for power evacuation from Matarbari PP.

6.1.4 Conclusion

A connection of units 3/4 at Matarbari PP with the grid is feasible.

6.2 Power flow analysis

6.2.1 Conditions for power flow analysis

(1) Demand forecast

In line with other studies such as a power demand-supply balance forecast, the Survey Team assumed the Low Case demand forecast without ED&C in the Revisiting PSMP 2016 for system analyses.

The Survey Team conducted power flow analyses under not only a peak demand condition but also an off-peak demand one. According to a load curve of the forecasted off-peak day in 2030, a ratio of the off-peak to the peak is 0.37.

(2) COD of Units 3/4

According to the generation plan provided by BPDB, the Units 3/4 is expected to start the operation in 2030. Thus, the Survey Team conducted system analyses under conditions regarding demand and expansion of generation and transmission facilities in 2030.

(3) Generator expansion and retirement plan

Expansion and retirement plans of power plants on March 23, 2021 and a formal announcement from the government on Jun 24, 2021 regarding scraping of coal fired power plant plans are shown in Chapter 3. Power system analyses were conducted on the basis of those generator expansion and retirement plans. The table below shows generation expansion plans in Matarbari, Banshkhali and Moheshkhali areas.

Table 6.2-1 Generation expansion plans in Matarbari, Banshkhali and Moheshkhali areas

Place of power plant	Power evacuation	Note
Matarbari 1,200MW USCPP (Phase 1: Units 1/2)	400kV transmission line to Madunaghat S/S	
Matarbari 1,200MW USCPP (Phase 2: Units 3/4)	Ditto	
Banshkhali 2 x 612MW Coal Fired Power Project (S.Alam Group)	Ditto	COD: December 2022
Moheshkhali 1,200MW USCPP (ECA)	765kV designed transmission line operated at 400kV to Madunaghat S/S	
Moheshkhali 1,200MW USCPP (Phase-2) (Bay of Bengal)	Ditto	
Matarbari 700MW USCPP (JV of Symcorp & CPGCBL) (Phase-1)		Scrapped.

Source: Study Team

(4) Output power from generators

A model with fixed terminal voltage and active power output was used to calculate power flow. In order to balance supply and demand in the power flow analysis, the Study Team assumed the output power of generators as shown below for the peak demand and off-peak demand conditions respectively from the perspective of severer conditions for loading condition of transmission facilities.

Table 6.2-2 Output power from generators for peak demand condition

Place of power plant	Output power
Matarbari 1,200 MW USCPP (Phase 1 and 2)	Rated gross power, station service power is modeled as a load (station service power ratio: 6.5%)
Chittagong Division	Rated net power
Nuclear power plant	Rated net power
USC power plant	Rated net power
Other Divisions	Reduced output power to balance supply and demand

Source: Study Team

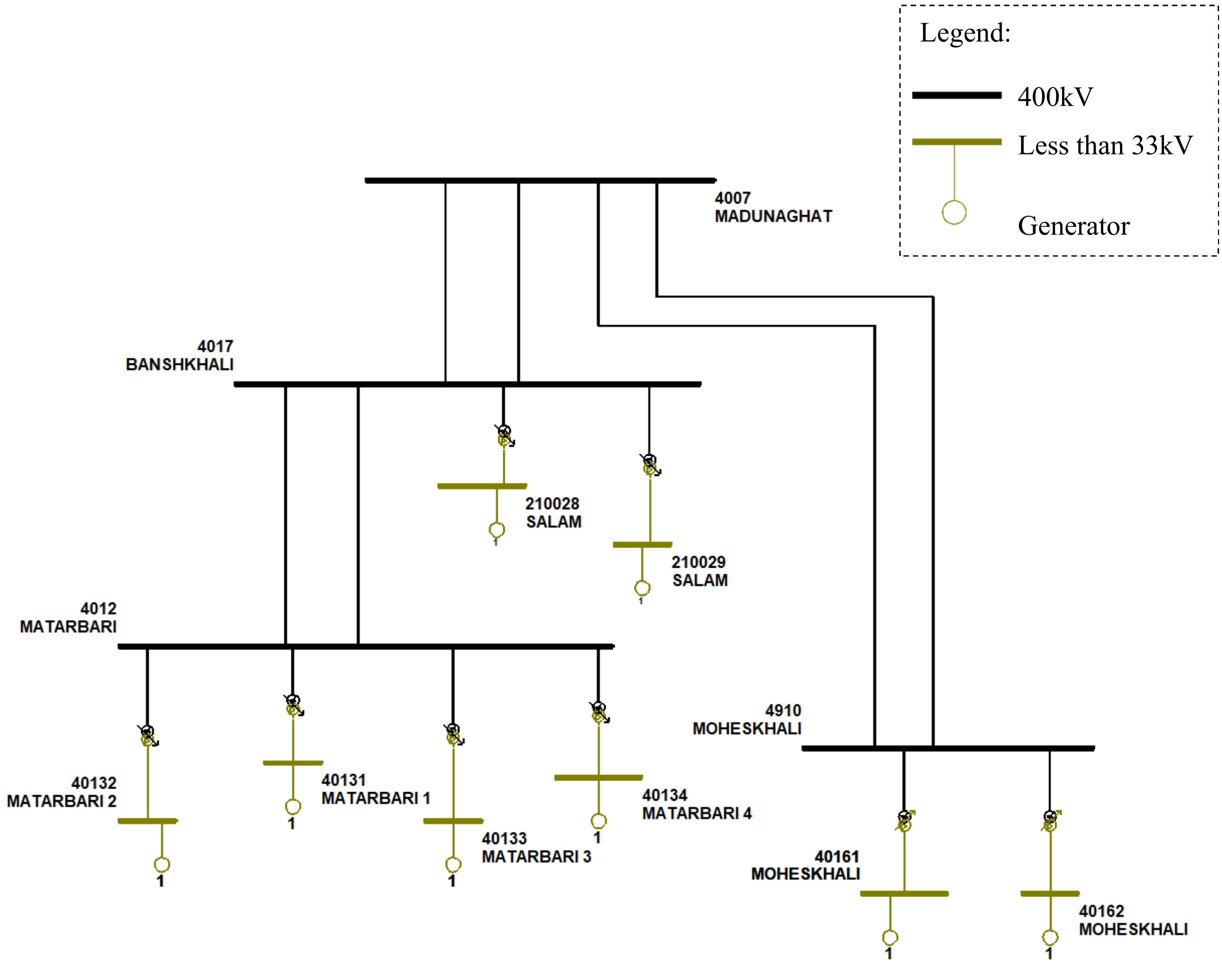
Table 6.2-3 Output power from generators for off-peak demand condition

Place of power plant	Output power
Matarbari 1,200 MW USCPP (Phase 1 and 2)	80% of rated gross power, station service power is same as the one for the peak condition
Chittagong Division	80% of rated net power
Nuclear power plant	Rated net power
Other Divisions	Reduced output power to balance supply and demand

Source: Study Team

(5) System configurations around Matarbari area

The figure below shows the basic system configurations of 2030 including Matarbari area.



Source: Study Team

Figure 6.2-1 Basic system configurations of 2030

(6) Voltage criteria

According to ELECTRICITY GRID CODE 2019, voltage limits on the planning stage are stipulated as below.

Table 6.2-4 Voltage limits

	Voltage limit
Normal Operating Condition	400kV: ±5%
	230kV: ±6%
	132kV: ±6%
Emergency Condition	400kV: ±10%
	230kV: +10/–15%
	230kV: +10/–15%

Source: ELECTRICITY GRID CODE 2019

The Study Team assumed that sufficient shunt capacitor banks are connected at 132kV buses of substations which voltage is lower than the voltage limit for proper power flow analyses.

(7) 400kV transmission line capacity

Power flow through a transmission line was compared with its current loading capacity in MVA in the power flow analysis.

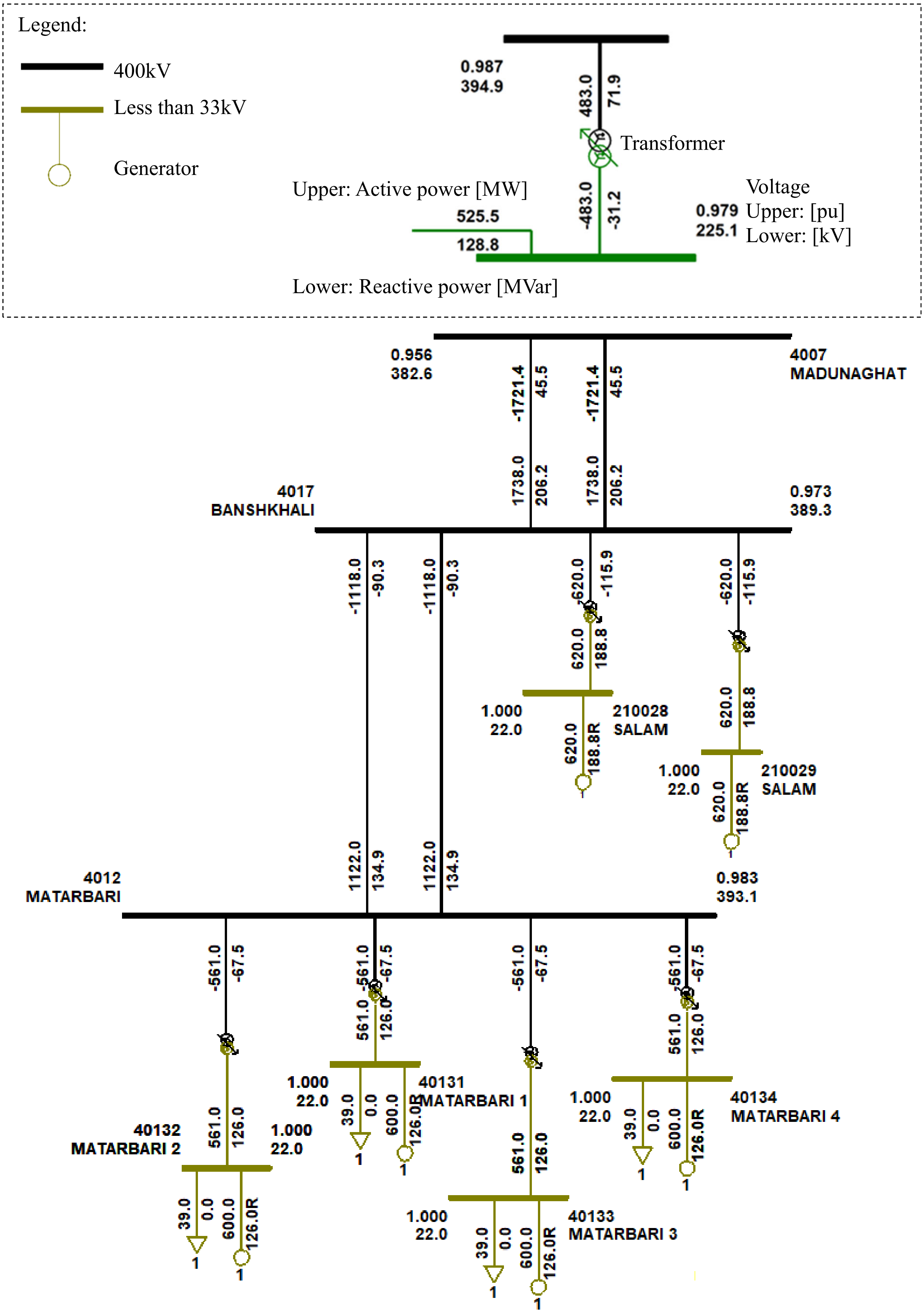
400kV transmission line capacity in MVA can be calculated as below.

$$\sqrt{3} \times 400kV \times 869A \times 4bundle = 2{,}408MVA$$

6.2.2 Result of power flow analysis

(1) Power flow analysis under the normal condition

The figure below shows the power flow calculation result regarding power evacuation from Matarbari PP under a normal or N-0 condition.



Source: Study Team

Figure 6.2-2 Power flow calculation result under an N-0 condition.

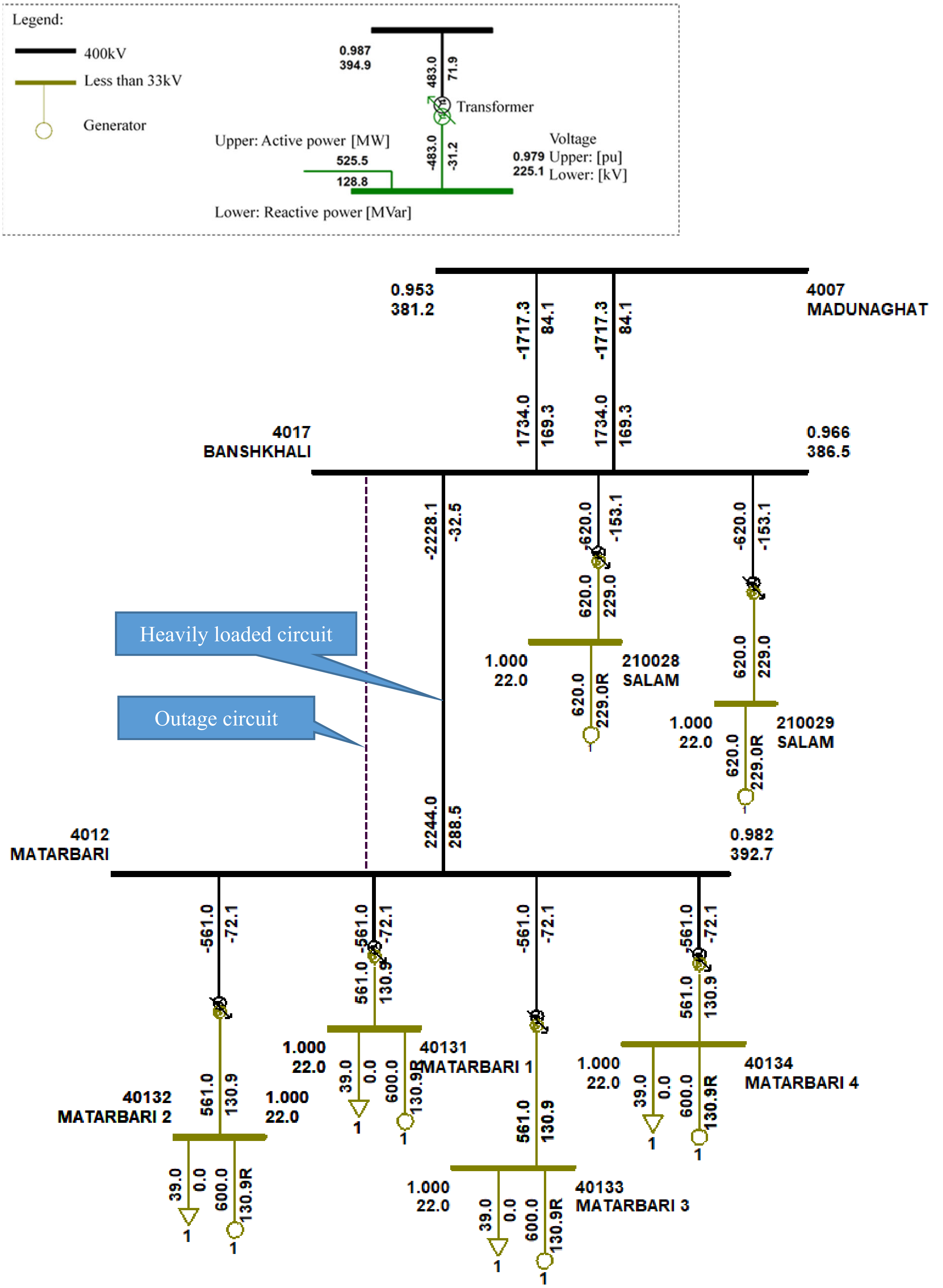
Since current loading capacity of the 400kV transmission line between Matarbari PP and Madunaghat SS (Substation) is 2,408MVA, there is no loading violation on the 400kV transmission line

(2) Power flow analysis under contingency conditions

Power flow calculations were also performed under contingency or N-1 conditions.

(a) Outage of a circuit between Matarbari PP and Banshkhali PP

The figure below shows the power flow calculation result under an N-1 condition, an outage of a circuit between Matarbari PP and Banshkhali PP.



Source: Study Team

Figure 6.2-3 Power flow calculation result under an N-1 condition, an outage of a circuit between Matarbari PP and Banshkhali PP

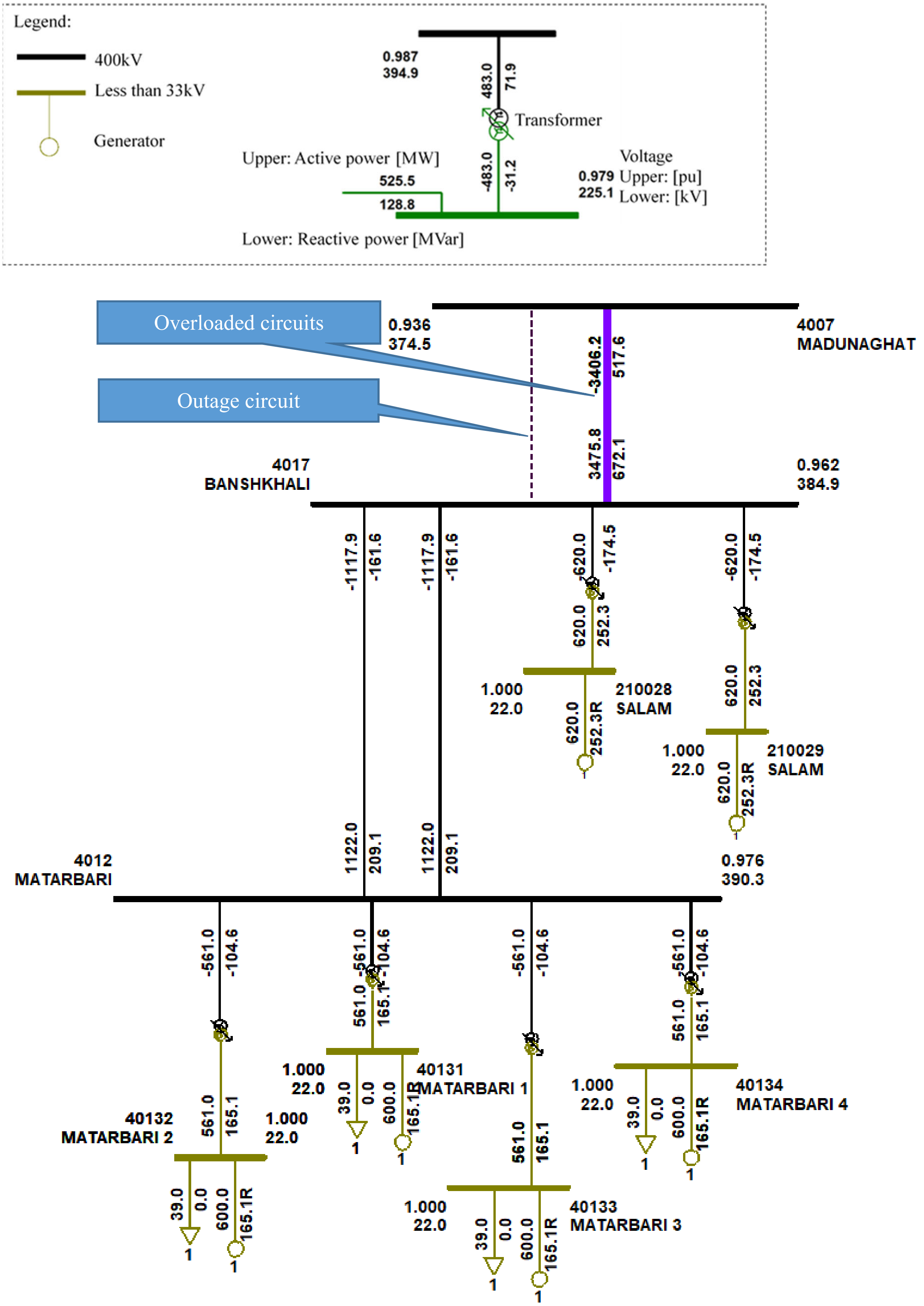
Loading ratio of the remaining another transmission line circuit between Matarbari PP and Matarbari (N) SS can be calculated as below.

$$\frac{\sqrt{2244^2 + 288.5^2}}{2408} = \frac{2262MVA}{2408MVA} = 0.94$$

Since the power flow of the transmission line is less than its capacity, there is no problem.

(b) Outage of a circuit between Banshkhali PP and Madunaghat SS

The Survey Team also performed power system analyses to figure out an effect of Banshkhali PP as a reference. A power flow calculation under an N-1 condition, an outage of a 400kV transmission line circuit between Banshkhali PP and Madunaghat SS, gave overloading of the remaining circuit of the same section as shown below.



Source: Study Team

Figure 6.2-4 Power flow calculation result under an N-1 condition, an outage of a circuit between Banshkhali PP and Madunaghat SS

Loading ratio of the remaining another transmission line circuit between Matarbari PP and Matarbari (N) SS can be calculated as below.

$$\frac{\sqrt{3475.8^2 + 672.1^2}}{2408} = \frac{3540MVA}{2408MVA} = 1.47$$

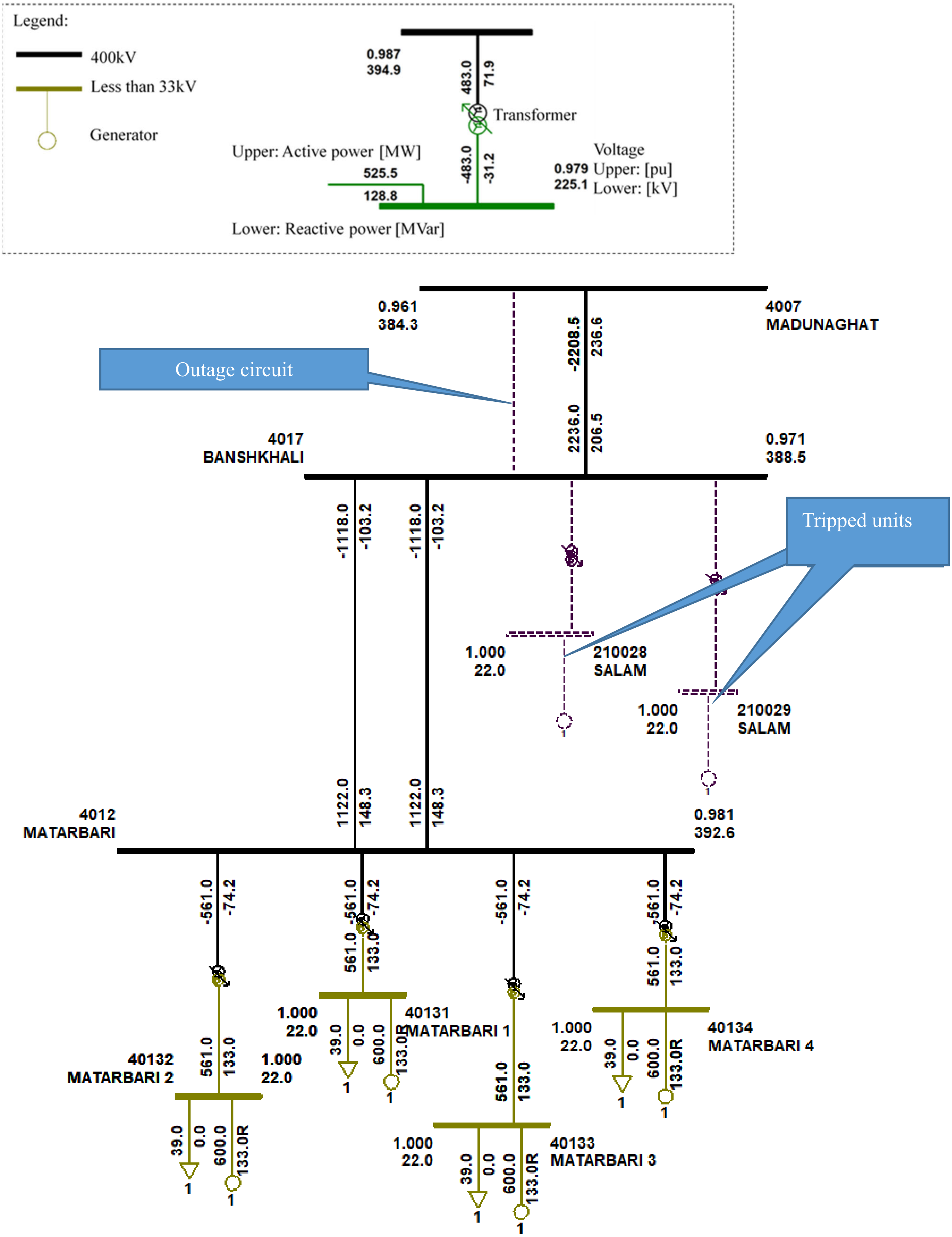
If the overloaded state is left as it is without any countermeasures, the conductor temperature will rise and the following problems will occur.

- The conductor thermally expands and the clearance from the ground or any structure cannot be sufficiently maintained, which may cause safety problems.
- Decrease in the conductor tensile strength

In order to reduce the power flow of the overloaded transmission line, output power from generators has to be reduced or some generators have to be tripped.

(c) Measure against overloading of the 400kV transmission line under N-1 condition

The figure below shows a power flow calculation result under an N-1 condition, outage of one transmission line circuit between Banshkhali SS and Madunaghat SS, with two units of Banshkhali PP tripped.



Source: Study Team

Figure 6.2-5 Power flow calculation result under an N-1 condition, an outage of a circuit between Banshkhali PP and Madunaghat SS with two units of Banshkhali PP tripped as a measure against the overloading

Loading ratio of the remaining another transmission line circuit between Matarbari PP and Matarbari (N) SS can be calculated as below.

$$\frac{\sqrt{2236+206.5^2}}{2408}=\frac{2245MVA}{2408MVA}=0.93$$

The power flow becomes less than its capacity by tripping the generators. PGCB will have to coordinate with generation companies beforehand to prevent the system collapse.

It is true that overloading of the said 400kV transmission line circuit is solved, but the generator tripping will cause frequency drop in the power system.

(d) Expected frequency drop caused by generator tripping

Frequency drop caused by a sudden outage of generators can be simply calculated by using a system frequency characteristic constant[1] in general. The Study Team calculated expected frequency drop under the condition below.

Table 6.2-5 Conditions for calculation of expected frequency drop caused by sudden outage of units in Banshkhali PP

System capacity	13,800MW (Off peak demand in 2030)
Capacity of tripped generators	1,240MW (2 units of Banshkhali PP)
Capacity Ratio of tripped generators to the system	0.090 (1,240MW/13,800MW)
System frequency characteristic constant	8%MW/Hz(Assumption: same as the system frequency characteristic constant of East Japan system)

Source: Study Team

Expected frequency drop is

$$\frac{0.090}{0.08}\approx 1.1\ \ (\mathrm{Hz})$$

According to the Grid code, any generators have to keep operating. Thus, this 1.1Hz frequency drop will not cause other generators to trip.

6.2.3 Power flow analysis for an optional case

(1) Power flow analysis with Matarbari (N) SS just for reference

(a) System configurations around Matarbari area

PGCB informed the Survey Team that they will construct a new 400kV substation (expressed as "MATARBARI (N)" in the figure below) to evacuate generated power from Matarbari area via not only 400kV transmission lines but also 230kV and 132kV transmission lines as shown below.

---

1 Definition of a system frequency characteristic constant:

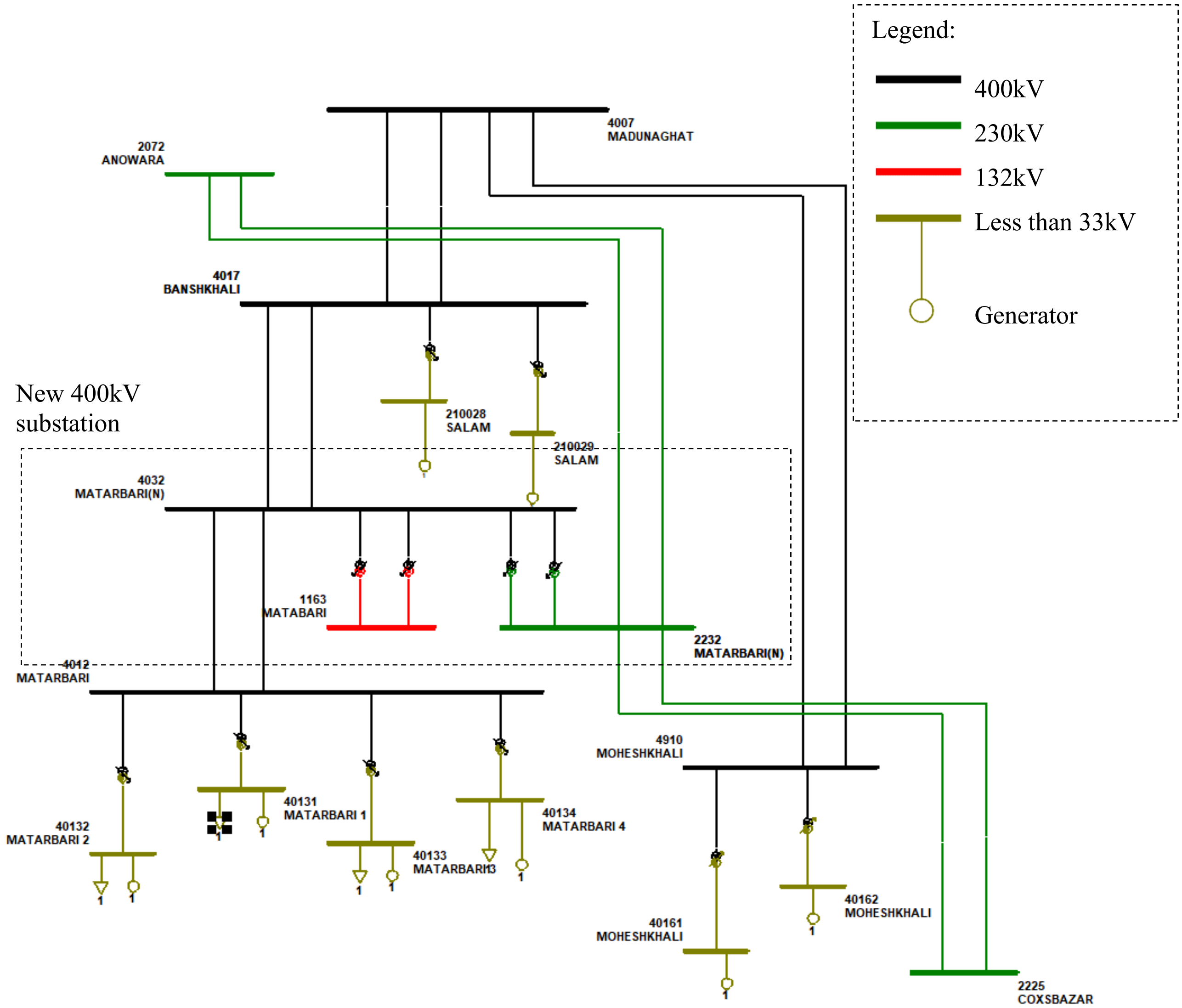
$$K=\frac{\Delta p/P}{\Delta \mathrm{f}}\,[\%\mathrm{MW/Hz}]$$

Where

Δp: Unit capacity of tripped generator [MW]

P: System capacity [MW]

Δf: Maximum frequency drop at outage [Hz]



Source: Created by the Study Team in line with information from PGCB

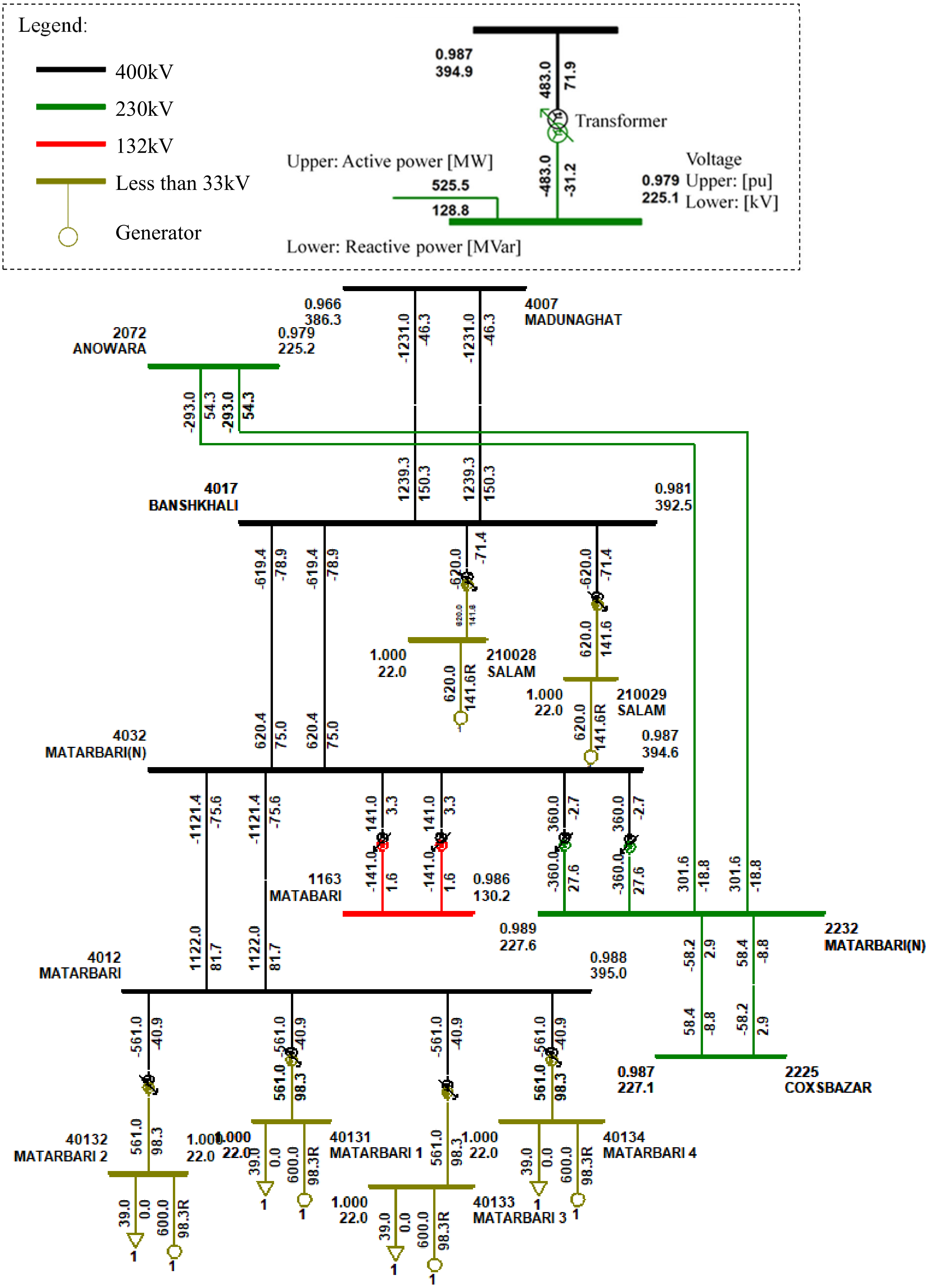
Figure 6.2-6 System configurations with Matarbari(N) SS

The Survey Team also conducted power flow analyses under the system configuration condition that Matarbari (N) SS has been constructed when Matarbari 3/4 units are connected to the grid as a reference. Since the power flow from Matarbari (N) to Banshkhali PP depends on loading conditions of transformers of Matarbari (N) SS, the Study Team performed power flow analyses under peak and off-peak demand conditions.

(b) Peak demand condition

1) N-0 condition

The figure below shows the power flow calculation result regarding power evacuation from Matarbari PP under a normal or N-0 condition.



Source: Study Team

Figure 6.2-7 Power flow calculation result with Matarbari (N) SS under an N-0 condition.

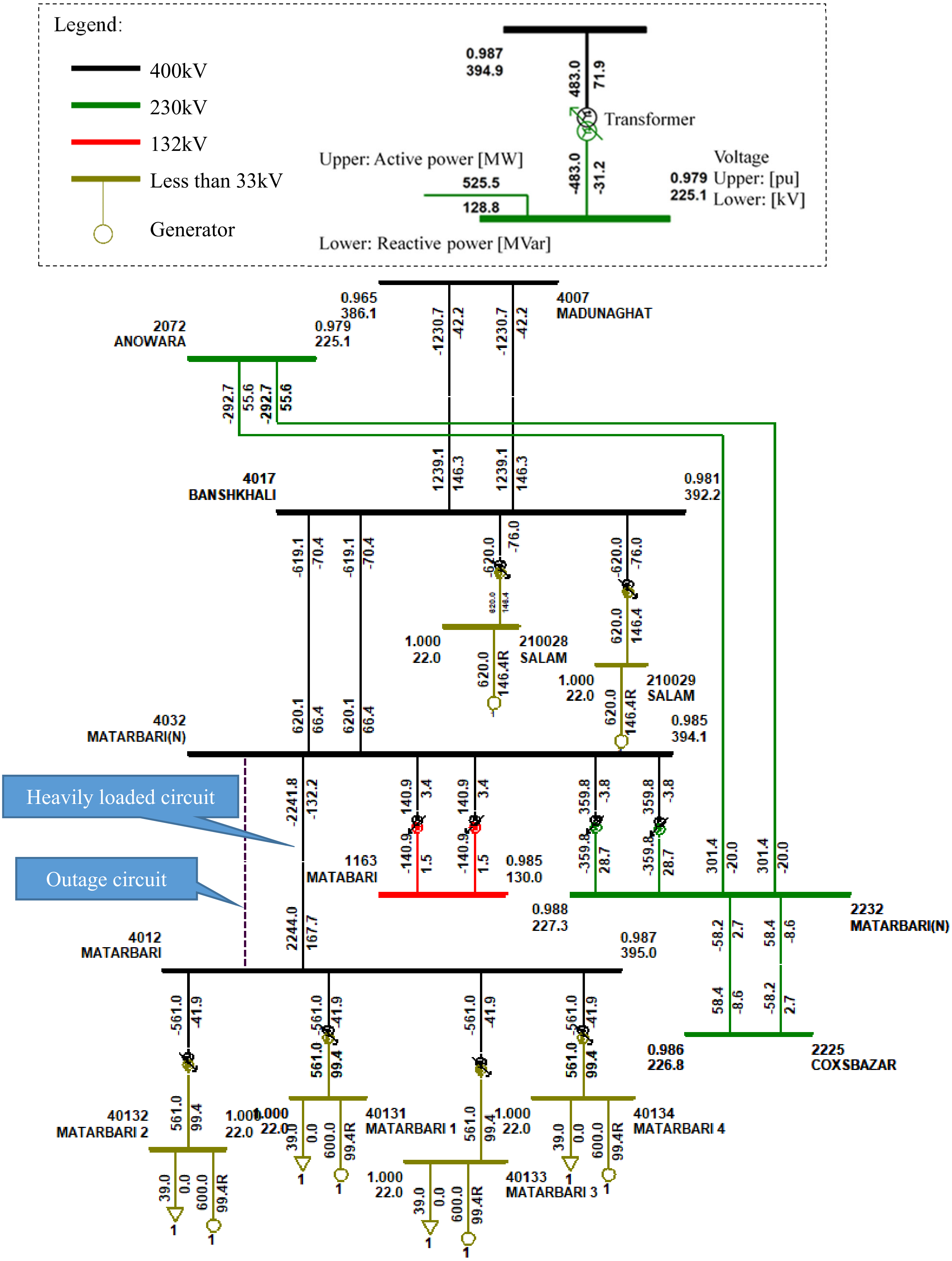
Since current loading capacity of the 400kV transmission line between Matarbari PP and Madunaghat SS is 2,328MVA, there is no loading violation on the 400kV transmission line.

2) N-1 condition

Power flow calculations were also performed under contingency or N-1 conditions.

a) Outage of a circuit between Matarbari PP and Matarbari(N) SS

The figure below shows the power flow calculation result under N-1 condition, an outage of a circuit between Matarbari PP and Matarbari(N) SS.



Source: Study Team

Figure 6.2-8 Power flow calculation result under an N-1 condition, an outage of a circuit between Matarbari PP and Matarbari (N) SS

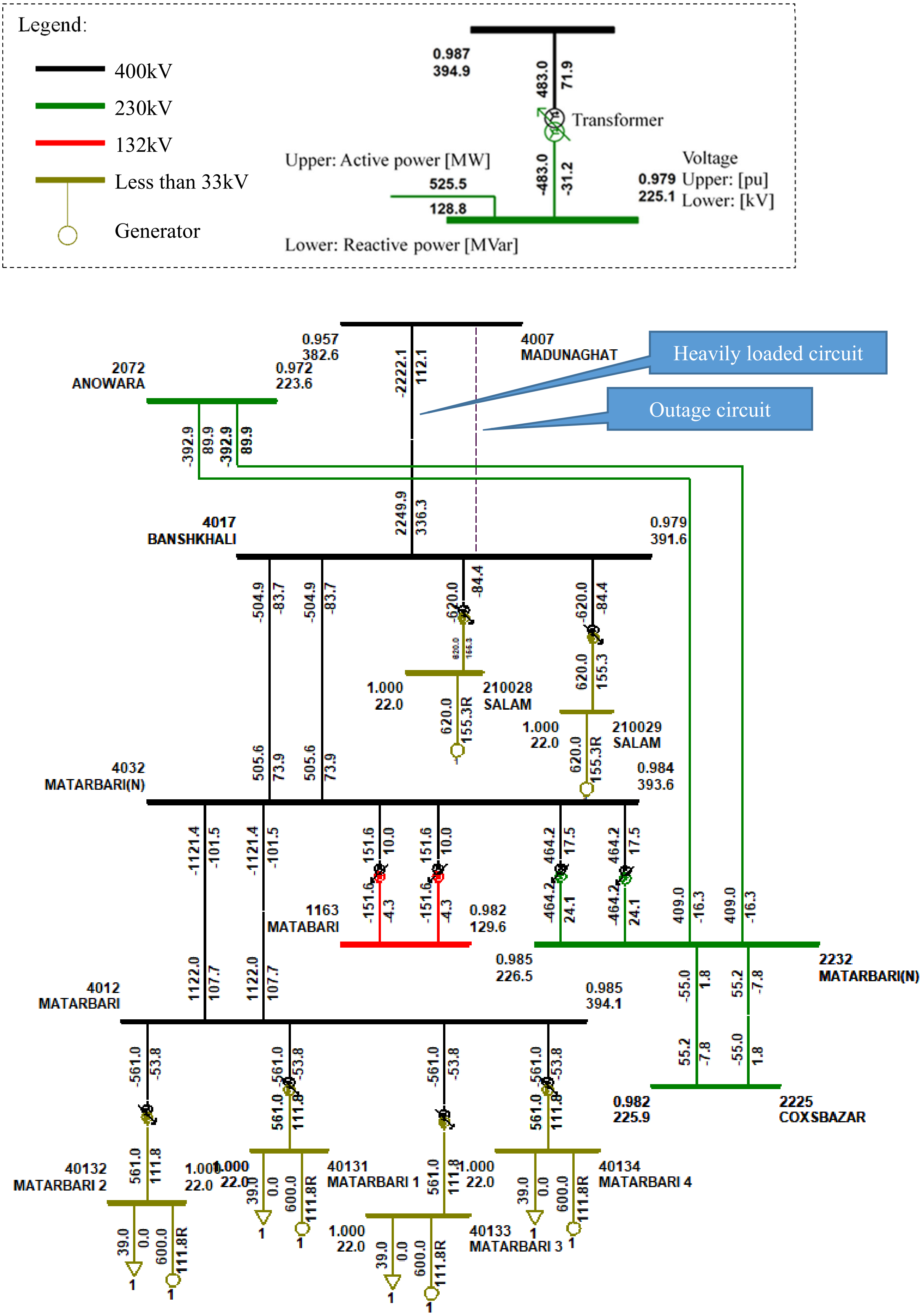
Loading ratio of the transmission line between Matarbari PP and Matarbari (N) SS can be calculated as below.

$$\frac{\sqrt{2244^2 + 167.7^2}}{2408} = \frac{2250MVA}{2408MVA} = 0.93$$

Since the power flow of the transmission line is less than its capacity, there is no problem.

b) Outage of a circuit between Banshkhali PP and Madunaghat SS

The Survey Team also performed power system analyses to figure out an effect of Banshkhali PP as a reference. The figure below shows a power flow calculation result under an N-1 condition, an outage of a 400kV circuit between Banshkhali PP and Madunaghat SS



Source: Study Team

Figure 6.2-9 Power flow calculation result under an N-1 condition, an outage of a circuit between

Banshkhali PP and Madunaghat SS

Loading ratio of the transmission line between Banshkhali PP and Madunaghat SS can be calculated as below.

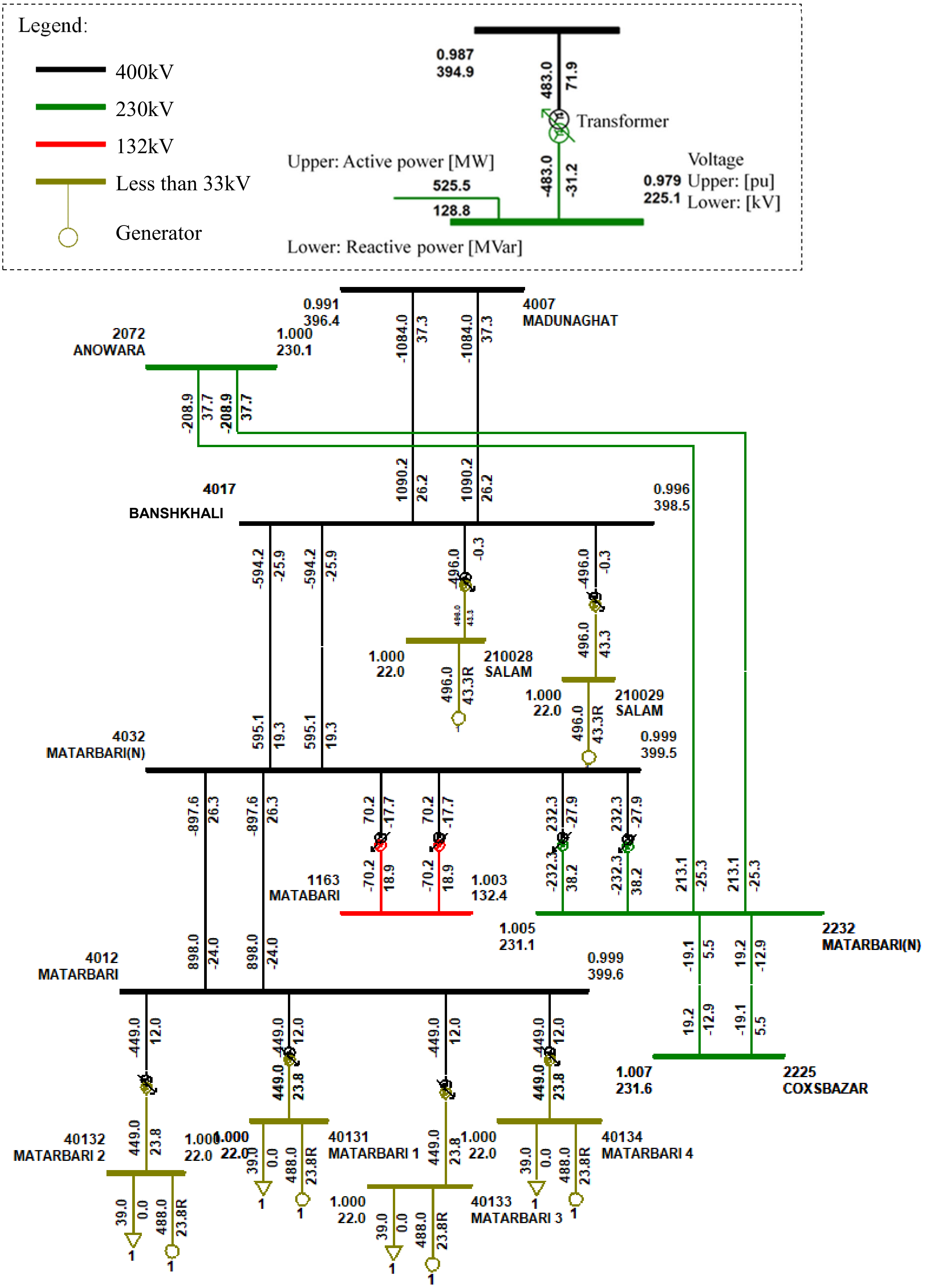
$$\frac{\sqrt{2249.9^2 + 336.3^2}}{2408} = \frac{2275MVA}{2408MVA} = 0.95$$

Since the power flow of the transmission line is less than its capacity, there is no problem.

(c) Off-peak demand condition

1) Power flow analysis under the normal condition

The figure below shows the power flow calculation result under off-peak demand and N-0 conditions.



Source: Study Team

Figure 6.2-10 Power flow calculation result under off-peak and N-0 conditions.

Since current loading capacity of the 400kV transmission line between Matarbari PP and Madunaghat

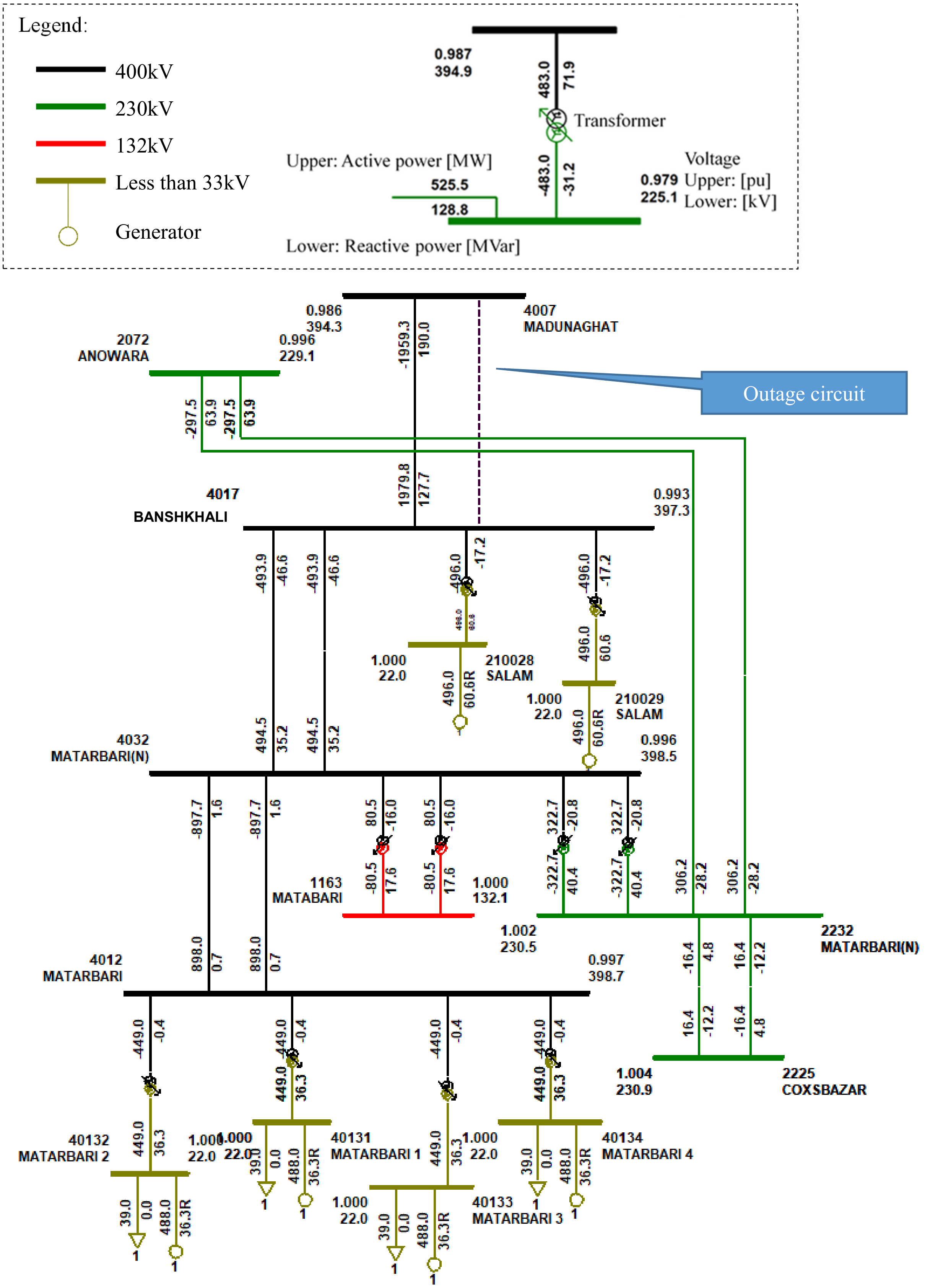
SS (Substation) is 2408MVA, there is no loading violation on the 400kV transmission line

2) Power flow analysis under the contingency condition

Power flow calculations were also performed under contingency or N-1 conditions.

a) Outage of a circuit between Banshkhali PP and Madunaghat SS

The Survey Team also performed power system analyses to figure out an effect of Banshkhali PP as a reference. The figure below shows a power flow calculation result under an N-1 condition, an outage of a 400kV circuit between Banshkhali PP and Madunaghat SS.



Source: Study Team

Figure 6.2-11 Power flow calculation result under an N-1 condition, an outage of a circuit between Banshkhali PP and Madunaghat SS on the off-peak demand

Since power flow of the remaining 400kV transmission line circuit between Banshkhali SS and Madunaghat SS under the N-1 contingency is 1979.6+j128.7, loading ratio of the circuit is

$$\frac{\sqrt{1979.8^2 + 127.7^2}}{2408} = \frac{1984MVA}{2408MVA} = 0.82$$

Power flow of the circuit is less than its capacity. There is no loading violation with other transmission lines.

If the construction of the Matarbari (N) substation is not in time by the start of operation of Matarbari power plant No. 3/4, PGCB will have to discuss output power reduction or trip of the generators in advance with the generation companies to solve grid overloading.

(2) Matarbari 700MW USCPP (JV of Symcorp & CPGCBL) (Phase-1)

As listed on Table 6.2-1, Matarbari 700MW USCPP (JV of Symcorp & CPGCBL) (Phase-1) has been scrapped. If the same capacity power plant fueled by LNG is developed in Matarbari area, the plant should be connected to Moheshkhali so as not to increase power flow on the 400kV transmission line from Matarbari PP.

6.3 Fault current analysis

6.3.1 Conditions for fault current analysis

The Study Team conducted fault current analysis under the conditions noted below.

Table 6.3-1 Conditions for the fault current analysis

Generator reactance	Xd”
Generators taken into account	All generators connected to 132kV system or more

Source: Study Team

The Maximum fault current levels are as follows.

Table 6.3-2 Maximum fault current level

Voltage	Maximum fault current level	Source
400kV	63kA	PGCB
230kV	50kA	
132kV	40kA	

6.3.2 Result of fault current analysis

The table below shows calculated fault current values in RMS regarding 230kV, 400kV and 765kV buses of substations in Chittagong Division and the main substations in Dhaka. The results shows that fault current values are less than the allowable levels shown in the table above.

Table 6.3-3 Calculated fault current of 230kV, 400kV and132kV buses

Bus number	Bus Name	Voltage (kV)	Fault Current (A)
2013	HATHAZARI	230	37,881
2016	MEGHNAGHAT	230	27,520
2017	OLDAIRPORT	230	31,537
2029	BHULTA	230	38,537
2032	MIR	230	29,628
2038	MADUNAGHAT	230	43,935
2041	NAOGAON	230	10,354
2049	SIKALBAHA	230	36,588
2057	KULSHI	230	24,292
2060	ANANDABAZAR	230	30,793
2072	ANOWARA	230	34,785
2078	FENI	230	19,752
2083	MADANGANJ	230	41,934
2084	MADUNAGHAT(O	230	33,066
2095	DHAKA(S)	230	30,526
2225	COXSBAZAR	230	5,238
4320	KORERHAT	230	36,632
92016	MEGHNAGHAT	230	43,541
41	BHULTA	400	48,926
901	MIRERSHARAI	400	29,023
4003	BHULTA	400	48,926
4005	GHORASAL	400	11,543
4006	KALIAKOIR	400	42,084
4007	MADUNAGHAT	400	39,116
4008	MEGHNAGHAT	400	54,178
4011	GOPALGANJ	400	39,502
4012	MATARBARI	400	26,855
4090	DHAKA(S)	400	44,502
4212	COMILLA(N)	400	9,980
4310	KORERHAT	400	33,108

Source: Study Team

The table below shows calculated fault current values in RMS of top ten 132kV buses.

Table 6.3-4 ten largest fault current values of 132kV buses

Bus number	Bus Name	Voltage (kV)	Fault Current (A)
1059	MADANGANJ	132	37,089
1234	GOPALGANJ	132	35,929
1049	KABIRPUR	132	34,649
1099	GREENMODEL	132	31,749
1060	MADUNAGHAT	132	31,333
1177	RAMPUR	132	30,662
1190	SIDDHIRGANJ	132	30,096
1089	RAMPURA	132	30,005
1101	SIKALBAHA	132	29,442
1106	ULLON	132	29,277

Source: Study Team

The system configuration is based on the one for revisiting PSMP. Some of the 132kV systems are already effectively split and not in loop configurations but rather in radial configurations. This is a main reason that fault current values are less than the allowable levels

6.4 Stability analysis

Since the Study Team was not provided with detailed data required for the stability analysis, some assumptions are made for the study as noted below.

6.4.1 Conditions for stability analysis

(1) Generator model

(a) Active and reactive power

A model with fixed current for active power and fixed impedance for reactive power was used for stability simulations.

(b) Generator constants of Matarbari PP

The following constants are adopted as the latest information.

1) Generator

Generator type: GENROU (Round-rotor model)

Constants:

Table 6.4-1 Generator Constants for Matarbari PP

T'do	9.7
T"do	0.032
T'qo	2
T"qo	0.05
H, Inertia	2.97
D, Speed Damping	0
Xd	1.93
Xq	1.9
X'd	0.285
X'q	0.511
X"d = X"q	0.226
Xl	0.195

S(1.0)	0.11
S(1.2)	0.41

Source: Manufacturer of Matarbari 1/2 units

2) Exciter Model
High initial response excitation systems are equipped for Matarbari 1/2 units and the same excitation system should be also done for 3/4 units.
Exciter type: ST6B
Constants:

Table 6.4-2 Constants for Exciter

TR(s), regulator input filter time constant	0.03
KPA(pu), regulator proportional gain (> 0)	67.9
KIA(pu), regulator integral gain	97
KDA(pu), regulator derivative gain	0
TDA(s), regulator derivative block time constant	1
VAMAX(pu), regulator output maximum limit	6.69
VAMIN(pu), regulator output minimum limit (<=VRMIN)	-5.32
KFF(pu), pre control gain of the inner loop fieldregulator	0
KM(pu), forward gain of the inner loop fieldregulator	1
KCI(pu), exciter output current limit adjustmentgain	1
KLR(s), exciter output current limiter gain	1
ILR(pu), exciter output current limit reference	30
VRMAX(pu), voltage regulator output maximum limit	6.69
VRMIN(pu), voltage regulator output minimum limit (>=VAMIN)	-5.32
KG(pu), feedback gain of the inner loop voltageregulator	0
TG(s), feedback time constant of the inner loopvoltage regulator	1

Source: Manufacturer of Matarbari 1/2 units

3) PSS Model
The PSS (Power System Stabilizer) is essential for the high initial response excitation system to stabilize the system.
PSS type: PSS2B
Constants:

Table 6.4-3 Constants for PSS-1

TW1 (>0) Washout Time constant - Signal 1	5
TW2 Washout Time Constant - Signal 1	5
T6 Lag Time Constant - Signal 1	0
TW3 (>0) Washout Time Constant - Signal 2	5
TW4 Washout Time Constant - Signal 2	0
T7 Lag Time Constant - Signal 2	5
KS2 Gain - Signal 2	0.843
KS3 Gain - Signal 2	1
T8 Ramp Tracking Filter Lead Time Constant	0.5
T9 (>0) Ramp Tracking Filter Lag Time Constant	0.1
KS1 Stabilizer Gain	6
T1 Lead Time Constant - Phase Comp. Block 1	0.16
T2 Lag Time Constant - Phase Comp. Block 1	0.03
T3 Lead Time Constant - Phase Comp. Block 2	0.16

T4 Lag Time Constant - Phase Comp. Block 2	0.03
T10 Lead Time Constant - Phase Comp. Block 3	0
T11 Lag Time Constant - Phase Comp. Block 3	0.03
VS11MAX Stabilizer Input Maximum. Input 1	10
VS11MIN Stabilizer Input Minimum. Input 1	-10
VS12MAX Stabilizer Input Maximum. Input 2	10
VS12MIN Stabilizer Input Minimum. Input 2	-10
VSTMAX Stabilizer Output Maximum	0.05
VSTMIN Stabilizer Output Minimum	-0.05

Source: Manufacturer of Matarbari 1/2 units

Table 6.4-4 Constants for PSS-2

IC1 First Stab. Input Code (see manual)	1
REMBUS1 First Remote Bus Number	0
IC2 Second Stab. Input Code (see manual)	3
REMBUS2 Second Remote Bus Number	0
M	5
N	1

Source: Manufacturer of Matarbari 1/2 units

4) Governor Model
Governor type: IEEEG1
Constants:

Table 6.4-5 Constants for Governor

K	20
T1	0.02
T2	0
T3 (> 0)	0.1
Uo	0.1
Uc (< 0.)	-0.2
PMAX	1.03
PMIN	0.03
T4	0.7378
K1	0.45
K2	0
T5	29.764
K3	0
K4	0
T6	0.2914
K5	0.3356
K6	0
T7	1.2669
K7	0.2144
K8	0

Source: Manufacturer of Matarbari 1/2 units

(c) Constants of other generators
Typical generator constants are used as listed below.

1) Generator
   a) Thermal Generator
      Generator type: GENROU (Round-rotor model)
      Constants:

Table 6.4-6 Constants for Thermal Generator

T'do	8.73
T"do	0.045
T'qo	0.97
T"qo	0.068
H, Inertia	2.6073
D, Speed Damping	0
Xd	2.26
Xq	2.2
X'd	0.275
X'q	0.405
X"d = X"q	0.214
Xl	0.1
S(1.0)	0.12
S(1.2)	0.6

Source: Study Team

   b) Hydro Generator
      Generator type: GENSAL (Salient-pole model)

Table 6.4-7 Constants for Thermal Generator

T'do	5
T"do	0.05
T'qo	0.06
T"qo	5.084
H, Inertia	1
D, Speed Damping	1.5
Xd	1.2
Xq	0.4
X'd	0.2
X'q	0.12
X"d = X"q	0.03
Xl	0.25
S(1.0)	5
S(1.2)	0.05

Source: Study Team

2) Exciter Model
   Exciter type: SEXS
   Constants:

Table 6.4-8 Constants for Exciter

TA/TB	0.1
TB (> 0)	10
K	100

TE	0.1
EMIN	0
EMAX	5

Source: Study Team

According to PGCB, type PSS2B of PSS will be equipped in the exciter system for BANSHKHALI power plant generators. The Study Team modeled PSS for the generators in BANSHKHALI power plant and assumed the same constants as the ones on for Matarbari power plant generators.

3) Governor Model
   a) Gas turbine
   Governor type: GAST
   Constants:

Table 6.4-9 Governor constants for gas turbine

R (Speed Droop)	0.05
T1 (> 0)	0.4
T2 (> 0)	0.1
T3 (>0)	3
Ambient Temperature Load Limit	1
KT	2
VMAX	1
VMIN	0
Dturb	0

Source: Study Team

   b) Hydro turbine
   Governor type: HYGOV
   Constants:

Table 6.4-10 Governor constants for hydro turbine

R, Permanent Droop	0.05
r, Temporary Droop	0.27
Tr (> 0) Governor Time Constant	4
Tf (> 0) Filter Time Constant	0.02
Tg (> 0) Servo Time Constant	0.5
VELM, Gate Velocity Limit	0.12
GMAX, Maximum Gate Limit	1
GMIN, Minimum Gate Limit	0
TW (> 0) Water Time Constant	1.02
At, Turbine Gain	0.91
Dturb, Turbine Damping	0.45
qNL, No Load Flow	0.06

Source: Study Team

   c) Other generators
   Governor type: IEEEG1
   Constants:

Table 6.4-11 Governor constants for others

K	20
T1	0.02

T2	0
T3 (> 0)	0.1
Uo	0.1
Uc (< 0.)	-0.2
PMAX	1.03
PMIN	0.03
T4	0.7378
K1	0.45
K2	0
T5	29.764
K3	0
K4	0
T6	0.2914
K5	0.3356
K6	0
T7	1.2669
K7	0.2144
K8	0

Source: Study Team

(2) Load model

A model with fixed current for active power and fixed impedance for reactive power was used for load in stability simulations.

The Survey Team conducted stability analyses under not only a peak demand condition but also an off-peak demand one.

(3) Fault conditions

(a) Fault clearance time

According to the GRID CODE 2019, "To be maintained stable during a fault clearance by three-phase trip within 5 cycles and followed by successful reclosure within 50 cycles (1 sec dead time), provided the fault is not a permanent one" in PLANNING AND SECUIRITY STANDARDS. This standard is not dependent on voltage levels in the GRID CODE. Generally, higher reliability and consequently shorter fault clearance time are required in higher voltage level. The GRID CODE 2019 also stipulates that target clearance time for 400kV & Above is "80 milliseconds". In consultation with PGCB, fault clearance time of 0.08 second was considered in the stability analysis. Furthermore, a differential relay scheme has been already adopted as a protection relay for the 400kV transmission line between Matarbari PP and Meghnaghat SS and the differential relay scheme can clear the fault in 0.07 second. Thus, the Study Team performed additional simulations with shorter fault clearance time if necessary. The table blow shows a simulation sequence for the stability analysis.

Table 6.4-12 Simulation sequence for stability analysis

time (seconds)	Action
0.0	Start of simulation
1.0	Fault occurrence
1.08 *1	Fault clearance *1
2.08	Reclosure
11.0	End of simulation

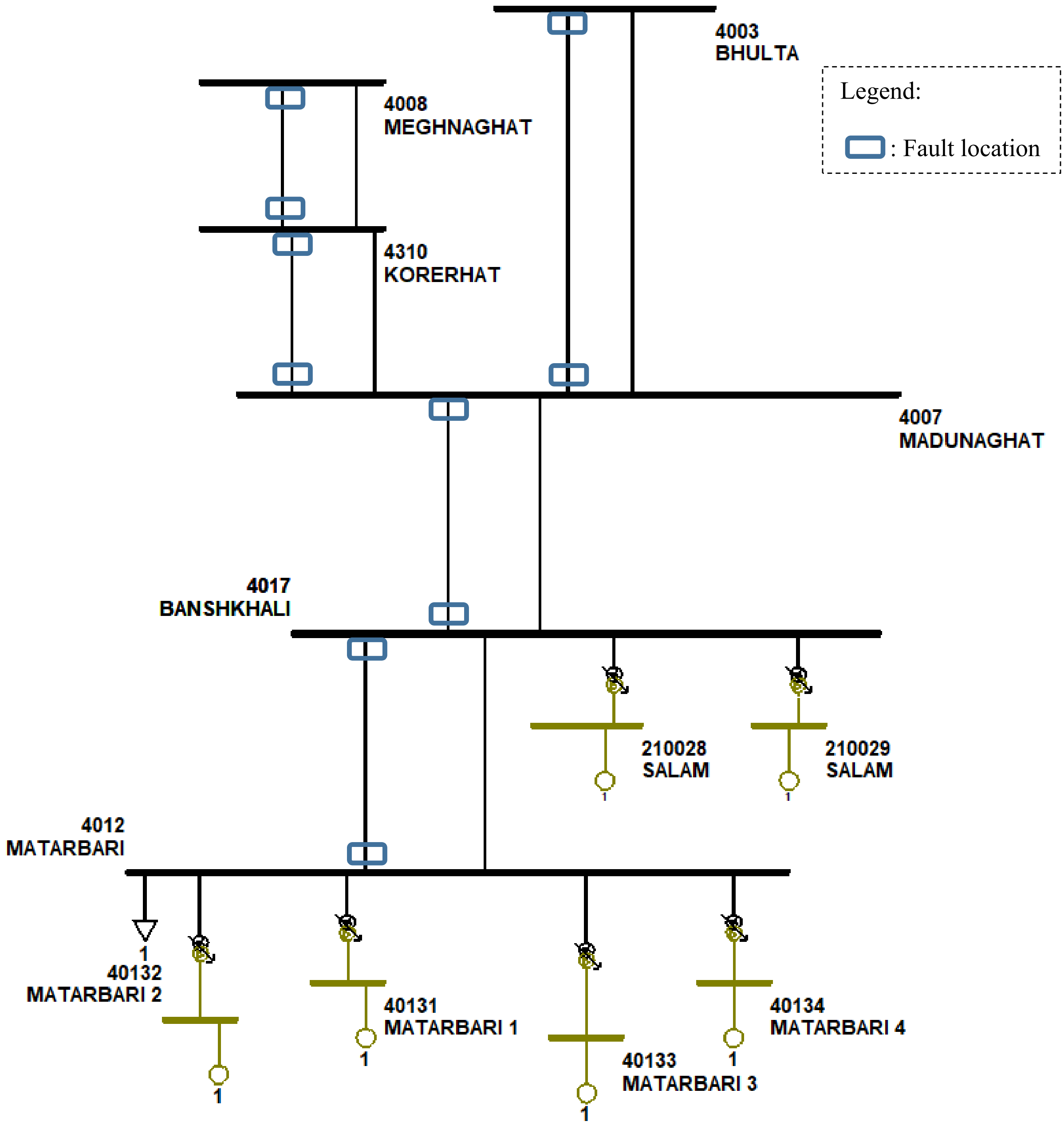
*1: Shorter fault clearance times were also used for additional simulations.
Source: Created by the Study Team referring the GRID CODE 2019, Bangladesh Energy Regulatory Commission

(b) Fault type

Fault type: Three phase short circuit
Fault impedance: 0 ohm

(c) Fault locations

Stability analyses were performed with a fault on sending and receiving ends of related 400kV transmission lines as illustrated below.



Source: Study Team

Figure 6.4-1 Fault locations for stability analysis

6.4.2 Result of fault stability analysis

(1) Peak demand condition

The table blow shows results of fault stability analyses under the peak demand condition.

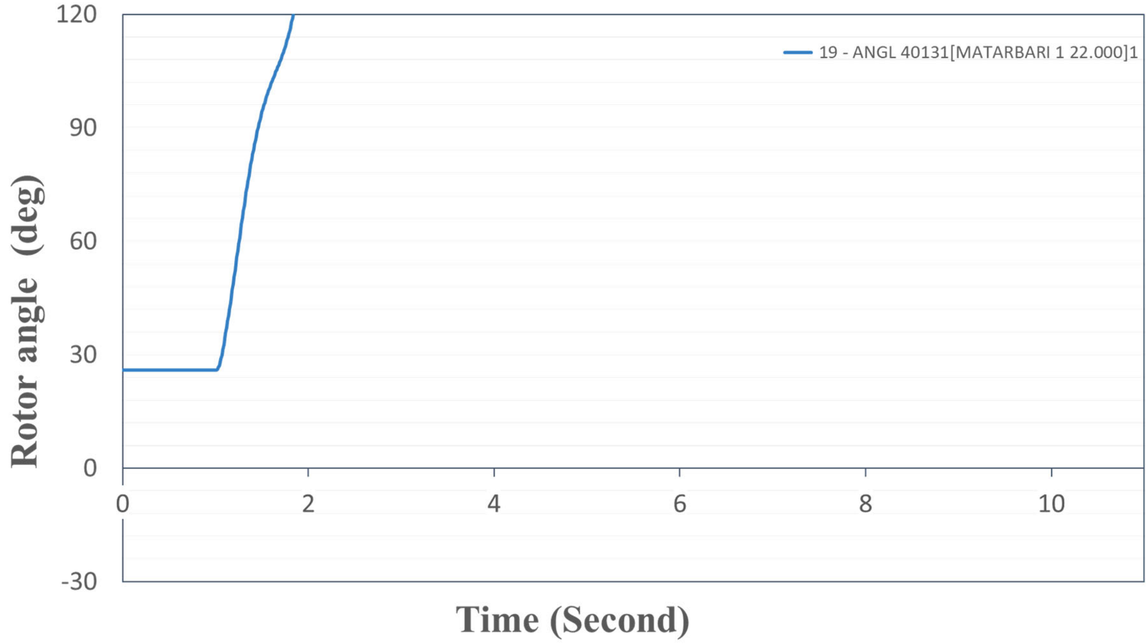
Table 6.4-13 Result of stability analysis

Case #	Fault transmission line					Fault clearance time	Stable/ Unstable
	From		To		Fault Location		
Case 001	4012	MATABARI	4017	BANSHKHALI	MATABARI	0.08 second	Stable
Case 002					BANSHKHALI	0.08 second	Stable
Case 003	4017	BANSHKHALI	4007	MADUNAGHAT	BANSHKHALI	0.08 second	Stable
Case 004					MADUNAGHAT	0.08 second	Unstable
Case 005					MADUNAGHAT	0.07 second	Stable
Case 006	4007	MADUNAGHAT	4310	KORERHAT	MADUNAGHAT	0.08 second	Stable
Case 007					KORERHAT	0.08 second	Stable
Case 008	4310	KORERHAT	4008	MEGHNAGHAT	KORERHAT	0.08 second	Stable
Case 009					MEGHNAGHAT	0.08 second	Stable
Case 010	4007	MADUNAGHAT	4003	BHULTA	MADUNAGHAT	0.08 second	Stable
Case 011					BHULTA	0.08 second	Stable

Source: Study Team

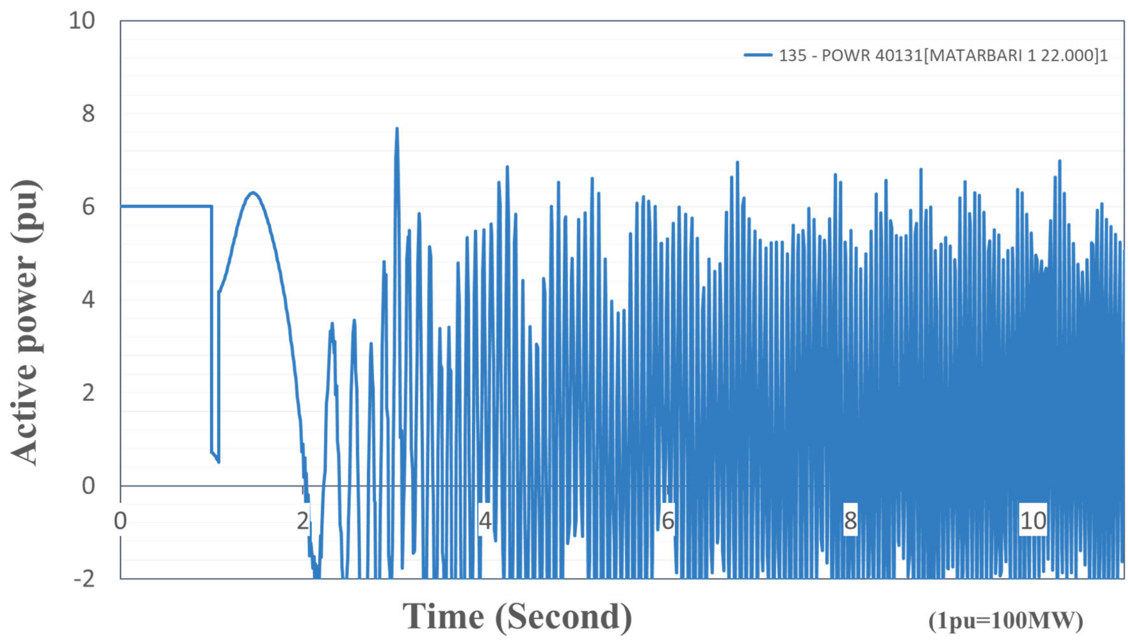
Results are unstable on Case 004. If fault clearance time is 0.07 second, the system is stable in all fault cases.

The figures below show rotor angle of a generator, active power, and reactive power of Matarbari PP as an examples of unstable and stable cases. The unstable case is the Case 004 with a fault at MADUNAGHAT end of the transmission line from BANSHKHALI to MADUNAGHAT cleared after 0.08 second and the stable one is the Case 005 with a fault at the same location cleared after 0.07 second.



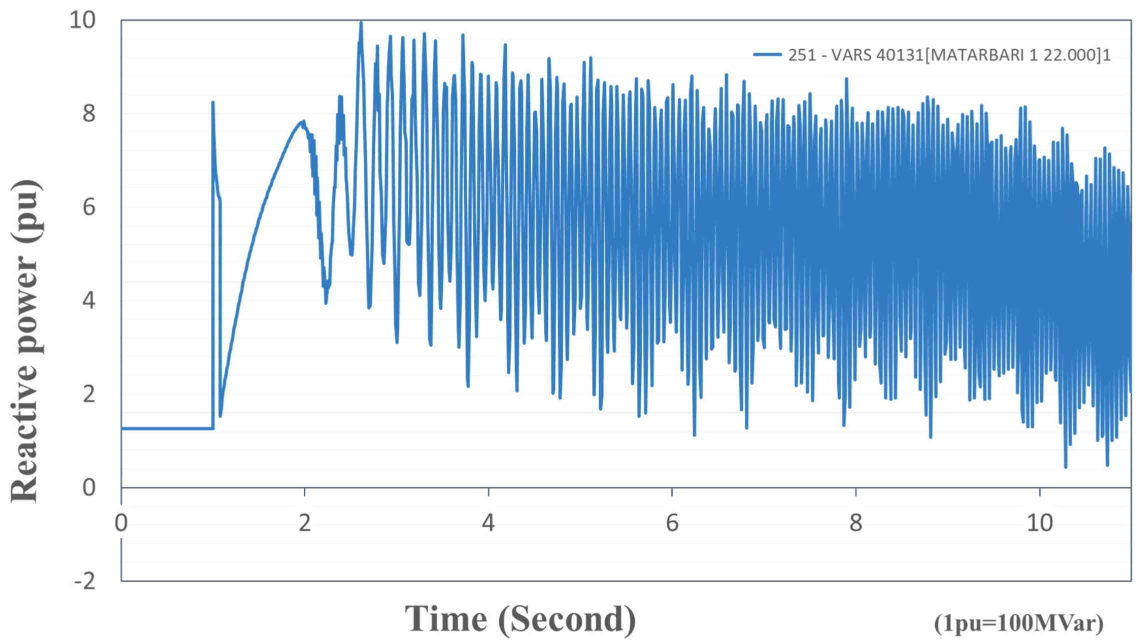
Source: Study Team

Figure 6.4-2 Rotor angle of the generator on Case 004, with a fault at MADUNAGHAT end of the transmission line from BANSHKHALI to MADUNAGHAT cleared after 0.08 second



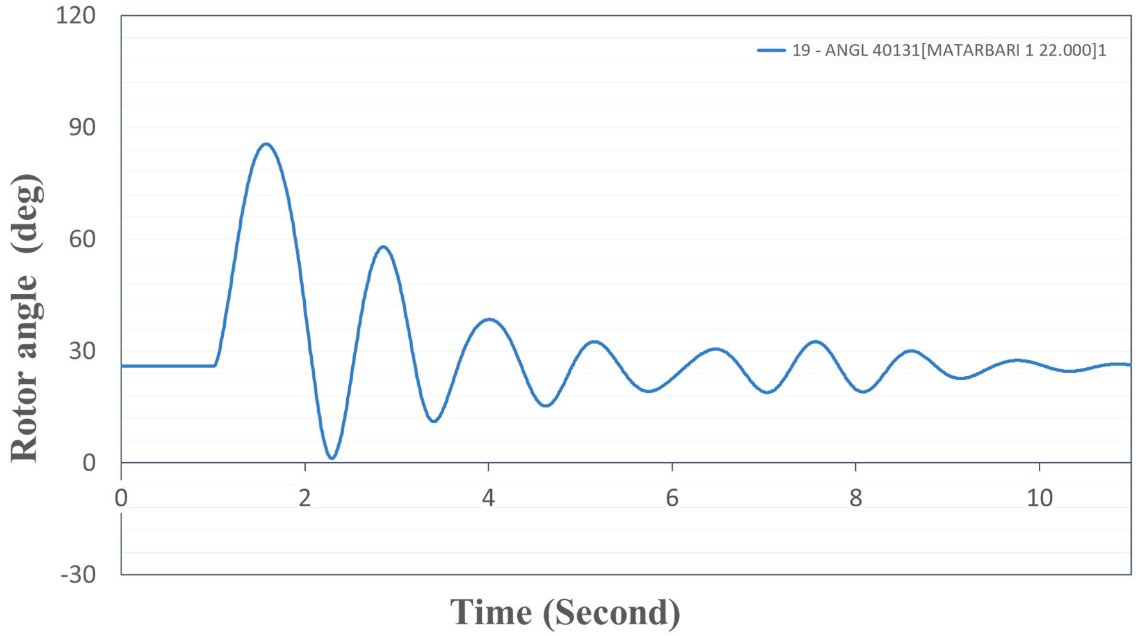
Source: Study Team

Figure 6.4-3 Active power of the generator on Case 004, with a fault at MADUNAGHAT end of the transmission line from BANSHKHALI to MADUNAGHAT cleared after 0.08 second



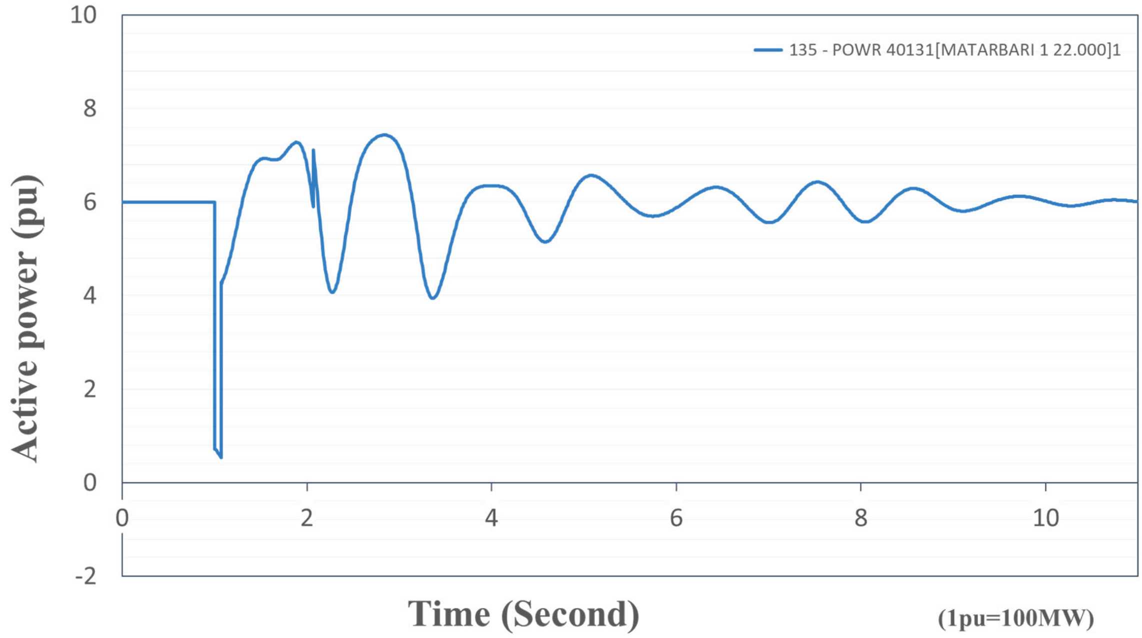
Source: Study Team

Figure 6.4-4 Reactive power of the generator on Case 004, with a fault at MADUNAGHAT end of the transmission line from BANSHKHALI to MADUNAGHAT cleared after 0.08 second



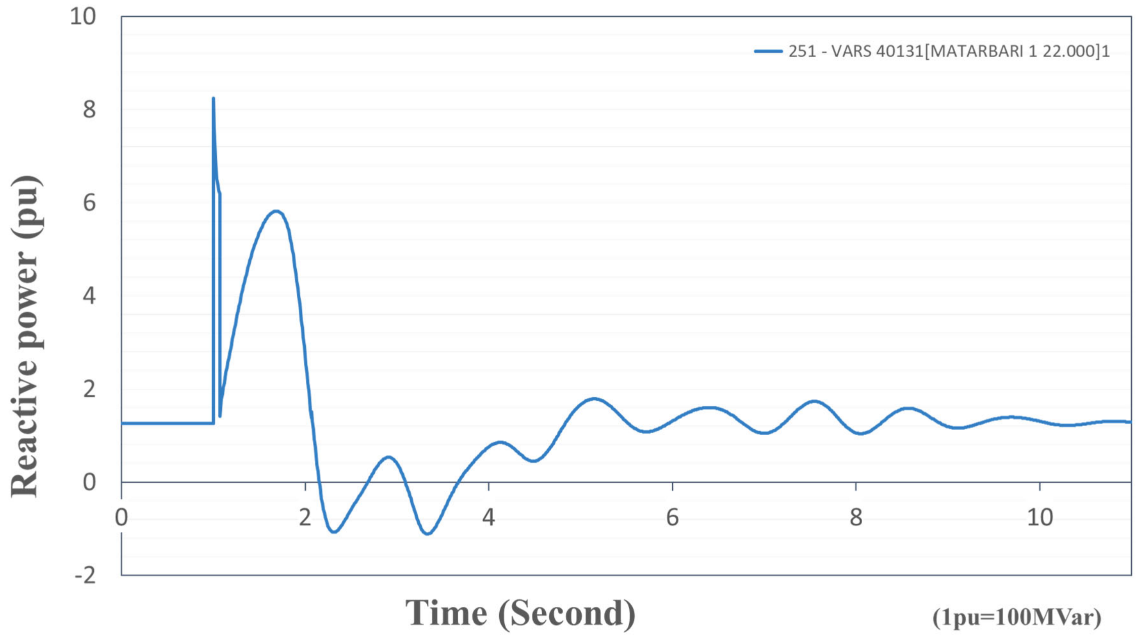
Source: Study Team

Figure 6.4-5 Rotor angle of the generator on Case 005, with a fault at MADUNAGHAT end of the transmission line from BANSHKHALI to MADUNAGHAT cleared after 0.07 second



Source: Study Team

Figure 6.4-6 Active power of the generator on Case 005, with a fault at MADUNAGHAT end of the transmission line from BANSHKHALI to MADUNAGHAT cleared after 0.07 second



Source: Study Team

Figure 6.4-7 Reactive power of the generator on Case 005, with a fault at MADUNAGHAT end of the transmission line from BANSHKHALI to MADUNAGHAT cleared after 0.07 second

If rotor angle oscillation attenuates as shown above in the Case 005, the system is stable.

(2) Off peak demand condition, 80% of rated output power of Matarbari and Banshkhali

The Study Team also performed stability analyses under off peak demand condition. Output power of power plants of Matarbari and Banshkhali 80% of rated one.

The table blow shows results of stability analyses under the off-peak demand condition.

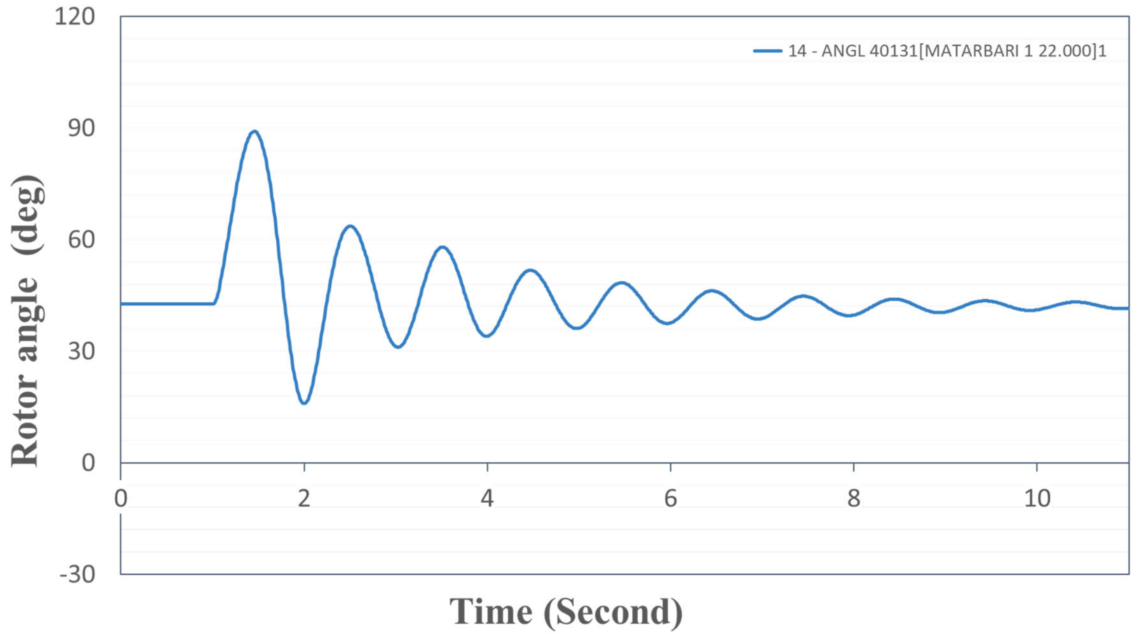
Table 6.4-14 Result of stability analysis under off-peak demand condition with 80% output power of Matarbari and Banshkhali PPs

Case #	Fault transmission line					Fault clearance time	Stable/ Unstable
	From		To		Fault Location		
Case 101	4012	MATABARI	4017	BANSHKHALI	MATABARI	0.08 second	Stable
Case 102					BANSHKHALI	0.08 second	Stable
Case 103	4017	BANSHKHALI	4007	MADUNAGHAT	BANSHKHALI	0.08 second	Stable
Case 104					MADUNAGHAT	0.08 second	Stable
Case 105	4007	MADUNAGHAT	4310	KORERHAT	MADUNAGHAT	0.08 second	Stable
Case 106					KORERHAT	0.08 second	Stable
Case 107	4310	KORERHAT	4008	MEGHNAGHAT	KORERHAT	0.08 second	Stable
Case 108					MEGHNAGHAT	0.08 second	Stable
Case 109	4007	MADUNAGHAT	4003	BHULTA	MADUNAGHAT	0.08 second	Stable
Case 110					BHULTA	0.08 second	Stable

Source: Study Team

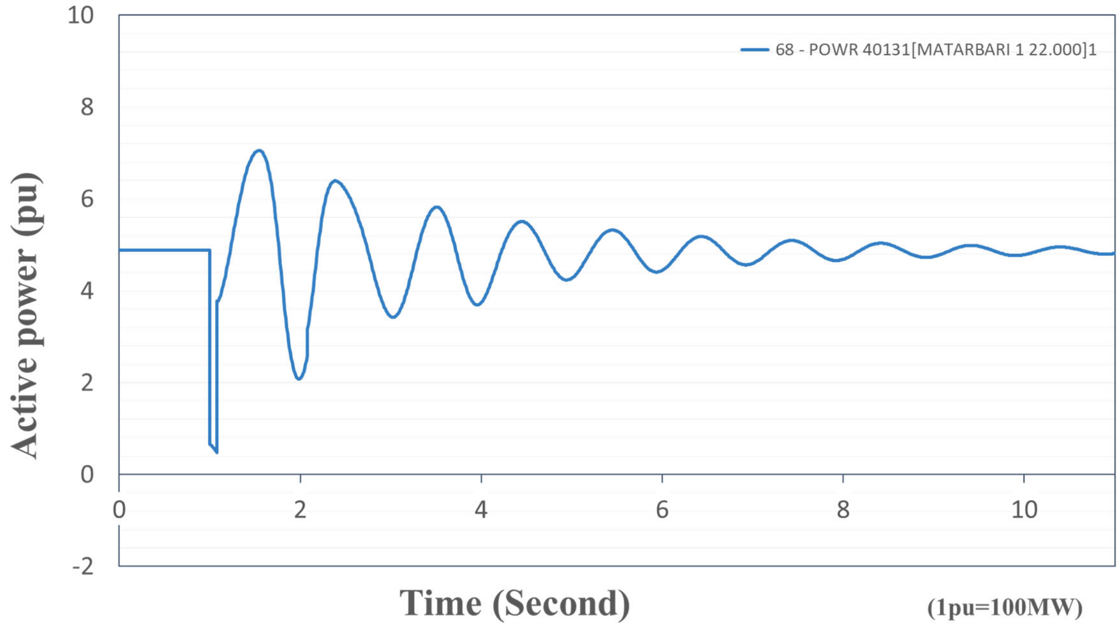
The system is stable in all fault cases under the off-peak demand condition.

The figure below shows result of simulation on Case 104 with a fault at MADUNAGHAT end of the transmission line from BANSHKHALI to MADUNAGHAT cleared after 0.08 second as an example.



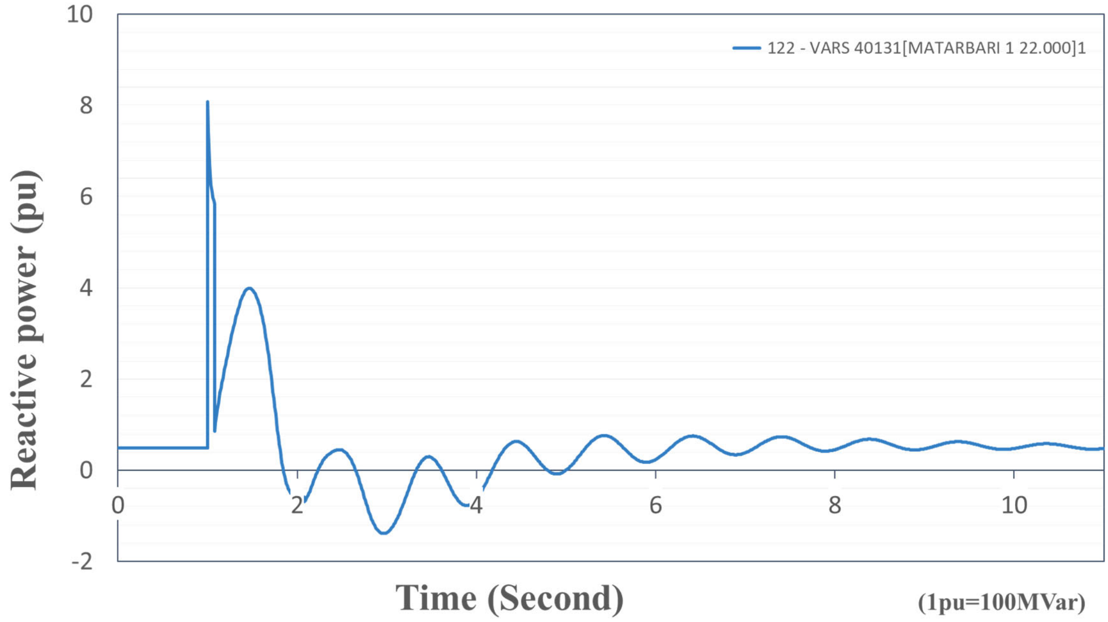
Source: Study Team

Figure 6.4-8 Rotor angle of the generator on Case 104, with a fault at MADUNAGHAT end of the transmission line from BANSHKHALI to MADUNAGHAT cleared after 0.08 second



Source: Study Team

Figure 6.4-9 Active power of the generator on Case 104, with a fault at MADUNAGHAT end of the transmission line from BANSHKHALI to MADUNAGHAT cleared after 0.08 second



Source: Study Team

Figure 6.4-10 Reactive power of the generator on Case 104, with a fault at MADUNAGHAT end of the transmission line from BANSHKHALI to MADUNAGHAT cleared after 0.08 second

6.4.3 Measures to improve system stability

(1) Higher voltage operation

Since the system stability will improve to some extent if 400kV transmission lines are operated at higher voltage[2], the following conditions are examples for the higher voltage operations.

[2] As the voltage increases, the current decreases in inverse proportion to the voltage. This current reduction effect generally improves stability.

- Terminal voltage of all generators is set to 1.05 pu
- Tap ratio of related transformers is adjusted to boost the voltage of the 400kV transmission lines

For the high voltage operation, the grid operator needs to cooperate closely with power generation companies and exchange sufficient information. Nevertheless, this method is considered to be worth studying for PGCB as a method that can improve stability without incurring a large cost.

(2) Generator constants

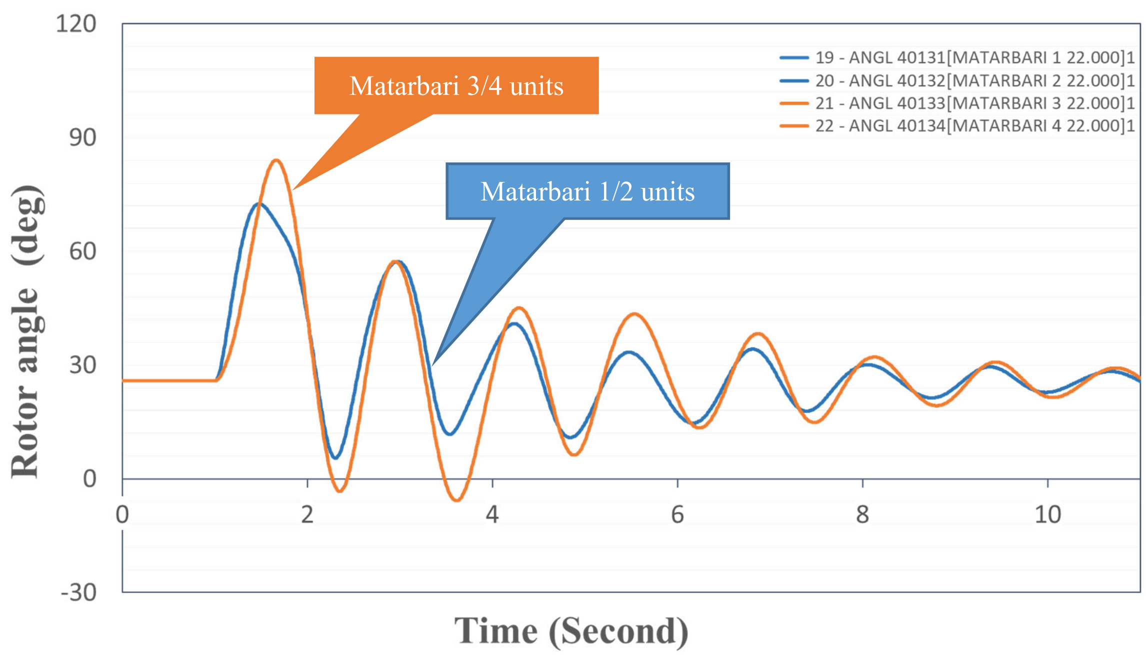
Smaller reactance or larger inertia of generators can improve the stability. However, since those changes from the manufactures original design will increase the cost of generators, the Study Team would not strongly recommend them. The Study Team performed a simulation of Case 004 on the Table 6.4-13 under the condition that generator inertia of Matarbari 3/4 is much larger than the ones of Matarbari 1/2 as a kind of sensitivity analysis.

Table 6.4-15 Assumed condition with larger generator inertia of Matarbari 3/4

Generator	Inertia (s)	
	Original	Assumption
Matarbari 1/2	2.97	2.97
Matarbari 3/4	2.97	6.00

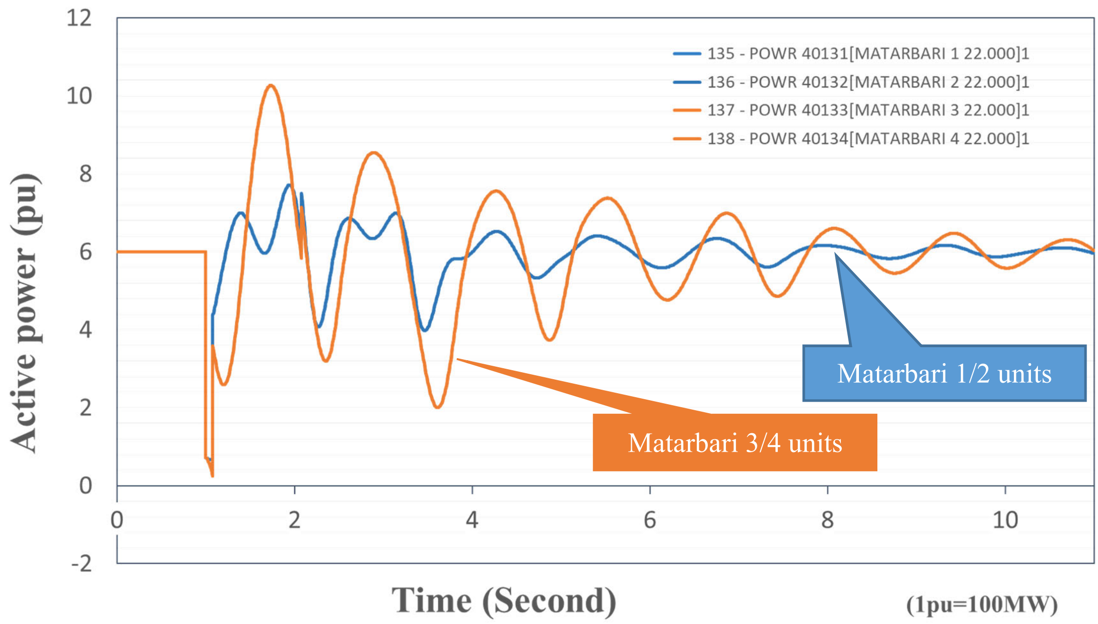
Source: Study Team

The figure below shows a stability simulation result of Case 004 under the assumption in the table above.



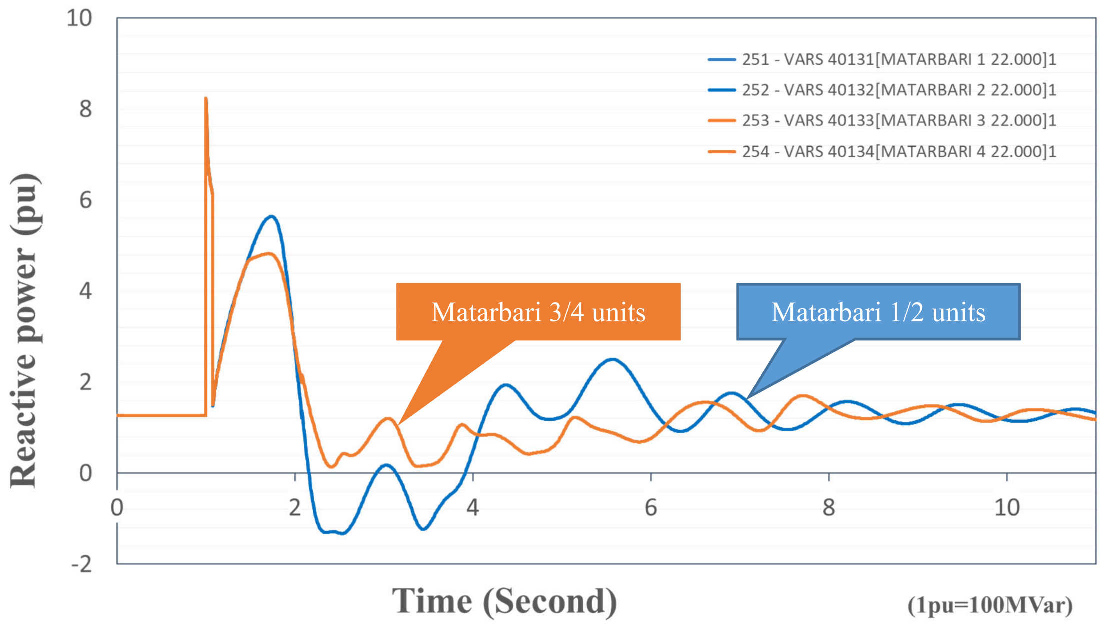
Source: Study Team

Figure 6.4-11 Rotor angle of the generator on Case 004: a fault at MADUNAGHAT end of the transmission line from BANSHKHALI to MADUNAGHAT cleared after 0.08 second with larger inertia of Matarbari 3/4 units



Source: Study Team

Figure 6.4-12 Active power of the generator on Case 004: a fault at MADUNAGHAT end of the transmission line from BANSHKHALI to MADUNAGHAT cleared after 0.08 second with larger inertia of Matarbari 3/4 units



Source: Study Team

Figure 6.4-13 Reactive power of the generator on Case 004: a fault at MADUNAGHAT end of the transmission line from BANSHKHALI to MADUNAGHAT cleared after 0.08 second with larger inertia of Matarbari 3/4 units

The figure above shows the system is stable under the assumption with a larger inertia constant of Matarbari 3/4.

Chapter 7 Outline of the Project Plan

7.1 Objective

This Project is an expansion phase of the Units 1/2 Project to construct a highly efficient ultra-super critical coal-fired power plant (Units 3/4) with a rated output of 1,200MW and related facilities.

This Project is in line with the policy of the Bangladesh's power sector to meet the Bangladesh's rapidly growing electricity demand and to diversify energy sources by using coal which is highly economical.

7.2 Main Facilities and Equipment

7.2.1 Overall Plan and Implementation Method

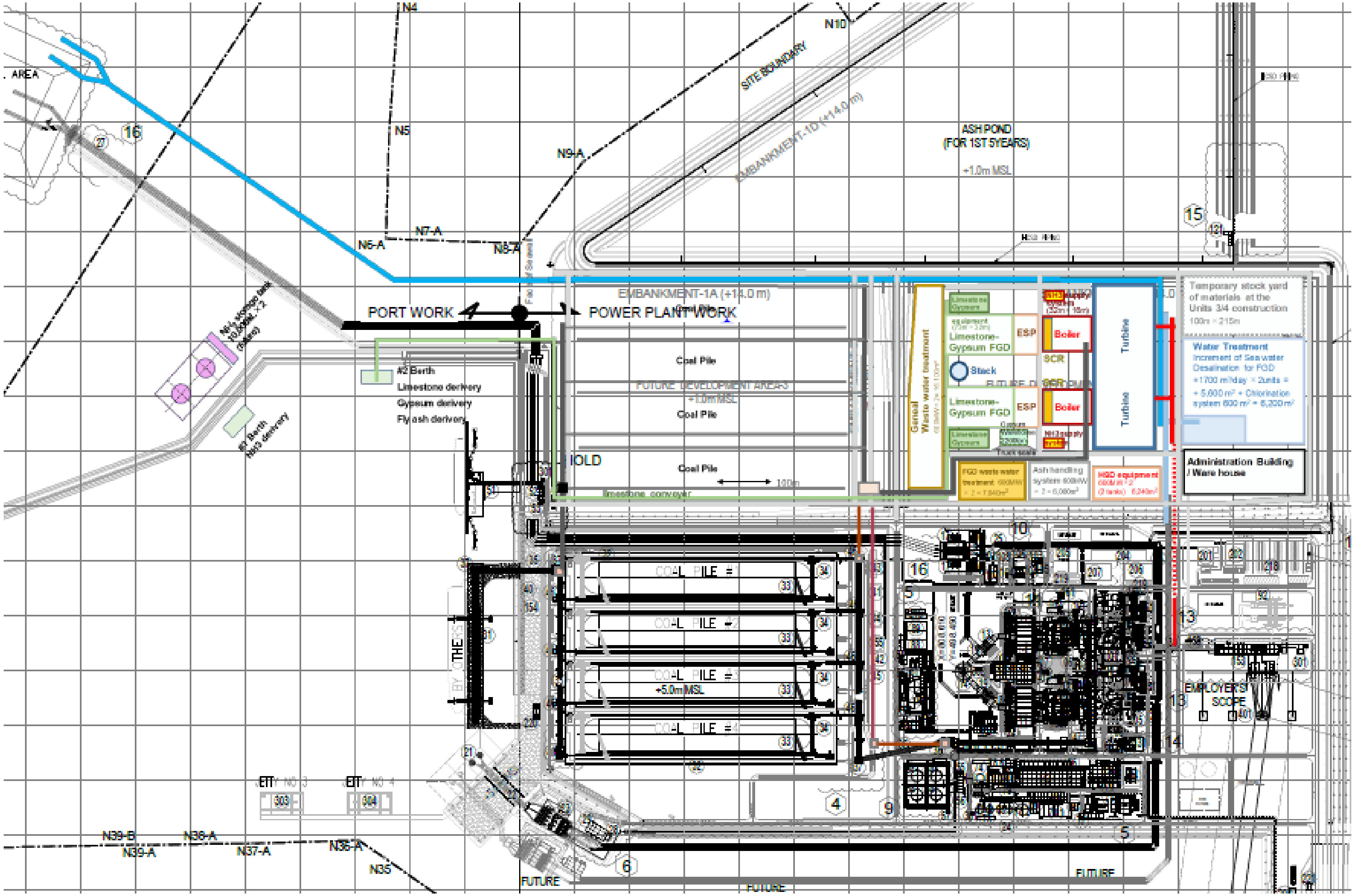
The ultra-supercritical coal-fired power plants (Units 3/4) and related facilities of this project are planned to be constructed adjacent to Units 1/2. Units 3/4 are planned to be high-efficiency coal-fired power plant same as Units 1/2 and further improvements will be considered in terms of environmental performance and that contribute to power system stabilization in view of the future renewable energy adoption.

In addition, this Project is an expansion project of the Matarbari coal-fired thermal power plant. Some equipment's and infrastructure of Units 1/2 project will be used as common facility for this Project. As a result, power generation cost of overall project (Units 1 - 4) will be lower.

7.2.2 Principle Plant Layout

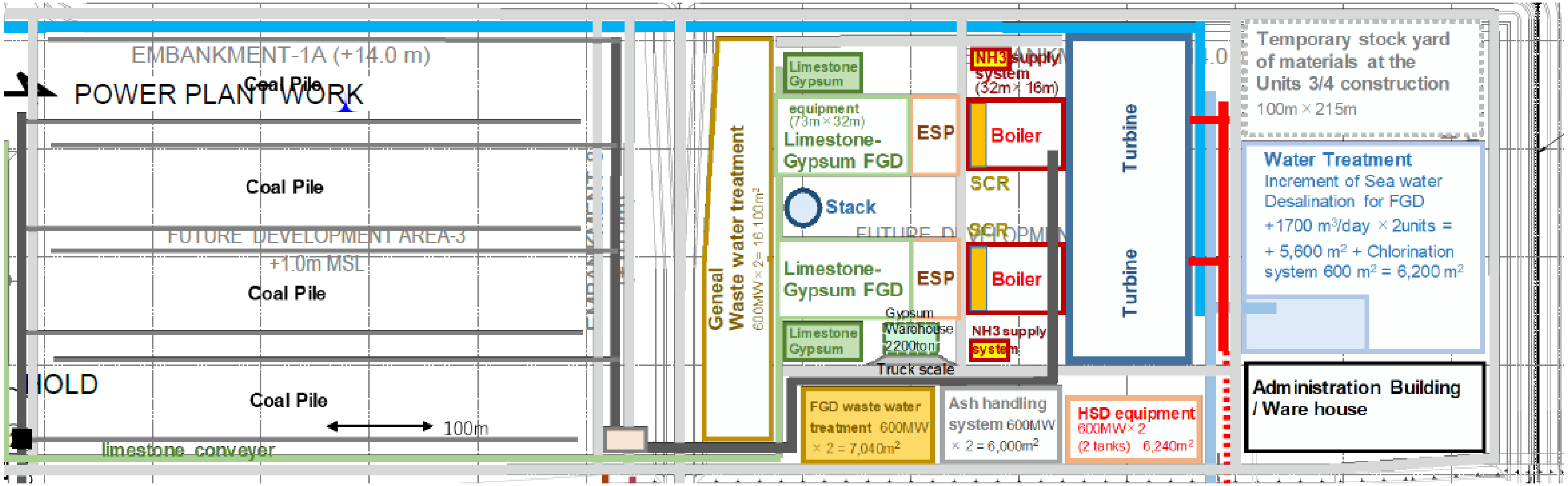
The plant layout of this project is planned to utilize the site space on the north side of Units 1/2, and the coal storage area and main equipment layout will be aligned with the plant layout of Units 1/2 as much as possible.

The required area for the coal storage area and main equipment area of this Project is approx. 55.3 ha.



Source: Study Team

Figure 7.2-1 Overall layout plan of Matarbari Coal-fired Power Plant



Source: Study Team

Figure 7.2-2 Plant Layout (Power Block and Coal Storage Area) for Phase 2 Project

7.2.3 Plant Type, size and Capacity

The plant type, size and capacity will be an ultra-supercritical coal-fired power plant with a single unit capacity of 600MW at generator end (generator terminal after deduction excitation loss) and two units same as Units 1/2. Therefore, the scale of the project is assumed to be 600MW x 2 = 1,200MW.

7.2.4 Works and services to be provided by the Contractor

The works include the complete project management, design, engineering, necessary studies to collect input data for design, liaison with third parties regarding the CPGCBL's permitting and licensing, progress monitoring and reporting materials and equipment procurement, construction and erection, transportation, importing of goods, compliance with all relevant statutory legislation and requirements of start-up, commissioning, trial run and performance testing, training of CPGCBL's personnel and contractor's documents including as-built documents, and other necessary facilities and services for a fully operational plant within the boundaries as defined in the specification.

(1) Boiler and Auxiliaries

The works include, but are not limited to, the following equipment and materials:

1) Boiler
2) Coal bunker
3) Coal pulverizer with inverter
4) Coal feeder
5) Coal burner
6) Ignition lighter
7) Start-up oil burner
8) Forced draft fan
9) Primary air fan
10) Soot blower system
11) Air heater
12) Induced draft fan
13) Electrostatic precipitator
14) Flue gas desulfurization system (Limestone gypsum method)
15) Flue gas denitration system (SCR: Selective Catalytic Reduction method)
16) Stack
17) Fuel oil service tank
18) Fuel oil pump
19) Essential spare parts as a minimum
20) Tools and test equipment
21) Consumable for commissioning and defect liability period

(2) Coal Supply Facilities

The works include, but are not limited to, the following equipment and materials:

1) Unloader (common facilities with Units 1/2)
2) Coal yard
3) Conveyor (Receiving, Stacking, Reclaiming and Feeding)
4) Stacker
5) Reclaimer
6) Essential spare parts as a minimum
7) Tools and test equipment
8) Consumable for commissioning and defect liability period

(3) Ash Handling Equipment

The works include, but are not limited to, the following equipment and materials:

1) Furnace bottom clinker handling equipment
2) Fly ash collection equipment

3) Fly ash storage silo
4) Ash discharging conveyor
5) Essential spare parts as a minimum
6) Tools and test equipment
7) Consumable for commissioning and defect liability period

(4) Steam Turbine and Auxiliaries

The works include, but are not limited to, the following equipment and materials:

1) Steam turbine
2) Condenser
3) Steam turbine bypass system (High pressure bypass)
4) Steam turbine bypass system (Low pressure bypass)
5) Condenser cathodic protection equipment
6) Condenser tube cleaning equipment
7) Condenser vacuum pump
8) Condensate pump
9) Grand steam condenser
10) Condensate demineralizer
11) Low pressure feed water heaters
12) Deaerator
13) Turbine-driven boiler feed pump
14) Motor-driven boiler feed pump
15) High pressure feed water heaters
16) Cooling water pump
17) Cooling water heat exchanger
18) Auxiliary oil pump
19) Emergency bearing oil pump
20) Oil cooler
21) Turning gears
22) Turning gear oil pump
23) Essential spare parts as a minimum
24) Tools and test equipment
25) Consumable for commissioning and defect liability period

(5) BOP (Balance of Plant)

The works include, but are not limited to, the following equipment and materials:

1) Auxiliary boiler
2) Circulating water supply system including screen, pump and piping
3) Chlorination plant
4) Desalination plant including service water supply facilities and service water tank
5) Demineralization plant
6) Make-up water tank
7) Chemical injection / sampling facilities
8) Hydrogen gas generation plant
9) Nitrogen and oxygen generation System
10) Carbon dioxide and nitrogen supply system
11) Compressed air (instrument air and service air) supply system
12) Wastewater treatment facilities
13) Fire-fighting system
14) Chemical laboratory equipment
15) Overhead crane

(6) Electrical Equipment

The works include, but are not limited to, the following equipment and materials:

1) Generator
2) Generator step-up transformer (GSUT)

3) Unit auxiliary transformer (UAT) and station auxiliary transformer
4) Unit electric supply facilities (Metal clad switchgear, Auxiliary transformer, Emergency diesel generator etc.)
5) Electrical protection and metering system
6) Equipment for 400kV switchyard
7) Generator auxiliaries including excitation system
8) Generator circuit system including GCB, IPB, VT / SA and NGR
9) Motor control center (MCC) and distribution board
10) Uninterruptable power supply facilities (UPS)
11) DC power system
12) Cathodic protection system
13) Power cables and wiring materials
14) Control cables and wiring materials
15) Cable trays and fitting materials
16) Grounding materials and lightning protection system
17) Plant lighting system
18) Communication system

(7) Instrumentation and Control Equipment

The works include, but are not limited to, the following equipment and materials:

1) Plant interlock system
2) Boiler control system
3) Burner control system
4) Turbine control system
5) Plant auxiliary interlock and sequence control system
6) Data acquisition historical storage and retrieval system
7) Local control system
8) Remote monitoring system
9) CEMS (Continuous Emission Monitoring System)
10) CMMS (Computerized Maintenance Management System)
11) Fuel coal analyzing system
12) Rotating machine vibration monitors
13) Water / steam analyzing system
14) Instrumentation and control cables

(8) Civil, Architectural Building

The works include, but are not limited to, the following equipment and materials:

1) Soil improvement
2) Land development
    - Coal yard area (+5.0 m M.S.L)
    - Power block area and switchyard area (+10.0 m M.S.L)
3) Turbine building
4) Central control building
5) Fuel oil pump and electrical room
6) H2 gas generation plant room
7) Electrostatic precipitator & coal ash electric/control room
8) FGD electrical control building
9) Desulfurization/denitration plant electrical room
10) Water treatment plant control building
11) Chemical laboratory building (Option[1])
12) Waste water treatment equipment electrical/control room
13) Filtered water pump, air/compressor room
14) Fire-fighting water pump room and electrical room (Option)
15) Coal yard control building

[1] Option: Necessity of equipment / facilities and building of Units 3/4 will be reconsidered during the detailed design stage since these equipment / facilities and building of Units 1/2 Project may utilize as common

16) Transfer tower control room for coal conveyor
17) Coal yard electrical room
18) High concentration slurry disposal (HCSD) building
19) Water intake, electro chlorination, desalination building
20) Cooling water pump area electrical building
21) Workshop (Option) and warehouse
22) Fire station (Option)
23) Administration building
24) Canteen building
25) Garage
26) Stack and foundation
27) TG foundation, boiler foundation and auxiliary foundation
28) Coal bunker foundation
29) Condenser cooling intake/discharge equipment (intake, intake channel, intake pit, outfall, outlet)
30) Electrostatic precipitator foundation
31) Desulfurization equipment foundation
32) Flue gas duct support foundation
33) Limestone conveyor foundation
34) Ash/limestone silo and foundation
35) Water treatment plant foundation
36) Waste water treatment plant foundation
37) Chlorination plant and piping foundation
38) Auxiliary tank and foundation
39) HSD tank foundation and dike
40) Pipe rack foundation and trench
41) Coal yard, Coal shed and foundation
42) Coal handling facilities foundation
43) Coal conveyor foundation, transfer tower foundation and junction tower
44) Limestone/ammonia unloading jetty
45) Transformer foundation
46) Switch yard foundation
47) Storm water drainage
48) Service road
49) Outdoor lighting foundation
50) Leveling and Landscaping
51) Fence and Gate

(9) Equipment and Tools for plant operation and maintenance

The works include, but are not limited to, the following equipment and materials:

1) Tool
   TIG welding machine/ AC welding Machine/ DC Welding machine/ Lathe/ Drill press/ Miller/ Grinder(installed type)/ Grinder(handy type)/ Pipe bender/ Compressor/ Other tools
2) Measuring Equipment
   Infrared thermograph/ Radiation thermometer/ Ultrasonic thickness gage/ Oximeter/ Noise level meter/ Gas detector/ pH meter/ other tools
3) Equipment for emergency
   Drainage pump (engine drive)/ Drainage pump (electromotive)/ Ventilation fan (big)/ Ventilation fan (small)/ others
4) Desk Equipment
   Personal Computer/ Copy machine/ Handy Video/ Camera/ Projector/ TV monitor
5) Fire Extinguisher
   Fire extinguisher (200L)/ Fire extinguisher (100L)/ Fire extinguisher (50L)/ Fire extinguisher (20L)/ Oil fence

(10) Construction Works

The works include, but are not limited to, the following construction and start-up / commissioning services:

1) Construction management including scheduling, expediting and supervision of the works concerned maintaining security and Safety
2) Provision, implementation and management of a fully compliant quality assurance / quality control program covering all aspects of the works
3) Provision of all documents / drawings necessary for erection / installation, piping, cabling and commissioning
4) Provision of all facilities, consumables and tools necessary for erection and commissioning
5) Provision of site office / housing with necessary equipment including drinking / service water, lightings and drainage / sanitary facilities
6) Provision of storage / housing for all equipment / materials
7) Shipping and custom clearance with necessary processing of notices and documents
8) Obtaining and securing all required local, state and government permissions
9) Transportation, storage and handling of all equipment / materials maintaining due quality
10) Fuel cost during start-up to successful initial synchronization
11) Provision of construction utilities including electricity, water, gas and compressed air
12) Erection, installation, adjustment and fixing of all equipment / facilities
13) Plumbing / piping and cabling / wiring of all equipment and facilities
14) Testing and commissioning of all equipment and facilities
15) Performance test including verification of guaranteed / required data / characteristics
16) Cleaning all equipment / facilities and clearing out all unnecessary materials after construction at site
17) Construction management
18) Hydrological, bathymetric, recirculation studies needed to clarify cooling water conditions
19) Site topographic geotechnical investigation / boring
20) Site soil investigations
21) Construction labor and tools
22) Construction equipment
23) Safety and loss control program
24) Quality assurance program
25) Procurement expediting
26) Manufacturer’s field services
27) Reception of equipment and materials (including custom clearance), handling and storage
28) Preoperational checkout, testing, and start-up
29) Construction closeout and site finishing
30) Construction of storage area
31) First aid and security (during construction)
32) Participate in coordination conferences and other meeting as the CPGCBL may request

(11) Engineering Works

The works include, but are not limited to, the following works:

1) Project management including scheduling and expediting of all works concerned with the resolution of unexpected difficulties and obstacles
2) Quality assurance of all works / equipment concerned including periodical reports to CPGCBL
3) Design of all systems and equipment, and provision of documents and drawings to the CPGCBL and consultant
4) Procurement / production of all equipment / facilities with the disclosure of purchasing documents if required
5) Workshop test with submission of documents in advance and of the results afterward to the CPGCBL
6) Workshop training with effective facilities / materials for the CPGCBL
7) Field training including deskwork and examination
8) Provision of protection relays setting plan
9) Participation in meetings for design review, progress and project coordination
10) Provision of operation and maintenance manual
11) Provision of additionally required drawings and documents during project execution

7.3 Fuel Supply Plan

7.3.1 Types of coal

Coal can be roughly divided into four types according to the progression of carbonization degree.
As shown in Figure 7.3-1, it is also classified into three categories according to their uses.
In order of decreasing bituminization, the coals are classified as brown coal, sub-bituminous coal, bituminous coal, and anthracite. The higher the carbon content, the higher the calorific value and the lower the moisture content of the coal.
The main applications of each category are as follows

- Anthracite: sintering, coal briquette
- Coking: iron making, coke raw material
- Thermal: power generation, cement fuel

Category	Brown Coal	Sub-bituminous	Bituminous	Anthracite
Bituminization	Low			High
Calorific Value (kcal/kg)	2,500 - 4,000	4,000 - 6,000	4,500 - 7,000	4,500 - 8,000
Moisture (%)	60 - 30	30 -15	Less than 15	Less than 10

Category	Thermal	Coking	Anthracite
Intended Purpose	Power generation Cement fuel	Iron making Coke raw material	Sintering Coal briquette

Source: Study Team

Figure 7.3-1 Types of Coal

7.3.2 Proven reserve of coal in the world

The proven reserve of coal in the world is shown in Table 7.3-1.

In 2019, the proven reserve of coal in the world is 1,069.6 billion tons, and the reserve-production ratio is 132 years. Compared to oil and gas, coal has a longer reserve-production ration and is found in various regions and countries.

The top-ranking countries of proven reserve is the United States, Russia, Australia, China and India.

Table 7.3-1 Proven Reserve of Coal in the World

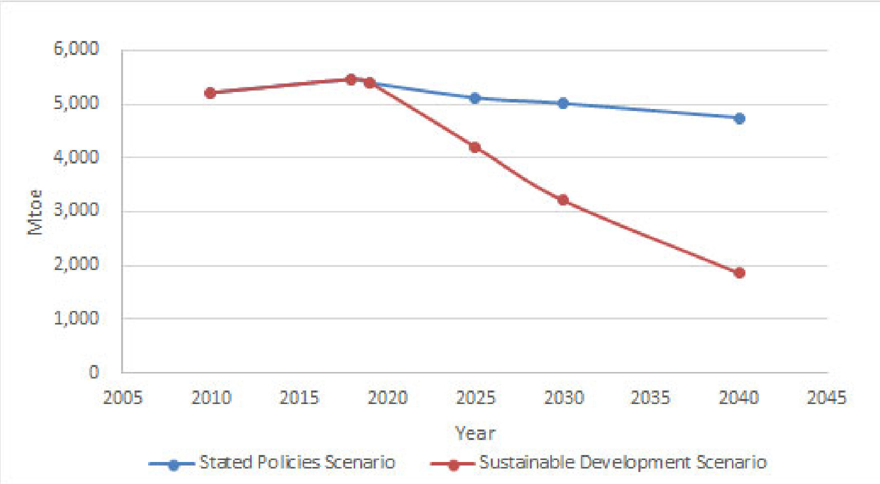
Million tonnes	Anthracite and bituminous	Sub-bituminous and lignite	Total	Share of Total	R/P ratio
Canada	4,346	2,236	**6,582**	0.6%	130
Mexico	1,160	51	**1,211**	0.1%	108
US	219,534	30,003	**249,537**	23.3%	390
Total North America	225,040	32,290	**257,330**	24.1%	367
Brazil	1,547	5,049	**6,596**	0.6%	*
Colombia	4,554	0	**4,554**	0.4%	55
Venezuela	731	0	**731**	0.1%	*
Other S. & Cent. America	1,784	24	**1,808**	0.2%	*
Total S. & Cent. America	8,616	5,073	**13,689**	1.3%	152
Bulgaria	192	2,174	**2,366**	0.2%	153
Czech Republic	413	2,514	**2,927**	0.3%	71
Germany	0	35,900	**35,900**	3.4%	268
Greece	0	2,876	**2,876**	0.3%	105
Hungary	276	2,633	**2,909**	0.3%	425
Poland	21,067	5,865	**26,932**	2.5%	240
Romania	11	280	**291**	♦	13
Serbia	402	7,112	**7,514**	0.7%	193
Spain	868	319	**1,187**	0.1%	*
Turkey	550	10,975	**11,525**	1.1%	140
Ukraine	32,039	2,336	**34,375**	3.2%	*
United Kingdom	26	0	**26**	♦	12
Other Europe	1,109	5,172	**6,281**	0.6%	141
Total Europe	56,953	78,156	**135,109**	12.6%	244
Kazakhstan	25,605	0	**25,605**	2.4%	222
Russian Federation	71,719	90,447	**162,166**	15.2%	369
Uzbekistan	1,375	0	**1,375**	0.1%	339
Other CIS	1,509	0	**1,509**	0.1%	331
Total CIS	100,208	90,447	**190,655**	17.8%	338
South Africa	9,893	0	**9,893**	0.9%	39
Zimbabwe	502	0	**502**	♦	215
Other Africa	4,376	66	**4,442**	0.4%	202
Middle East	1,203	0	**1,203**	0.1%	*
Total Middle East & Africa	15,974	66	**16,040**	1.5%	57
Australia	72,571	76,508	**149,079**	13.9%	294
China	133,467	8,128	**141,595**	13.2%	37
India	100,858	5,073	**105,931**	9.9%	140
Indonesia	28,163	11,728	**39,891**	3.7%	65
Japan	340	10	**350**	♦	462
Mongolia	1,170	1,350	**2,520**	0.2%	44
New Zealand	825	6,750	**7,575**	0.7%	*
Pakistan	207	2,857	**3,064**	0.3%	481
South Korea	326	0	**326**	♦	300
Thailand	0	1,063	**1,063**	0.1%	76
Vietnam	3,116	244	**3,360**	0.3%	73
Other Asia Pacific	1,333	726	**2,059**	0.2%	32
Total Asia Pacific	342,376	114,437	**456,813**	42.7%	77
Total World	**749,167**	**320,469**	**1,069,636**	**100.0%**	**132**

Source: BP Statistical Review of World Energy 2020

7.3.3 Global coal demand

Figure 7.3-2 shows the actual global coal demand up to 2019 and the forecast up to 2040.
In the IEA's scenario, following 2 cases are described.

- Stated Policies Scenario: Covid-19 is gradually brought under control in 2021 and the global economy returns to pre-crisis levels the same year
- Sustainable Development Scenario: a surge in clean energy policies and investment puts the energy system on track to achieve sustainable energy objectives in full, including the Paris Agreement, energy access and air quality goals.



Source: IEA World Energy Outlook 2020

Figure 7.3-2 Forecast of Global Coal Demand

Global coal demand, which had been growing steadily before Covid-19, is prospected to decline slowly until 2040 in the Stated Policies Scenario.

In the Sustainable Development Scenario, coal demand in 2040 is prospected to decline by about 34% compared to 2019.

7.3.4 Global coal production

The global coal production is shown in Table 7.3-2. The global coal production in 2019 is 8.1 billion tons. The production amount by country, China is overwhelming in comparison to other countries and its volume accounts for more 47% of the total world coal production followed by the India, the United States, and Indonesia.

Table 7.3-2 Global Coal Production

Million tonnes	2019
Canada	50.5
Mexico	11.2
US	639.8
Total North America	701.5
Brazil	7.8
Colombia	82.4
Venezuela	0.3
Other S. & Cent. America	1.2
Total S. & Cent. America	91.7
Bulgaria	15.4
Czech Republic	41.0
Germany	133.9
Greece	27.3
Hungary	6.9
Poland	112.4
Romania	21.7
Serbia	39.0
Spain	0.1
Turkey	84.0
Ukraine	26.2
United Kingdom	2.2
Other Europe	67.5
Total Europe	577.4
Kazakhstan	115.4
Russian Federation	440.4
USSR	n/a
Uzbekistan	4.1
Other CIS	6.9
Total CIS	566.8
Total Middle East	1.5
South Africa	254.3
Zimbabwe	2.3
Other Africa	22.0
Total Africa	278.7
Australia	506.7
China	3846.0
India	756.4
Indonesia	610.0
Japan	0.8
Mongolia	57.1
New Zealand	3.0
Pakistan	6.4
South Korea	1.1
Thailand	14.1
Vietnam	46.3
Other Asia Pacific	63.8
Total Asia Pacific	5911.8
Total World	8129.4

Source: BP Statistical Review of World Energy 2020

7.3.5 Coal export countries

The major coal exporting countries in 2019 are shown in Table 7.3-3.
Indonesia, Australia, and Russia are in the top-ranking. On the other hand, the amount of coal export of China, India and United States is small due to their own consumption.

Table 7.3-3 Top-ranking of Coal Export Countries

(million tonnes)

Indonesia	455
Australia	393
Russian Federation	217
US	84
South Africa	81
Colombia	72
Canada	36
Mongolia	28
Kazakhstan	25
Philippines	14

Source: IEA Coal Information 2020

7.3.6 Coal import countries

The major coal importing countries in 2019 are shown in Table 7.3-4
Top coal importers are mainly East Asian countries such as China, India, Japan, and South Korea. European countries are also importers

Table 7.3-4 Top-ranking of Coal Import Countries

(million tonnes)

China	298
India	247
Japan	185
Korea	130
Chinese Taipei	67
Viet Nam	44
Germany	41
Turkey	38

Source: IEA Coal Information 2020

7.3.7 Coal Specification

This Project will construct a high-efficiency ultra-supercritical pressure coal-fired power plant (Units 3/4) and related facilities as an expansion phase of the Units 1/2 Project.

The coal receiving jetty will be shared with the Units 1/2 project. Therefore, it is better to select the coal mine same as the Units 1/2 Project from economic point of view.

Although the coal mine for the Units 1/2 Project has not yet been finalized as of October 2021, the specifications of the performance coal and design coal are presented to the EPC contractor of the Units 1/2 Project are shown in Table 7.3-5.

In addition to the specifications shown in Table 7.3-5, the following should also be taken into consideration when determining the coal mine in the future.

- Hardgrove Grindability Index (HGI)
  There are no allowable values in the international standards.
  This index is pulverizability of coal; the higher index, the better the grindability.
  This index is taken into account in the design of the pulverizer.
  The range of HGI in the basic design of Units 1/2 Project is 55 - 63.

- Lower Hg, Cd and Pb
  There are no allowable values in the international standards.
  The lower is the better, since the trace elements affect human body.
  According to published documents[2] by IEA Clean Coal Center, the results of trace element analysis of coal (average) is as follows.

Element	Average range (mg/kg)
Cadmium (Cd)	0.01 - 0.19
Mercury (Hg)	0.03 - 0.19
Lead (Pb)	1.1 - 22

Source: IEA Clean Coal Center

Table 7.3-5 Specification of Performance Coal and Design Coal

Item	Unit	Performance Coal	Range	
			Single Band	Blending Coal
(1) Heating Values				
GAR (Gross as received) (HHV)	kcal/kg	4,600	4,200 - 5,200	4,500 - 4,900
NAR (Net as received) (LHV)	kcal/kg	4,240		
(2) Total Moisture (as received base)				
Total moisture	%	31.0	Max. 38.0	Max. 38.0
(3) Proximate Analysis (air dry base)				
Inherent moisture	%	16.0	Max. 25.0	Max. 25.0
Ash	%	6.0	Max. 7.0	Max. 20.0
Volatile matter	%	40.0		
Fixed carbon	%	38.0		
(4) Total Sulphur (air dry base)				
Total Sulphur	%	1.0	Max. 1.0	Max. 1.0

Source: Study Team

The index of performance coal is a reference value to be corrected when calculating the guaranteed performance values (output and efficiency) from the measured values of output and efficiency during the performance test.

The index of design coal can be broadly classified into the case of a single type of coal (single brand) and the case of a mixture of multiple types of coal (blending coal). In both cases, the power plant should be operated continuously within the range of Table 7.3-5.

The description of coal properties is as follows

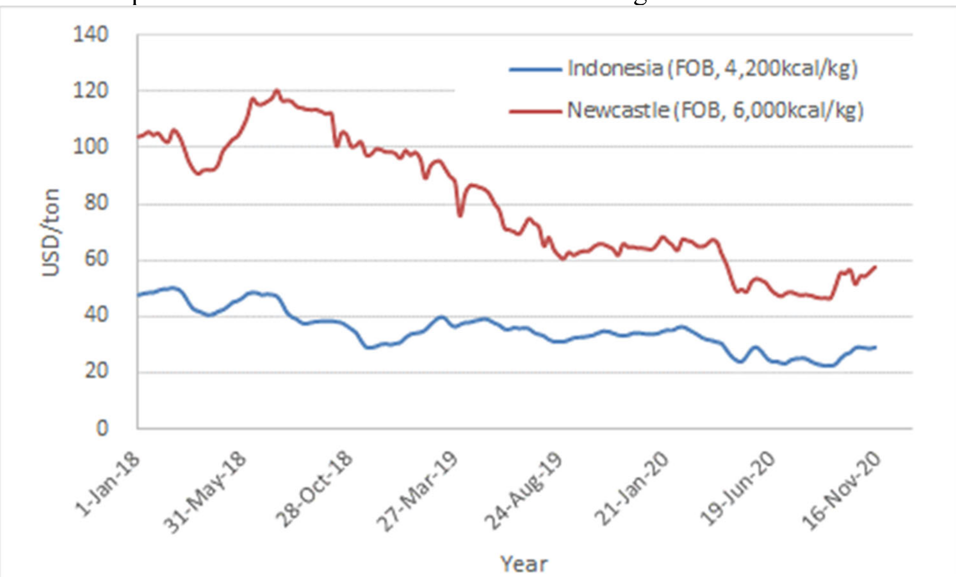
[2] Trace element emissions from coal

- Gross as received (HHV): Higher heating value when coal is received in Bangladesh. The sum of the lower heating value (NAR (Net as received) (LHV)) and the latent heat (heat of vaporization of water), which affects the coal consumption.
- Total moisture: Total value of moisture held by coal and adhered moisture, affecting efficiency.
- Inherent moisture: Moisture content held by coal, it is one of the indices of carbonization degree and affects the spontaneous exothermicity.
- Ash: Unburned content in ash, affects ash disposal.
- Volatile matter: Affects combustibility and efficiency.
- Fixed carbon: One of the indicators of carbonization degree.
- Total sulfur: Affects the amount of SOx generated.

7.3.8 Coal Price

(1) Price trend

The coal price trend from 2018 to 2020 is shown in Figure 7.3-3.



Source: IEA Coal 2020

Figure 7.3-3 Trend of Coal Price

It can be seen that coal prices vary with calorific value.

After 2019, the price difference between different calorific values is almost constant and the coal price with 4,200 kcal/kg is 47%-50% of the coal price with 6,000 kcal/kg.

Coal price are influenced by situation in the major exporting countries (Australia and Indonesia) and the major importing countries (China and India).

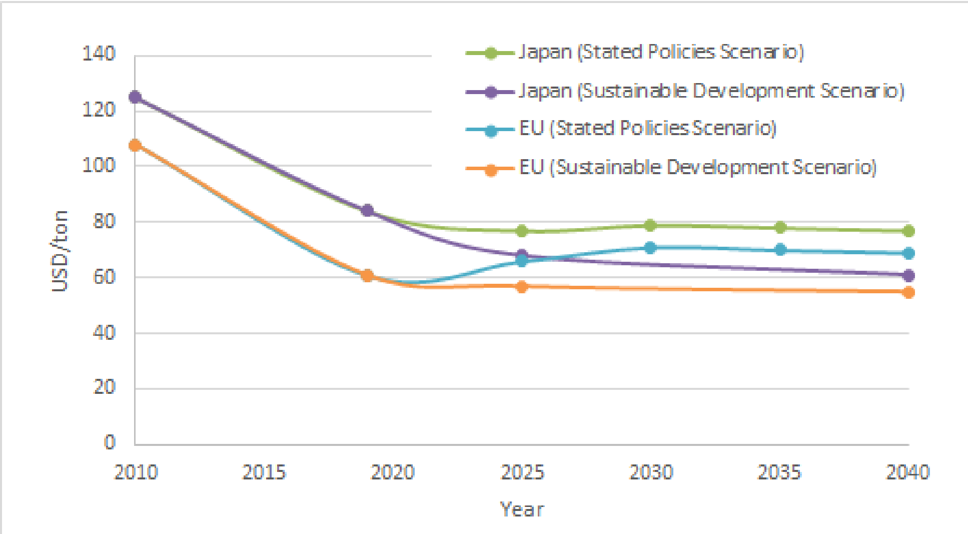
After December 2020, the coal market price is affected by increasing demand due to economic recovery from Covid-19 and importing restriction on Australian coal in China.

Coal price has risen to their highest level in a decade due to a global coal supply shortage.

(2) Price forecast

Figure 7.3-4 shows the actual prices of imported coal (average heating value is 6,000kcal/kg) in Japan and the EU up to 2019 and the forecast up to 2040.

In the IEA forecast scenario, the Stated Policies Scenario and the Sustainable Development Scenario are described.



Source: IEA World Energy Outlook 2020

Figure 7.3-4 Forecast of Coal Price

In the case of Japan, comparing the actual results in 2019 with the forecast in 2040, the Stated Policies Scenario prospects that coal prices will remain almost the same, while the Sustainable Development Scenario prospects that prices will decrease by about 20%.

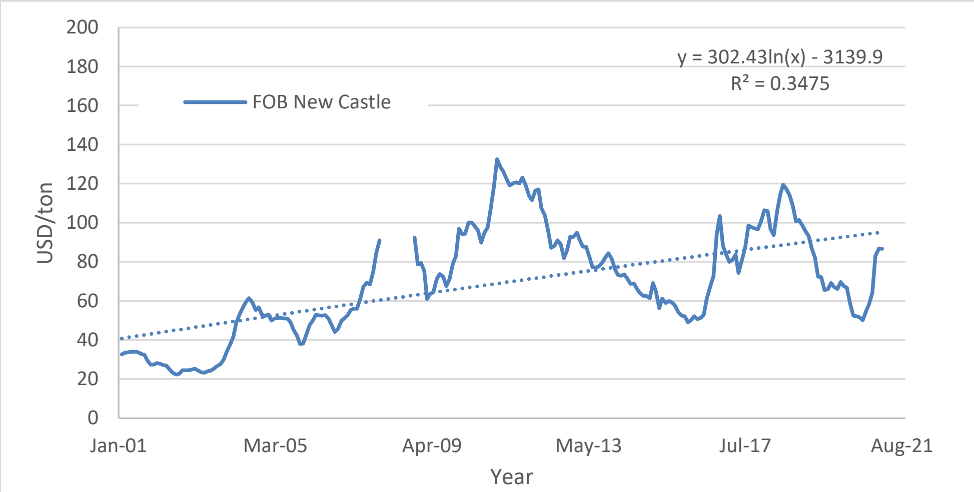
(3) Forecast of the imported coal price in Bangladesh

Figure 7.3-5 shows the FOB price trend of coal with calorific value of 6,000 kcal/kg at the port of Newcastle, Australia since 2001.

Source: Study Team from index mundi website

Figure 7.3-5 FOB price trend of coal (6,000 kcal/kg) at Newcastle

In examining the trend, the rapid price increase from January to October 2008 shown in Figure 7.3-5 is inappropriate for predicting future prices, so the period is removed and the regression line was obtained, the results of which are shown in Figure 7.3-6.

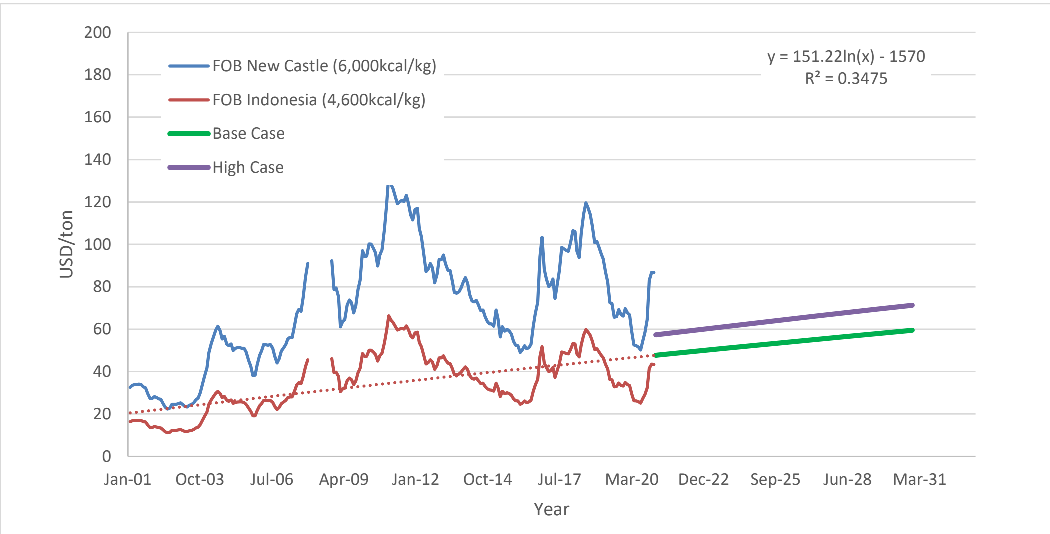


Source: Study Team

Figure 7.3-6 Regression line from Figure 7.3-5 excluding the data from January to October 2008

As shown in Figure 7.3-3, the price difference of coal is almost constant depending on the calorific value. Therefore, based on the FOB price trend of coal with a calorific value of 6,000 kcal/kg at Newcastle shown in Figure 7.3-6, the assumed FOB price of the performance coal (calorific value of 4,600 kcal/kg) to be imported from Indonesia is shown in Figure 7.3-7.

Using the price difference shown in Figure 7.3-3 as a reference, the FOB price of coal (calorific value of 4,600 kcal/kg) when imported from Indonesia is assumed to be 50% of the FOB price of coal at the Newcastle. This is assumed to be the base case, and the high case is assumed to be the base case plus 20%.



Remarks: Assumptions until 2030 which will be COD of Units 3/4

Source: Study Team

Figure 7.3-7 Forecast of FOB price

The reason of the IEA's prediction that the imported coal price in Japan and the EU will decrease due to accelerate for zero emission and decreasing the coal demand. On the other hand, it is true that some countries including Bangladesh will continue to operate the coal-fired power plants depending on their government policies, so the coal will continue to be essential for these countries.

Therefore, it depends on the supply-demand balance of coal, but as far as the trend of imported coal prices over the past 20 years is concerned, it could be expected that the price of imported coal will be increased.

The price of imported coal in Bangladesh is the FOB price of coal plus freight & insurance costs and handling costs in Bangladesh.

In recent years, transportation and insurance costs have been rising. This cost is difficult to predict as it varies greatly depending on the tightness of vessel operations. In this study, this cost is quoted from Argus Coal Transportation published by Argus Media Group on December 8, 2020 and regular research reports by the Institute of Energy Economics, Japan as a reference, and assumed a transportation and insurance cost of USD 15/ton in the base case and USD 18/ton, a 20% increase, in the high case.

The handling cost in Bangladesh is estimated at USD10/ton, taking into account the number of operators, salaries and O&M costs. Since this cost will be part of the O&M costs used in the project evaluation in Chapter 15, it is considered as a fixed cost.

Table 7.3-6 shows the results of the calculation after considering all the costs mentioned above.

Table 7.3-6 Price of imported coal in Bangladesh (USD/ton)

Year	FOB Price (4,600kcal/kg)		Freight & Insurance (DWT 80,000)		Handling Cost	Total of Coal Price	
	Base Case	High Case	Base Case	High Case		Base Case	High Case
2021	48.6	58.4	15.0	18.0	10	73.6	86.4
2022	49.9	59.9	15.0	18.0	10	74.9	87.9
2023	51.1	61.3	15.0	18.0	10	76.1	89.3
2024	52.3	62.8	15.0	18.0	10	77.3	90.8
2025	53.5	64.2	15.0	18.0	10	78.5	92.2
2026	54.7	65.7	15.0	18.0	10	79.7	93.7
2027	55.9	67.1	15.0	18.0	10	80.9	95.1
2028	57.1	68.5	15.0	18.0	10	82.1	96.5
2029	58.3	69.9	15.0	18.0	10	83.3	97.9
2030	59.4	71.3	15.0	18.0	10	84.4	99.3

Source: Study Team

7.3.9 Coal transportation, loading port, transportation route and navigation days

The FS report for the Units 1/2 project discusses in detail the case of procuring coal from Indonesia, Australia, South Africa and Mozambique, which is validated based on the results of a study of coal types (sub-bituminous coal) that can be imported by the country, shipping distances, coal mines in exporting countries, coal production capacity, and loading ports.

On the other hand, it is confirmed with CPGCBL that as of October 2021, the coal mine has not yet been determined, but from the view of economic efficiency, it is highly possibility that coal will be imported from Indonesia or Australia, which are neighboring countries considered in the Units 1/2 FS report.

Therefore, in this section, the navigation days is re-estimated based on the results of the study if coal is imported from Indonesia and Australia as described in the Units 1/2 FS report, and reflecting the planned Units 1/2 equipment specifications is shown in Table 7.3-7.

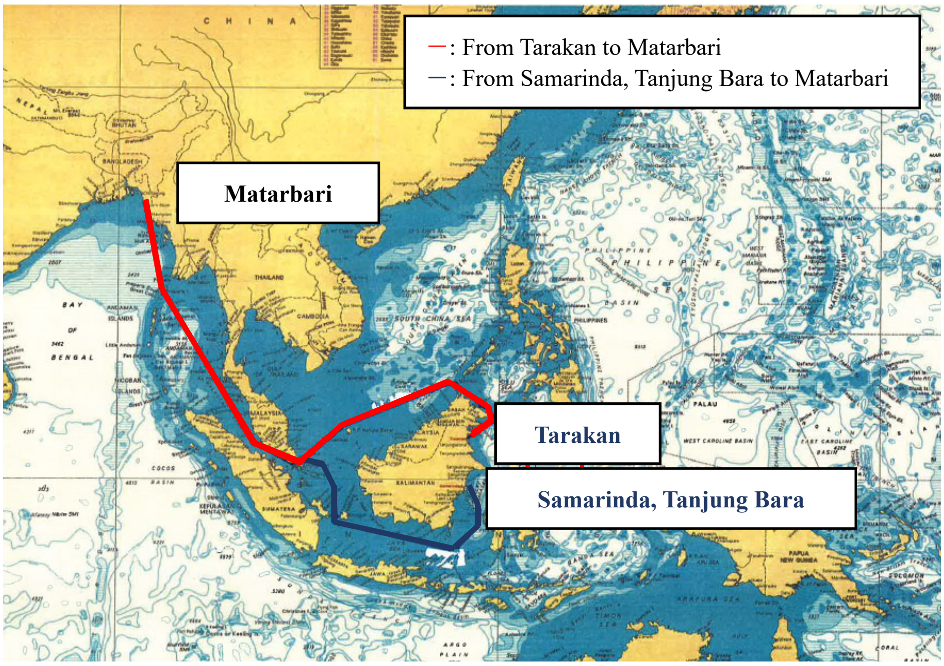
Figure 7.3-8 shows the transportation route between Matarbari Port and East Kalimantan Island of Indonesia, and Figure 7.3-9 shows the transportation route from Newcastle Port in Australia.

In addition, it is recommended that CPGCBL confirm whether the coal supplier conducts appropriate environmental considerations at the stage of selecting the coal mine.

Table 7.3-7 Navigation Days from the Main Port in Indonesia and Australia

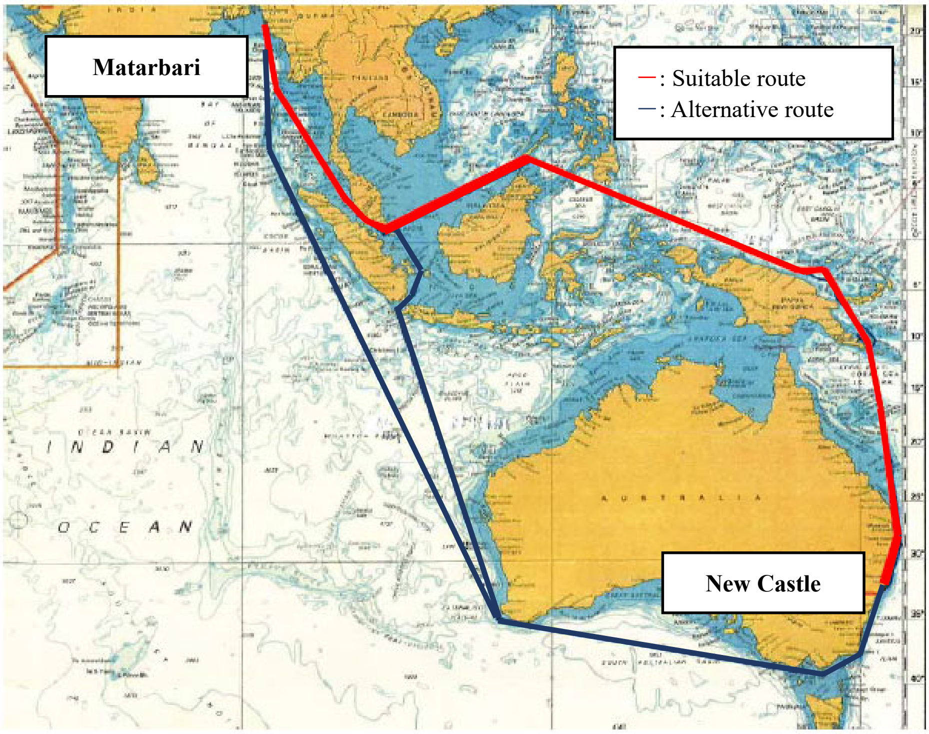
Item	Representative Port			
Loading Port	Australia	Indonesia		
	NEW CASTLE (Jetty)	TARAKAN (Anchored)	SAMARINDA (Anchored)	TANJUNG BARA (Jetty)
Planned vessel Expected sailing speed (Outward / Homeward)	PANAMAX type (DWT 80,000) 14knt / 13knt			
[Bound]				
Distance of shipping via Singapore (mile)	5,824	2,837	2,647	2,716
Navigation days (day)	17.33 (= 5,824/14knt)	8.44 (= 2,837/14knt)	7.88 (= 2,647/14knt)	8.08 (= 2,716/14knt)
Time of fuel supply at Singapore (day)	0.3			
Waiting days of loading on offing (day)	10	3		
Loading capacity of one day (ton/day)	30,000	10,000	17,000	35,000
The total number of loading days (day)	2.7 (= 80,000/30,000)	8.0 (= 80,000/10,000)	4.7 (= 80,000/17,000)	2.3 (= 80,000/35,000)
[Return]				
Distance of shipping via Singapore (mile)	5,824	2,837	2,647	2,716
Navigation days (day)	18.67 (= 5,824/13knt)	9.09 (= 2,837/13knt)	8.48 (= 2,647/13knt)	8.71 (= 2,716/13knt)
Waiting days of unloading (day)	2			
The total number of unloading days (day)	2.29			
The toal number of navigation days (day)	53.3	33.1	28.7	26.7
The number of annual shipping (shipping/year)	6	11	12	13

Source: Study Team from Preparatory Survey on Chittagong Area Coal Fired Power Plant Development Project in Bangladesh



Source: Preparatory Survey on Chittagong Area Coal Fired Power Plant Development Project in Bangladesh

Figure 7.3-8 Transportation Route from East Kalimantan Island, Indonesia



Source: Preparatory Survey on Chittagong Area Coal Fired Power Plant Development Project in Bangladesh

Figure 7.3-9 Transportation Route from Australia

Chapter 8 Conceptual Design

8.1 Overview of power generation equipment

8.1.1 Design policy

(1) Power generation equipment design policy

Since Units 3/4 is adjacent to Units 1/2, which is under construction in advance, the basic design follows the plan of Units 1/2, but it is becoming a global trend to strengthen global warming countermeasures these days. Therefore, further improvements will be considered for plant performance, environmental performance, and functions that contribute to power system stabilization with a view to the spread of renewable energy in the future.

In addition, since this project is premised on the export of high-quality, highly efficient, and environmentally friendly infrastructure from Japanese manufacturers or G7 countries, the design conditions will be such that the high performance can be utilized.

(2) Design conditions for power generation equipment (natural conditions)

Based on the same design air temperature 30^{o}C (15^{o}C – 35^{o}C), design humidity 80%, and seawater temperature 30^{o}C (turbine capability 32^{o}C) as planned for Units 1/2.

(3) Model of power generation equipment

As described in “8.2 Basic Study of Plant System”, the power generation equipment will be planned as a coal-fired USC 600MW sliding pressure plant, which is the same as the plan for Units 1/2.

The gross output is planned to be 600MW at the same power generation as Units 1/2 and an auxiliary power consumption rate is 6.5%, so the net power output will be 561MW.

The reason for using a sliding pressure plant is to enable high-efficiency operation even when dealing with intermediate loads, in consideration of the introduction of renewable energy in the future.

For the improvement of the load change rate, the constant pressure plant has an advantage because there are few plant fluctuation factors, but it is judged comprehensively that it is a sliding pressure plant.

(4) Thermal efficiency of power generation equipment

The total thermal efficiency of the power generation equipment of Units 3/4 is as follows.

Coal-fired power generation equipment:
Thermal efficiency at rated output: 41.1% or more
(HHV gross base, firing with sub-bituminous coal: Performance coal of Units 1/2)

Since the thermal efficiency of the boiler changes depending on the type of coal, Units 3/4 is planned as a power generation facility that can satisfy 41.1% when sub-bituminous coal are exclusively burned.

The steam conditions for the boiler and turbine are ultra-supercritical pressure (USC).

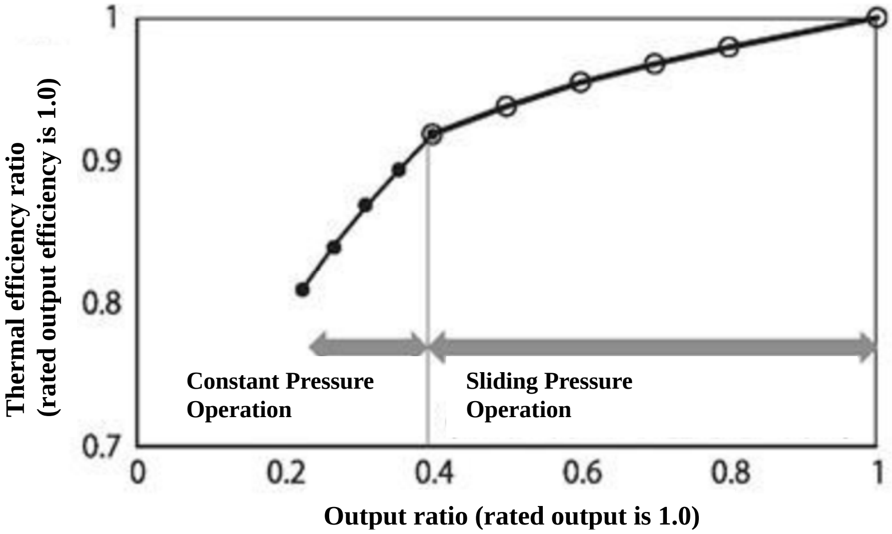
The thermal efficiency (HHV, gross base) differs depending on the steam conditions and the planned coal type (bituminous coal or subbituminous coal). The difference is the order shown below.

- In the case of bituminous coal
  Main steam temperature / reheat steam temperature = 600^{o}C / 600^{o}C, 43.5%
- In the case of sub-bituminous coal (Performance coal of Units 1/2)
  Main steam temperature / reheat steam temperature = 600^{o}C / 600^{o}C, 41.1%
  600^{o}C / 610^{o}C, 41.1% + 0.1% (absolute value)
  600^{o}C / 620^{o}C, 41.1% + 0.2% (absolute value)

The rated steam conditions for the preceding Units 1/2 are main steam pressure 24.5MPa, main steam temperature 600^{o}C, and reheat steam temperature 600^{o}C, and Units 3/4 are planned under steam conditions as same as Units 1/2.

The net heat rate is planned to be 9,295 kJ/kWh, similar to Units 1/2.

The total thermal efficiency of the power generation equipment at partial load changes as shown in Figure 8.1-1.



Source: October 28, 2020 Electric Newspaper (Central Research Institute for Electricity)

Figure 8.1-1 Coal-fired steam power generation plant output and total thermal efficiency

From Figure 8.1-1, assuming that the total thermal efficiency (high calorific value, gross) at rated output is 41.1%, the total thermal efficiency at each load is 40.4% at 85%, 40.0% at 75% load, 38.6% at 50% load and 36.6% at 35% load.

Table 8.1-1 Estimated total thermal efficiency (HHV/LHV) and in-house power ration

	Total thermal efficiency-**gross** (according to above figure) HHV / LHV	Estimated In-house power ratio (including common facilities)	Total thermal efficiency-**net** HHV / LHV
100% ECR	41.1 % / 44.6 %	6.50 %	38.4 % / 41.7 %
85% ECR	40.4 % / 43.8 %	6.51 %	37.8 % / 41.0 %
75% ECR	40.0 % / 43.4 %	6.51 %	37.4 % / 40.6 %
50% ECR	38.6 % / 41.9 %	7.86 %	35.6 % / 38.6 %
35% ECR	36.6 % / 39.7 %	9.69 %	33.2 % / 36.0 %

Note: In-House power ratio is estimated by the performance test data of 1,000MW Coal-fired plant with Limestone-Gypsum FGD + SCR, Performance Coal HHV= 4,600 kcal/kg, LHV=4,240 kcal/kg base

100%MCR plant efficiency will be estimated approx.39.6% (41.1%／(BMCR 623.1MW / MCR 600MW))

Plant efficiency at 623.1MW ECR condition is estimated approx.41.0%.

However, the design output of the generator is 600 MW, and it is necessary to separately confirm the possibility of continuous operation exceeding 600 MW, and this efficiency is just a reference value.

Auxiliary power consumption is estimated 6.5% (approx. 39MW) and breakdown is as follows.

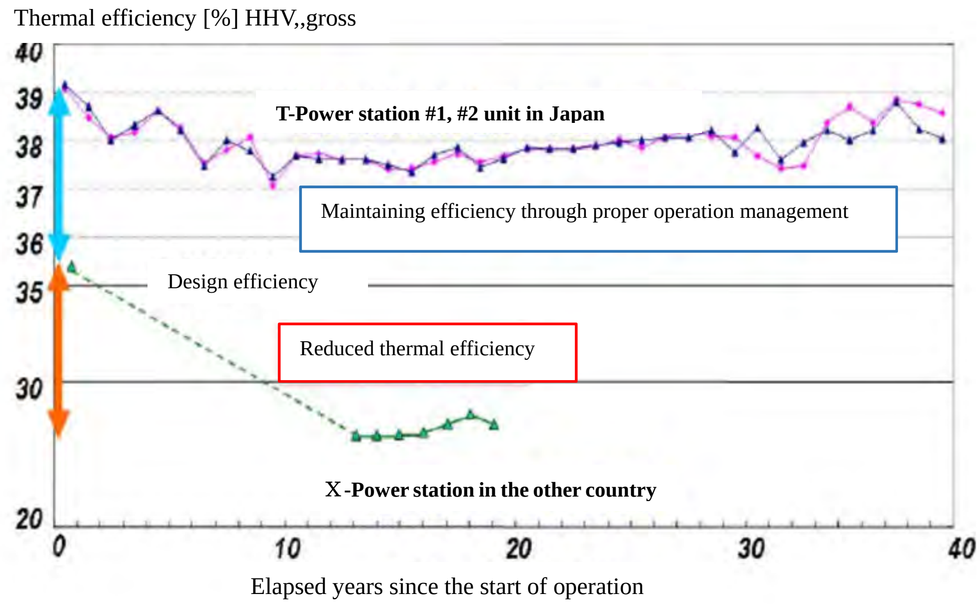
・Boiler auxiliary equipment (FDF, IDF, PAF, Pulverizer, etc.): 34%

・Turbine-Generator and utility auxiliary equipment (CP, CWP, water treatment, wastewater treatment, ash handling etc.): 44%

・Environmental equipment (ESP, FGD etc.): 22%.

Source: Study Team

Figure 8.1-2 shows an example of domestic coal-fired power generation (Coal-fired, 250MW subcritical pressure unit) for changes in the total thermal efficiency due to aging deterioration of power generation equipment.



Source: March 2015, METI Comprehensive Energy Study Group

Figure 8.1-2 Changes of the thermal efficiency of coal-fired power plant over time

Even if appropriate operation management is implemented from Figure 8.1-2, the total thermal efficiency (high calorific value, gross) has deteriorated by about 1.0 to 1.5% (absolute value) in 20 years after the start of operation.

Compared to the actual unit of 250MW subcritical pressure in Figure 8.1-2, Units 3/4 is USC 600MW, so it is considered that it will be relatively small against deterioration such as expansion of steam leakage from the turbine.

However it is estimated that there will be a decrease in thermal efficiency of about 1% in 20 years.

(5) Operational performance of power generation equipment

Regarding the operational performance of power generation facilities, from the perspective of ensuring system stability as the introduction of renewable energy, which has many unstable factors as supply capacity to the power system in the future, is expanded, the operational performance of Units 3/4 has the following capabilities.

The operational performance of Units 3/4 is different from the value of Units 1/2, but it is planned within the range of the actual results of the commercial plant and within the range that the equipment cost does not increase significantly.

(5-1) Load changing rate

The load changing rate of Units 1/2 is planned to be 3%/min in the load range of 50% to 95%.

In Units 3/4, for the purpose of power system stabilization, it is planned to be 4%/min in the load range of 50% to 100% rated, within the range that does not require significant equipment expansion. (under discussion with counterpart)

In Units 3/4, in order to eliminate the plant output holding time that accompanies the stabilization of the mill start and stop during load changes, the mill motor is planned to be equipped with an inverter, and the turndown range of the mill will be expanded.

(5-2) Minimum stable load

The minimum stable load for coal combustion is generally 30%, but Units 3/4 will be equipped with 15% ECR.

Since it is a USC plant and sliding pressure operation is a design condition, 15% ECR is planned to ensure stable operation after the boiler shifts to wet (circulation operation) mode.

(5-3) Plant startup time

In particular, as a response to system disturbances that occur in the short term due to instability as a supply capacity of renewable energy, hot start is possible (from ignition to rated output in the startup time within 8 hours stop) within 120 minutes.

The hot start time of Units 1/2 is planned to be 180 minutes.

For Units 3/4, 120 minutes was set to the extent that no significant equipment expansion was necessary and in consideration of recent plant operation results with coal burning.

Start up time is defined as from the first ignition to 100% load.

(5-3-1) Cold start: Approx. 650 minutes

Cold start is defined as:

Start after 56 continuous shutdown hours, boiler unfired and not drained.

For shutdown periods of less than 72 hours, the boiler may not be drained.

If the shutdown period exceeds 72 hours, the boiler shall be drained.

(5-3-2) Warm start: Approx. 300 minutes

Warm start is defined as:

Start after more than 8 hours, but less than 56 continuous shutdown hours, boiler unfired and not drained.

(5-3-3) Hot start: Approx. 120 minutes

Hot start is defined as:

Start after not more than 8 continuous shutdown hours.

(5-3-4) Black start

Not applicable.

(5-4) In-house independent operation (FCB function)

In coal-fired power plants, the number of plants with equipment configurations that can carry out independent operation (FCB: Fast Cut Back main fuel rapidly decreasing function) is increasing.

Units 3/4 is also planned as a facility that can be operated independently in the facility by shutting off the load from the rated output by equipping it with an appropriate steam bypass system (high pressure turbine bypass, low pressure turbine bypass, etc.).

(5-5) Continuation of operation when the system frequency drops

Even if the system frequency drops due to the withdrawal of supply of solar power generation and wind power generation in a wide range due to the expansion of the introduction of renewable energy in the future, the plant operation will be continued within the range that does not hinder the maintenance of equipment.

There is a margin in endurance in coal fired steam turbine generator shaft twist caused by the inertial moment (GD^2) between the turbine and the generator when the grid system frequency drops, because that the weight of the turbine generator rotating body of a coal-fired steam power plant is smaller than that of a gas turbine (combined cycle) with the heavy compressor.

And also gas turbine blades tends to be more risk of the damaged due to approaching the natural frequency.

Due to the natural frequency of the gas turbine blade, the gas turbine (combined cycle) usually takes 1 minute when the system frequency (at 50 Hz) is 48.5 Hz, and it is generally an instantaneous trip at 47.5 Hz. is there.

At Units 3/4, the unit is tripped with large vibration or “over excitation protection” on the generator side without setting a trip value due to a decrease in the system frequency. Or even if the system frequency is 47.5 Hz or less, it will be set to not instantly trip. The plan is to contribute to grid system stabilization when the grid system frequency drops, assuming that the risk of equipment damage is low, such as setting a timer for a certain period of time (for example, 20 seconds).

In addition, even if the system frequency drops, the coal-fired plant that trips the power generation equipment with "over excitation protection" continues to operate up to 46.3Hz at the time of system blackout, and there is a track record of no equipment damage.

Table 8.1-2 Operational Requirement (comparison table of Units 1/2 and Units 3/4)

	Units 1/2	Units 3/4
Load changing rate (in the load range of 50% to 95%)	3% / minutes	4% / minutes
Minimum stable load (coal combustion without oil)	30% ECR	15% ECR

Plant start up time (Hot start) (from ignition to rated output)	180 minutes	120 minutes
In-house independent operation (FCB: Fast cut back function)	With function	With function

Source: Study Team

(6) Environmental performance of power generation equipment

(6-1) Air quality

The SOx, NOx, and dust concentrations in the exhaust gas at the stack outlet shall be below the emission standards of Bangladesh and considering IFC/WB EHS Guideline. The stack outlet emission concentration of Units 3/4 is planned as follows.

SOx: 200 mg/Nm^3
NOx: 62 mg/Nm^3 (as NO_2)
Particulate matter: 25 mg/Nm^3
Both (ref. O_2 = 6% dry base)

In the JICA project, the international standards that have been finalized should be referred to, and therefore, the IFC/WB EHS Guidelines (Thermal Power Station; 2008) (final version) are basically referred to in this project.

However, for the emission concentration at the stack outlet of Units 3/4, in light of the recent situation surrounding coal-fired power plant projects, it is decided to use stricter standards (IFC/WB EHS Guidelines (Thermal Power Station; 2017 draft)) which have not yet been finalized but are already widely referred to at present, are used as a reference.

In this IFC/WB EHS Guideline (Thermal Power Station; 2017 draft), there are two categories of the emission concentration setting such as DA (Degraded airshed) and NDA (Non-degraded airshed).

Because Units 3/4 is an expansion project of Units 1/2 and to reduce the ambient concentration up to minimum level, DA setting of emission concentration should be considered.

Furthermore, among the stack outlet emission concentration of Units 3/4 is set to 62 mg/Nm^3 (as NO_2) for NOx, because regarding to the maximum landing concentration of 1 hour for Units 1 to 4 that is set to less than 200 µg/m^3 (as NO_2) by the IFC/WB EHS Guideline 2007.

In addition to the recent greenhouse prevention measures (USC technology), the environmental conservation measures equipment will be planned to reduce the environmental load as much as possible, and to be the equipment that can demonstrate the best performance currently proven.

(6-1-1) The SOx reduction measure

The SOx reduction measure is planned the "limestone gypsum method", which is a desulfurization device that can achieve a high desulfurization rate and reduce pollution to the sea area.

Table 8.1-3 shows a comparison between the limestone gypsum method and the seawater desulfurization method (600MW).

Table 8.1-3 Comparison of desulfurization methods (limestone gypsum method and seawater desulfurization method: 600MW)

Process	Limestone / Gypsum method	Seawater desulfurization method
Chemical reaction	Sulfur dioxide gas + calcium carbonate + water + oxygen ⇒ Gypsum + carbon dioxide $SO_2 + CaCO_3 + 2H_2O + 1/2\ O_2$ $\Rightarrow CaSO_4 . 2H_2O + CO_2$	Sulfurous acid gas + seawater ⇒ Sulfurous acid ion Sulfate ion + oxygen ⇒ Sulfate ion $SO_2 + H_2O \Rightarrow SO_3- + 2H$ $SO_3- + 1/2\ O_2 \Rightarrow SO_4-$
Desulfurization rate	90 - 99%	90 - 95%
Absorbent	Limestone	Seawater
By-product	Gypsum (used as cement / gypsum board)	Drainage (returned to the sea)
Wastewater treatment	Water treatment by wastewater treatment equipment	Ocean acidification in an oxidation pond

Installation space	Large (limestone / gypsum processing equipment, etc.)	Small (sea hydroxide pond)
Water consumption	Desalination water	None (seawater)
Comprehensive economic efficiency	base Construction cost (additional to seawater desulfurization method) Limestone + gypsum equipment + non-recovery wastewater treatment system = +1.92 billion JPY, absorption tower make-up water / seawater desalination equipment = +1.87 billion JPY / unit	Low costs (Approx. -3.79 billion JPY / unit)
Track record	Many since the 1970s	Matarbari Units 1/2 etc.
Notices	・It is essential to establish a distribution route for the supply of limestone and the sale of gypsum. (Gypsum can be processed at the ash dump, but the life of the ash dump is shortened.) ・ Because no seawater is used, an excellent method for environmental conservation in the sea area without any problems. ・In the limestone / gypsum method, CO_2 is emitted from the carbon contained in the limestone. The amount of CO_2 emitted from the desulfurization equipment is 51,729 ton-CO_2 / year / 600 MW x 2 units.	Compared to the Limestone/Gypsum method, there is a possibility that auxiliary power can be reduced by about 10%.

Source: Study Team

Refer to Appendix-14 for the cost difference (approximate) between the desulfurization equipment "limestone-gypsum method" and "seawater desulfurization method" of Unit 3/4.

In addition, this limestone-gypsum method is required the procurement of valuable limestone and the gypsum is produced as by-product which will be sold to cement factories.

There is a possibility that the gypsum can be sold to a cement factories or a gypsum board company, and there is no increase in operating costs due to offsetting.

(6-1-2) The NOx reduction measure

A full-scale selective catalytic reduction denitrification equipment using ammonia (SCR) was first introduced in commercial boilers in 1978, and SCR has been adopted for all commercial coal-fired power plants in Japan since 1990.

NOx reduction measures will be equipment that can achieve a boiler outlet NOx concentration of 308mg/Nm^3 = 150ppm (as NO_2 ref.O_2 = 6% dry base) or less by adopting a low NOx burner, two-stage combustion, and a high fine particle size mill.

In addition, from the viewpoint of reducing NOx at the boiler outlet due to the introduction of multi-coal species, an SCR (DeNOx device) is to be installed at the boiler outlet to reduce the NOx concentration at the chimney inlet to 62 mg/Nm^3 = 30 ppm (as NO_2 ref.O_2 = 6% dry base) or less.

The reason why the boiler outlet NOx concentration target was set to 308mg/Nm^3 = 150 ppm or less is that sub-bituminous coal has a large amount of volatile matter, and the boiler outlet NOx concentration is suppressed to be lower than that of bituminous coal. In addition, as a countermeasure against the increase in the differential pressure of the air preheater, it is effective to reduce the SCR device inlet NOx as much as possible, so the value was set to 308mg/Nm^3 = 150 ppm or less.

The mechanism of the differential pressure rise of the air preheater will be described.

In Units 3/4, there is a plan to install a DeNOx device, and leak (unreacted) ammonia from the DeNOx device reacts with SO_3 in the exhaust gas to generate acidic ammonium sulfate, which adheres to the element of the air preheater and differential pressure rises.

If this differential pressure exceeds the control value, the risk of damage to the lower bearing of the air preheater increases, and if it exceeds the control value, the plant should be stopped (or the load is reduced to 50% and one lung operation is performed). The heating elements of air preheater needs to be washed with water. As a measure to prevent the differential pressure of the air preheater from increasing, it is effective to reduce the leak (unreacted) ammonia from the DeNOx device as much as possible (control concentration is 3 ppm or less). Suppressing the DeNOx inlet NOx (boiler outlet NOx) reduces the amount of ammonia injected by the DeNOx device, and the leaked ammonia can be reduced accordingly. As a result, it is possible to suppress an increase in the differential pressure of the air preheater.

The capacity of the DeNOx device is planned so that the catalyst can be easily added in order to prevent the differential pressure of the air preheater (GAH) installed under the DeNOx device from rising.

Based on the below assumption, the result of cost estimation of the denitration device (SCR + NH_3 supply system) is shown in Appendix-14.

(a) "SCR + NH_3 supply system"

SCR inlet NOx → 309 mg / Nm^3 (as NO_2) = 309 x 22.4 / (14 + 16 x 2) = 150 ppm (as NO_2)

SCR outlet NOx → 62 mg / Nm^3 (as NO_2) = 62 x 22.4 / (14 + 16 x 2) = 30 ppm (as NO_2)

<Target / denitration rate>

SCR inlet NOx 150 ppm = 309 mg/Nm^3

Target NOx reduction rate = (150 - 30)/150 x 100 = 80% (SCR outlet NOx 30ppm = 62 mg/Nm^3 as NO_2)

Target SCR outlet unreacted (leak) NH_3 ≤ 3 ppm (air preheater AH differential pressure prevention / experience value)

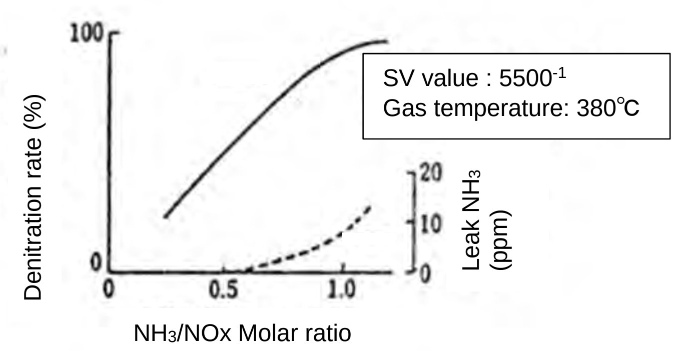
Leak NH_3 [ppm] = SCR inlet NOx [ppm] × (Molar ratio: NH_3/NOx－ Denitration rate η/ 100)

3ppm = 150ppm x (Molar ratio - 80/100) → Target Molar ratio = 0.825 ≒ 0.83

(SCR outlet NOx 30 ppm as NO_2 = 62 mg / Nm^3)

(b) SCR catalyst model: Honeycomb type (lattice)

From Figure 8.1-3, SV value [h-1] (treatment gas flow rate [Nm^3/h] / catalyst amount [m^3]) = 5500 h^{-1}.



Source: TENPES 1996.2

Figure 8.1-3 Relationship between molar ratio, denitration rate, and SV value

	SCR inlet NOx **309** mg/ Nm^3 (as NO_2)
SCR inlet NOx	**150** ppm = **309** mg/ Nm^3 (as NO_2)
SCR outlet NOx	**30** ppm = **62** mg/ Nm^3 (as NO_2)
Required NOx reduction rate	**80** %
Required Molar ratio (NH_3/NOx)	0.83
leak NH_3	leak $NH_3 \leqq$ 3ppm base
SV value (*not Plate type)	5500 h^{-1}
Exhaust gas flow	1.849 $\times 10^6$ Nm^3/h- dry gas
SCR inlet exhaust gas temp.	380 °C
Exhaust gas velocity in SCR	4 m/s
estimated **Catalyst volume**	**336.2** m^3
Reactor cross section	307.1 m^2
Catalyst height	1.1 m
Number of catalyst layer	2～3 layers
NH_3 consumption	**177.5 kg/h-NH_3 / 600MW × 1unit**
NH_3 spacific gravity 0.771 [kg/ ℓ]	$NH_3 = 1.849 \times 10^6 \times 150 \times 10^{-6} \times 0.83 \times 0.771$ exhaust gas SCR inlet NOx Molar ratio (NH_3/NOx)

Source: Study Team

(c) SCR + NH_3 supply system operating cost

With the adoption of the denitration device, the Flue gas pressure loss due to SCR increases by about 100 mmH_2O, and the power of FDF tends to increase slightly, but the ratio to the total internal power is small. The increase in in-house power is excluded from the evaluation.

The operating cost of the SCR + NH_3 supply system shall be the cost associated with NH_3 consumption. A detailed investigation is required for the NH_3 distribution market in Bangladesh, but the use of NH_3 in the water treatment system for Unit 1/2 and the standard market for NH_3 on the web site information (Jamuna Fertilizer Co., Ltd. - JFCL, reported on 14/July/2021). The unit price is shown.

NH_3 consumption: 177.5 kg / h-NH_3 / 600 MW x 1 unit

NH_3 unit price: (2,700kg = 88,106.4 BDT) 42.3 JPY/kg (1 BDT = 1.2965 JPY)

Price of loading + sea transportation: regarded 3 JPY/kg

→ 2.3 JPY/Nm^3 (source: 2018 METI of Japan) → NH_3 gas = 0.771kg/Nm^3, 2.3/ 0.771 ≒ 3 JPY/kg

Total NH_3 local unit price = 42.3 + 3 = 45.3 JPY/kg

NH_3 International price: 250～300 USD/ton (Oct. 2020 from China, Malaysia, Indonesia etc.)

→ 28～33 JPY/kg → regarded 33 JPY/kg

Total international NH_3 unit price is regarded 36 JPY/kg (33+3)

177.5 kg/h x 36 JPY/kg = 6,390 JPY/h

Annual NH_3 cost = 44.8 million JPY/year/600MW x 1 unit (* Annual plant operating rate is 80%)

As a particulate matter reduction measure, plan an electric dust collector that meets the emission standard even when burning high-resistance dust coal exclusively or when hammering.

(6-2) Water quality

Water quality standards from the plant are planned to fully meet Bangladesh emission standards.

Also, for trace components in wastewater, consider not only satisfying the emission standards but also making the equipment configuration with as little environmental load as possible.

Table 13.1-9 shows the wastewater emission standards for Units 3/4.

(7) Life of power generation equipment

The life of the power generation equipment is planned to be 30 years or more in consideration of the life of general thermal power.

The life of the power generation equipment is 30 years, which is the same as that of Units 1/2.

The definition of a lifetime of 30 years is that civil engineering / construction and power generation equipment do not involve major repairs or replacements during 30 years of operation.

In the plant service life shall be of not less than 30 years of operation or 200,000 full load operating hours, whichever is longer.

Since it is an ultra-supercritical (USC) plant, the life of the pressure part with a high temperature exceeding 600^{o}C is 200,000 hours or more, taking into consideration deterioration such as creep, high-temperature corrosion, and ash erosion. It is necessary to select and design materials as much as possible.

8.2 Basic study of plant system

8.2.1 Single plant capacity selection

Under the condition of coal-fired USC, a single plant capacity of 350MW (minimum output of USC) or more is selected.

Basically, the capacity of a single plant can be selected according to the needs, but from the viewpoint of design results, it is desirable to consider the standard capacity of the manufacturer.

Here, 600MW and 1000MW are compared as the manufacturer's standard / single plant capacity.

However, in Units 3/4, since it is assumed that Units 1/2 will be installed in the adjacent land, two 600 MW can be installed, but due to space restrictions, only one 1000 MW will be installed.

Even considering the SCR and the desulfurization of the limestone gypsum method planned for the environmental equipment of Units 3/4, it can be arranged layout in the specified site space. (Refer to Figure 8.3-1)

(1) Economic evaluation of 600MW and 1000MW

Compared to 600 MW, 1000 MW has economies of scale up, but on the other hand, 1000MW has no choice but to use two systems due to the limitation of auxiliary equipment capacity, but there is also a plant record of using one system for flue gas channel system and seawater circulating water system for 600 MW. Therefore, it is considered that there is no difference in the economies of scale of construction costs due to the increase in capacity at this time.

Since there is no difference in power generation thermal efficiency between 600MW and 1000MW, it is considered that there is no difference in power generation cost considering the fixed cost + variable cost of both.

(2) Operational performance of 600MW and 1,000MW

Since the load change rate of 4% / min. and the minimum stable load of 15% ECR, which are the operational performance of the plant, are the same, there is no difference in superiority depending on the capacity of a single plant.

However, the total of 600MW is 1,200MW with two units, and it can be said that the selection of 600MW is superior to the 1,000MW x 1 unit in terms of operational performance that contributes to the system.

In addition, 1,000MW has a considerable effect on the system when tripping due to unit trouble.

Therefore, for Units 3/4, we plan to have two units with a single plant capacity of 600 MW.

Table 8.2-1 The comparison result of USC 600MW and 1,000MW

	USC 600MW	USC 1,000MW
Economical	Construction unit price (JPY / kW) / base	Construction unit price is equivalent to 600MW
Operational performance	Load change rate 4% / min.	Equivalent to 600MW at load change rate 4% / min.
Site space	Two units can be placed in the Units 3/4 site space	Only one can be placed in the Units 3/4 site space.

Source: Study Team

8.2.2 Candidates for steam cycle

USC or IGCC (Integrated Coal Gasification Combined Cycle) can be cleared that the thermal efficiency at rated output 43% or more (HHV gross base), for current coal-fired power generation facilities.

Here, we compare USC and IGCC equivalent to 600 MW.

(1) Economics of USC and IGCC

The construction cost of USC is about 1,800 USD/kW, but IGCC will increase by 20 to 30%.

Currently in Japan, IGCC commercial plant Nakoso IGCC Power Station (525MW; net thermal efficiency LHV=48%) is starting commercial operation in April 2021, and it is thought that the construction cost of IGCC will be reduced by mass production from now on, but at the moment the power generation cost is also higher than USC. The price is slightly higher, and it can be said that the economic efficiency is a little tough.

(2) USC and IGCC CO_2 emission intensity

The thermal efficiency of 42% (LHV-net) for pulverized coal-fired USC, while it is net 48% (LHV-net) for 543MW class IGCC, so the CO_2 emission intensity can be significantly reduced.

USC CO_2 emission intensity (coal calorific value 6,200 kcal/kg, elemental analysis: carbon 70%)
= 820 g-CO_2/kWh
IGCC CO_2 emission intensity = 650 g-CO_2/kWh
The steam cycle of Units 3/4 will be planned by USC from the viewpoint of economy.

Table 8.2-2 The comparison result of USC and IGCC

	USC 600MW	IGCC 543MW class
Economical	Construction unit price (JPY / kW) / base	Construction unit price 120～130% of USC 600 MW
Operational performance	Load change rate 4% / min.	Load change rate 16% / min. (on the demonstration plant)
Thermal efficiency CO_2 emission intensity	42% (Low calorific value LHV, net) 820 g-CO_2 / kWh	48% (low calorific value LHV, net) 650 g-CO_2 / kWh

Source: Study Team

8.2.3 Material of main part

For coal-fired USC materials, especially for high-chrome steel used for high-temperature (over 590°C to 600°C) pressure-resistant parts, in the past USC development process, the creep strength of welds may be lower than planned. Therefore, it is necessary to pay particular attention to the selection of materials.

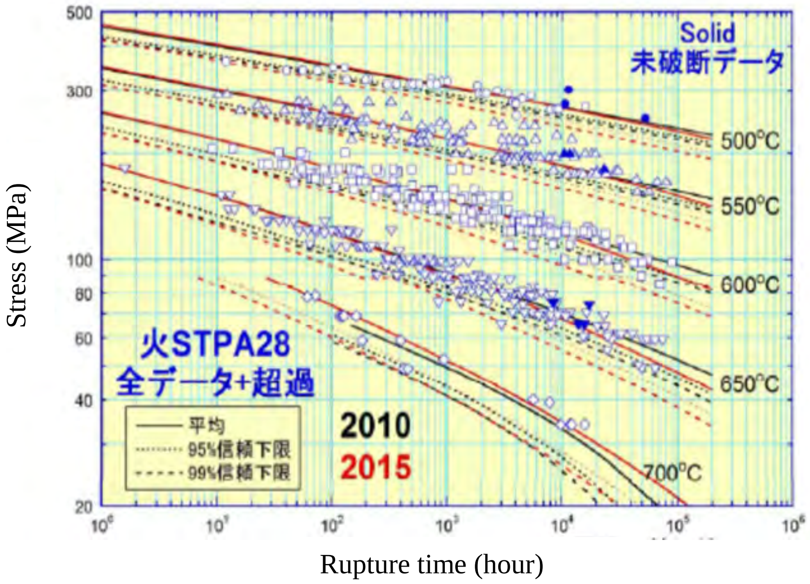
When using high chrome steel, Units 3/4 has a rated operation life of 200,000 hours or more, so the creep life of the high-temperature pressure-resistant part must also be at least 200,000 hours or more.

The allowable stress of Ka-STBA28 and Ka-STPA28 (ASME Gr.91: Modified 9Cr-1Mo Steel) was revised by the METI in 2019, and the creep rupture curve of the base metal and weld joint is presented for more than 200,000 hours, and at the same time creep. The METI revised version of the life calculation formula. The creep rupture curve on which this calculation is based is also for weld joint.

Since it is based on long-term creep rupture data (60,000 hours) and has high reliability, it can be used in plants that require a life of 200,000 hours or more.

However, for Ka STBA29 and Ka STPA29 (ASME Gr.92), METI has given allowable stress, but the creep rupture data of the weld joint is up to 30,000 hours, and it is unreliable for creep life evaluation of 200,000 hours. (The high reliability of extrapolation of the long-term creep rupture curve is said to be up to 3 times the time of the longest creep rupture data .: JIS, ISO)

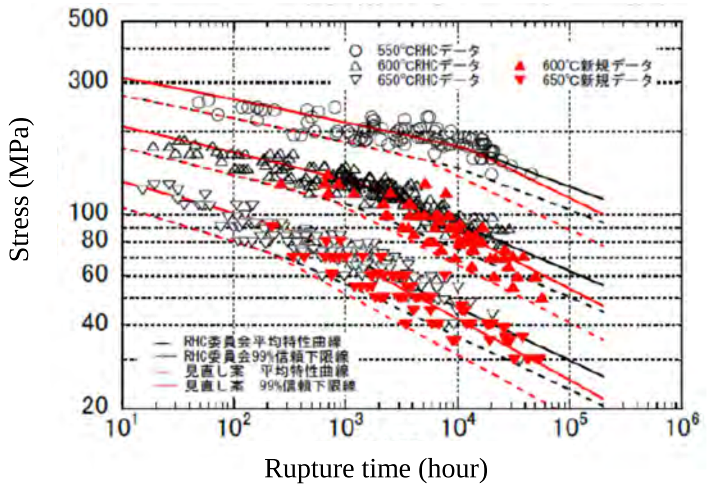
Therefore, when using high chrome steel for the main steam pipe, high temperature reheated steam pipe, pipes in the boiler, stubs, etc. in Units 3/4, it must be a seamless pipe, and the materials should be Ka STBA28 and Ka STPA28 (ASME Gr.91: Modified 9Cr-1Mo Steel).



ASME Gr. 91 base metal Creep Rupture Curve

The longest rupture data at 600 °C is 90,000 hours

Source:
METI- Advisory Committee



ASME Gr. 91 weld joint Creep Rupture Curve

The longest rupture data at 600 °C is 60,000 hours

Source:
METI- Advisory Committee

As for stainless steel pipes used for superheater pipes and reheater pipes, proven SUS316 shot pipes, SUS347HTB pipes, SUPER304H pipes, etc. can be considered, but as a measure against steam oxidation scale inside the pipes, fine-grained structures are considered.

Rotor material of steam turbines can be commonly evaluated by whether the temperature which maintains the creep rupture time of 100,000 hours under stress of 100MPa is higher than its working temperature or not. For a USC plant with 600/600°C steam conditions, modified 12% Cr ferrite steel or higher grade materials can be used as the material of steam turbine rotors.

8.2.4 Cooling method

From the economical point of view, the cooling method will be the same deep water intake / seawater cooling method as Units 1/2.

For Units 3/4, the FGD will use the limestone-gypsum method instead of the seawater desulfurization method, so the water intake and discharge temperature difference is planned to be 6 to7°C. (The basis of adoption limestone-gypsum method for FGD, please refer to clause 7.1.1 (6))

The circulating water (seawater) line supplied to the condenser will be a backwash valve system, and the vacuum level of the condenser will be maintained.

8.3 Basic conditions for power plant design

8.3.1 Design conditions (PQ requirements)

The PQ requirements for the Units 3/4 power plant are described in Clause 16.1.4.

8.3.2 Assumed plant performance

(1) Plant thermal efficiency

In a coal-fired plant, the thermal efficiency varies greatly depending on the type of coal. In particular, in the case of water / hydrogen content loss (boiler heat loss due to latent heat of vaporization) as in high-moisture coal, the boiler efficiency becomes low regardless of the plant performance.

Units 3/4 is planned to be based on sub-bituminous coal (Performance Coal of Units 1/2) and with steam conditions 600^{o}C/600^{o}C, which exceed the thermal efficiency of 41.1% (HHV gross base).

8.3.3 Applicable standards

Regarding applicable standards, it is possible to comply with JIS, ASME, etc. as well as the ignition standards set by Japan, but basically the same standards should be used and it should be avoided to combine them with other standards.

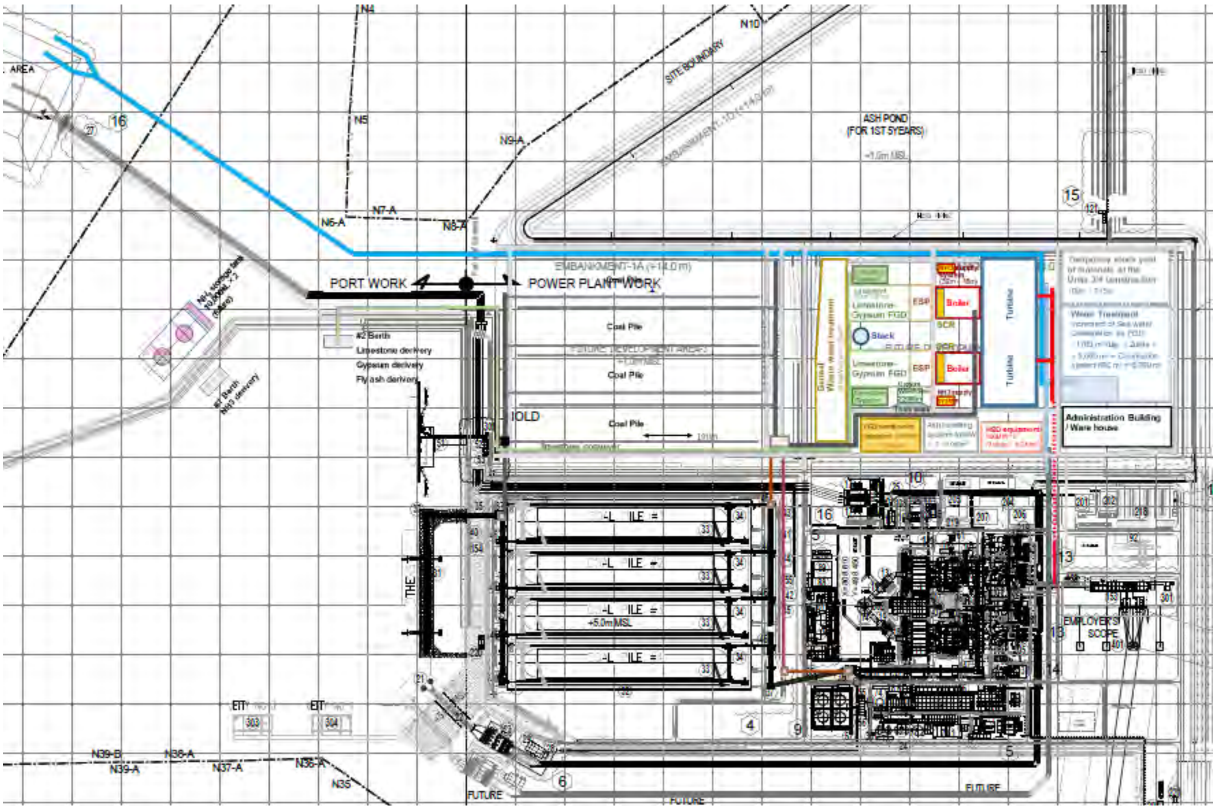
The selection of materials for high-temperature and high-pressure parts and the evaluation of the life of 200,000 hours or more shall basically be planned in accordance with the world-leading Technical standards of Thermal Power Generation Plant and notification of the Ministry of Economy, Trade and Industry of Japan.

8.3.4 Plant Layout

The premises of Units 3/4 will utilize the site space on the north side of Units 1/2.

The layout of the coal storage yard and the main generation equipment will be arranged same in the layout of Units 1/2 as much as possible.

In addition, the sizing of major equipment such as coal storage pile, boiler, turbine, and electrical equipment was made equivalent to Units 1/2.



Source: Study Team
Figure 8.3-1 Plant Layout

Figure 8.3-1 shows the plant layout of Units 3/4.

Since the installation space of Units 3/4 is slightly smaller than that of Units 1/2 and the SCR and desulfurization equipment method are different from those of Units 1/2, the following points (1) to (6) were noted.

Note that each color-filled part in the layout plan represents equipment that will be added to Units 1/2.

In addition, regarding the redundancy of equipment and systems, the following two points were noted.

- Basically, it is considered it has 100% reserve (standby) for items that affect the output when a failure occurs.
  However, equipment (mills, etc.) consisting of multiple units is always reserved as one unit.
- Large auxiliary machines (FDF, IDF, PAF, AH, etc.) with high equipment reliability and sufficient track record will not have spares.

(1) SCR

The SCR is installed between the boiler and the ESP.

The denitration rate of SCR is planned to be about 80%, and it is considered that there will be no major change compared to the layout of the boiler / environmental equipment of Units 1/2.

(2) Ammonia (NH_3) supply system

The ammonia supply system attached to the SCR consists of an NH_3 storage tank, NH_3 vaporizer, etc., and the installation space is 32m x 16m for 600MW x 1 unit, based on the planned results of the preceding 600MW plant.

(3) FGD of limestone gypsum method

(3-1) FGD

The space required for the limestone gypsum method FGD body is not significantly different from that of the seawater desulfurization type, but the stack arrangement is expected to be slightly west of Units 1/2.

(3-2) Limestone and gypsum equipment

The limestone and gypsum equipment was set to 73m x 32m per 600MW x 1 unit based on the planned results of the preceding 600MW plant.

Also, on the premise that the by-product gypsum will be carried out of the premises, a truck scale was considered in the vicinity of the Unit 3 limestone gypsum equipment.

(3-3) Industrial water production and storage using seawater desalination equipment

In the limestone gypsum method FGD, part of the water of the limestone slurry that circulates in the absorption tower becomes saturated steam and is discharged from the stack together with the exhaust gas, so it is necessary to replenish industrial water (Desalinated water).

Similar to Units 1/2, Units 3/4 will be equipped with a seawater desalination system, but Units 3/4 will need to be further expanded for FGD.

The amount of make-up for industrial water for FGD is estimated to be approximately 1700 m^3 / day / 600 MW x 1 unit.

Based on the results of the preceding 600MW plant, the space of the seawater desalination equipment was assumed to be 100m x 40m = 4,000m^2 with a processing amount of 4,800m^3 /day, and 1,700m^3 /day x 2 units / 4,800m^3 / day x 4,000m^2 ≒ 2,800m^2 for 600MW x 2 units (space of desalination equipment for FGD).

In addition, 1 day x utilization rate 80% ≒ 1,400 m^3 industrial water tank x 2 (2 units) space 35m x 70m plus pump space to make 2,800 m^2, totaling 5,600 m^2.

And also considering an increase of 600 m^2 as the installation space for the chlorination and electro chlorination system for the seawater desalination system capacity of 3,400 m^3 / day for FGD of 600MW x 2 units.

The brine (drainage of high-concentration salt) discharged from the seawater desalination device is discharged below the emission standard by the general wastewater treatment device. In addition, sludge generated from seawater desalination equipment will be transported to an appropriate disposal site.

(3-4) Non-recovery wastewater treatment equipment

The limestone gypsum method FGD requires non-recovery wastewater treatment equipment.

Based on the results of the preceding 600 MW x 2 units, the Units 3/4 was set to 7,040 m^2.

(3-5) Limestone receiving berth / limestone receiving conveyor

It is assumed that limestone will be imported by ship (about 2,000DWT), and a part of the existing temporary landing site on the north side will be utilized.

The existing north temporary landing site will also be used to receive Unit 3/4 denitration ammonia by sea, so limestone receiving equipment and a limestone receiving conveyor will be installed so as not to impair the function of the multipurpose berth.

The limestone receiving conveyor is planned to be raised at a predetermined inclination after receiving and passed through the upper part of the light oil piping rack to avoid interference.

(4) Power generation equipment other than FGD

(4-1) Ash treatment equipment

A space of the same size as Units 1/2 was secured separately for Units 3/4.

(4-2) Water treatment equipment

General water treatment other than the seawater desalination equipment to be added for the FGD of Units 3/4 is the same size space required as Units 1/2.

(4-3) General wastewater treatment equipment

General wastewater treatment other than non-recovery wastewater treatment of Units 3/4 FGD has the same size space required as Units 1/2.

(4-4) Light oil supply equipment for auxiliary combustion

Utilizing 4 light oil storage tanks installed in Units 1/2, Units 3/4 is assumed to consist of 2 small capacity light oil service tanks + light oil pump yard and 6,240m^2 / 600MW x 2 units.

Estimated consumption of light oil = 2,480 ton/year/600MW x 2 units

((Cold start 280 ton + Normal stop 30 ton) x 4 times/year x 2 units)

Units 3/4 Light Oil Service Tank capacity will be planned 530 m^3 x 2. (1 cold start and 1 normal stop: 310 ton x 1.5 (margin) / 0.8757 kg/ℓ ≒ 530m^3)

Light oil storage tank for Units 1/2: 4,000 m^3 x 4 (= 16,000 m^3)
There is no light oil service tank for Units 1/2.
Light oil storage tank for Units 3/4 will not be constructed.

Total storable capacity of light oil is 16,000 + 1,060 = 17,060 m^3

(5) Administration office

The administration office, maintenance building, etc. of Units 3/4 secured almost the same size space as Units 1/2.

(6) Equipment stockyard at the time of Units 3/4 construction

Approximately 21,500 m^2 of stock yard for Units 3/4 construction work is secured on the north side of the water treatment facility yard.

For the loading road for large equipment received by sea transportation, the east-west straight loading road is considered on the south side of the Units 3/4 / coal storage yard and power generation facility.

This large equipment carry-in route intersects the coal receiving conveyor, coal discharging conveyor (Article 2), sea water intake channel, high-voltage cable, etc. from Units 1/2 on the way, but they should be underground or fictitious.

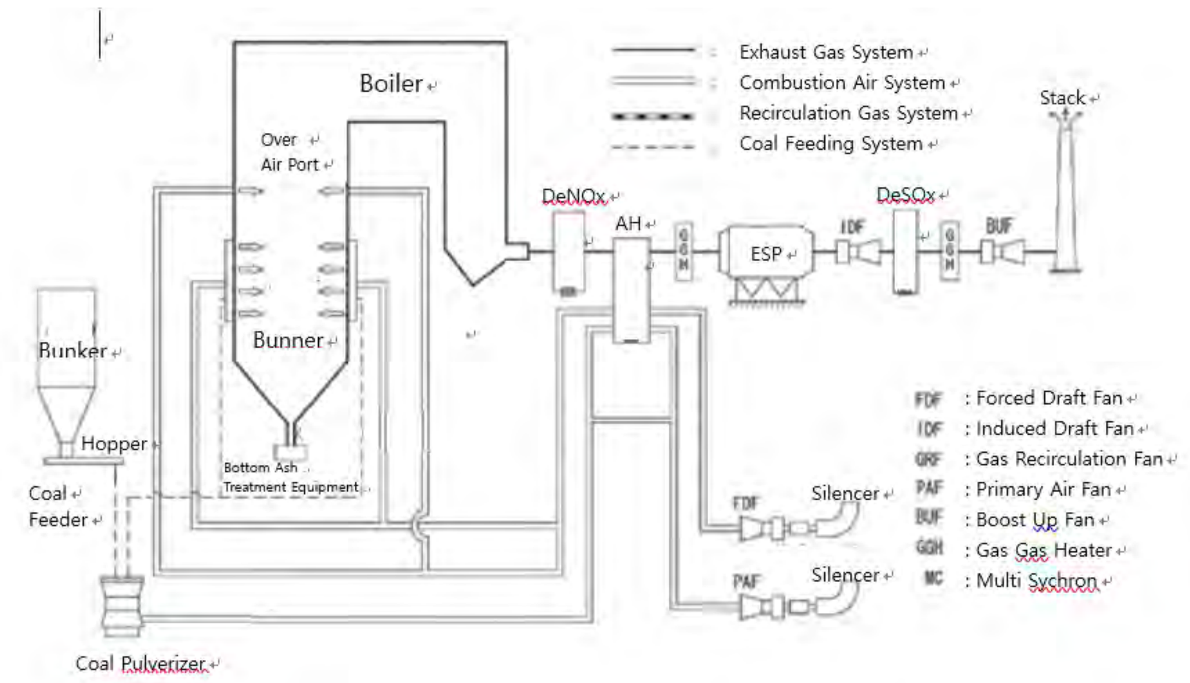
This will prevent problems in transporting large equipment along the carry-in route.

8.3.5 Environmental requirements

It goes without saying that the emission standards for air and water are satisfied, but the plan is to introduce the latest environmental technology (In-furnace denitration, technology like Boiler two stage combustion + low NOx burner + using a high-performance mill etc.) and strive to reduce the environmental load as much as possible.

8.3.6 Boilers and Auxiliaries

Boilers and its auxiliaries for units 3 and 4 each of this project shall be composed of boiler, two forced draft fans (FDF), two air heaters (AH), two primary air fans (PAF), five coal pulverizers, five coal feeders, two induced draft fans (IDF) and so forth, and each of which is associated with each of the two condensing type steam turbines of 600 MW generation capacities. Figure 8.3-2 shows composition of typical 600MW class USC Boiler and Auxiliaries.



Source: Thermal Power Engineering Soc. of Japan
Figure 8.3-2 Composition of Boiler and Auxiliaries

(1) Boiler

The two boilers shall both be pulverized coal firing, radiant reheat, and variable pressure once-through boilers for outdoor installation. Each boiler will be designed as a balanced draft furnace with low NOx burners and over fire (two stage firing) system and pulverized coal from vertical shaft roller type mills shall be fired directly in the boiler. The design criteria of the boilers are shown in Table 8.3-1.

Table 8.3-1 Boiler Design Criteria

Type	Radiant Reheat, Variable Pressure, Once-through Boiler (Outdoor Installation)
Steam Flow Rate at B-MCR; Main steam: Reheat steam:	 1,760 t/h 1,490 t/h
Steam Pressure at B-MCR; Superheater outlet: Reheater outlet:	 25.4 MPa (g) 4.75 MPa (g)
Steam temperature; Superheater outlet: Reheater outlet:	 604 ºC 602 ºC
Firing system	Pulverized coal firing with Low NOx burners and over fire air (two stage firing) Light oil or high speed diesel oil (30% capacity) for unit start up, and ignition and stabilization of coal burners
Drafting System	Balanced draft with forced draft fans and induced draft fans
Primary air system	Cold primary air fan
Steam temperature control method	Feed water/fuel flow ratio and spray water for main steam and flue gas damper and spray water (emergency) for reheat steam

Note: B-MCR means Boiler Maximum Continuous Rating
Source: Study Team

The boiler will be designed for pulverized coal firing and light oil will be used for igniters and initial warm up for unit starting up. The boiler shall have corner or opposite fired, water cooled furnace, radiant- and convection- heat transfer superheaters and reheaters, attemperators, economizers, regenerative air heaters, and a HP/LP turbine bypass system.

(2) Primary Air Fans, Forced Draft Fans

Each boiler has 2 x 50% capacity primary air fans (PAF) and 2 x 50% capacity forced draft fans (FDF) for supplying the required primary/secondary air for the boiler. These fans will be of axial flow type with variable pitch moving blades.

(3) Induced Draft Fans

Each boiler will be equipped with 2 x 50% capacity induced draft fans for keeping the draft of the furnace at slightly reduced pressure to prevent flue gas leakage. These fans will be of axial flow type with variable pitch moving blades.

(4) Boiler Circulation Pumps

There will be 1 x 25% boiler circulation pump with glandless submerged motor. The purpose of this pump is to return water drained from the water separator to the inlet of the economizer and recover the heat during the operation at 25% or lower load.

(5) Soot Blowing System

The boiler shall be provided with dozens of long retractable soot blowers and wall blowers. The entire soot blower operations shall be carried out from the DCS of the plant control system. An intelligent automatically controlled operation system will be applied for the soot blower system.

(6) Burner Management & Automatic Plant Control Systems

The boiler will be equipped with a complete burner management system including mill automation and secondary air control with all required accessories as detailed in the DCS System (Control and Instrumentation).

(7) Pulverizers & Pulverizing System

Each boiler shall be installed with five vertical shaft roller type pulverizers, including one standby for the pulverized coal firing system. Each pulverizer has a gravimetric raw coal feeder. The pulverized coal from each pulverizer is transported through several pulverized coal pipes to the burners. The burners are arranged for tangential firing or opposite firing. Four pulverizers would meet the normal rating of B-MCR with designed coal while one will be for maintenance or stand by.

(8) Specification

Table 8.3-2 shows the specification of Boiler and auxiliaries which are installed in this Project.

Table 8.3-2 Specification of Boiler and Auxiliaries

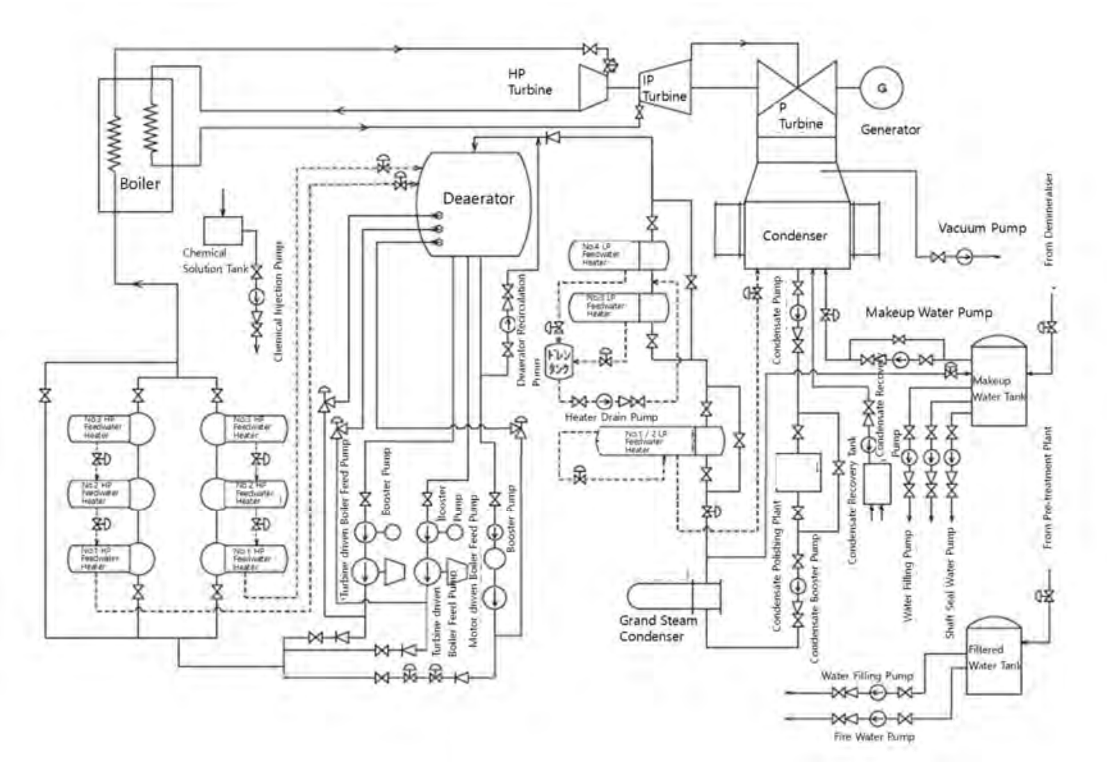
Items	Specification	Remarks
(1) Boiler		
a. Type	Ultra super critical once0through sliding pressure reheat type	Same as Units 1/2
b. Combustion method	Coal firing	
c. Boiler Efficiency	86.28% (HHV) 94.77% (LHV)	
d. Main Steam Flow Rate at B-MCR	1,760 ton/hr (MCR)	
e. Ambient temperature	26.1°C*1	
f. Exhaust gas temperature (AH outlet)	140°C	
g. Drafting	Parallel drafting	
(2) Firing system		

Items	Specification	Remarks
a. Pulverizer		
Number	5 sets / unit	Same as Units 1/2
Capacity	4 sets operation (1 set standby)	Same as Units 1/2
b. Coal bunker		
Method	Front bunker	
Type	Steel plate	
Capacity	12 hours of fuel consumption at MCR	Same as Units 1/2
(3) Light oil firing system		
a. Start-up and light off oil pump	30% of ECR Capacity x 2 sets / unit	Same as Units 1/2
b. Light oil burner	30% of ECR capacity	
c. Light off torch	For all burners	
(4) Drafting system		
a. Forced draft fan (FDF)	50% of MCR capacity x 2 sets (variable pitch axial flow type)	
b. Induced draft fan (IDF)	50% of MCR capacity x 2 sets (variable pitch axial flow type)	
c. Primary air fan (PAF)	50% of MCR Capacity x 2 sets (axial flow type)	
d. Air heater (AH)	50% of MCR Capacity x 2 sets (vertical rotary type)	

*1: Average ambient temperature at project site in 2020
Source: Study Team

8.3.7 Steam Turbine and Auxiliaries

The steam turbine plant will be comprised of a steam turbine, condenser, condensate equipment, feed water heaters, boiler feed pumps and condenser circulating cooling water system as the fundamental configuration. Figure 8.3-3 shows composition of typical 600MW class Steam Turbine and Auxiliaries.



Source: Thermal Power Engineering Soc. of Japan
Figure 8.3-3 Composition of Steam Turbine and Auxiliaries

(1) Steam Turbine

(a) Type

The steam cycle system will be a single reheat, ultra-supercritical, condensing type required for high efficiency and a large-size power plant. The steam cycle is of ultra-supercritical pressure considering that the unit size is 600 MW class.

(b) Shaft Configuration

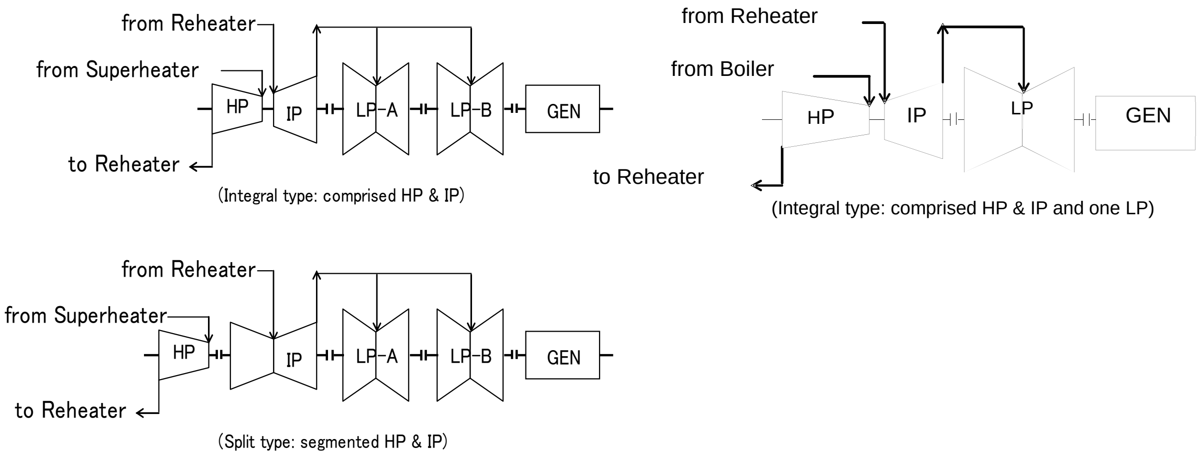
There are two types of shaft configuration, which are the tandem compound (hereinafter referred to as "TC") and cross compound (hereinafter referred to as "CC").

For the TC shaft configuration, high pressure (HP), intermediate pressure (IP) and low pressure (LP) steam turbines are connected in the same shaft. For the CC shaft configuration, the shafts of HP, IP and LP steam turbines are separated. The shaft of the HP steam turbine is called the primary shaft, the other one is called the secondary shaft. Figure 8.3-4 shows the TC shaft configuration, while Figure 8.3-5 shows the CC type.

In the case of the CC type, the secondary axial side runs at half speed (1,500 rpm) and is referred to as a two speed compound machine.

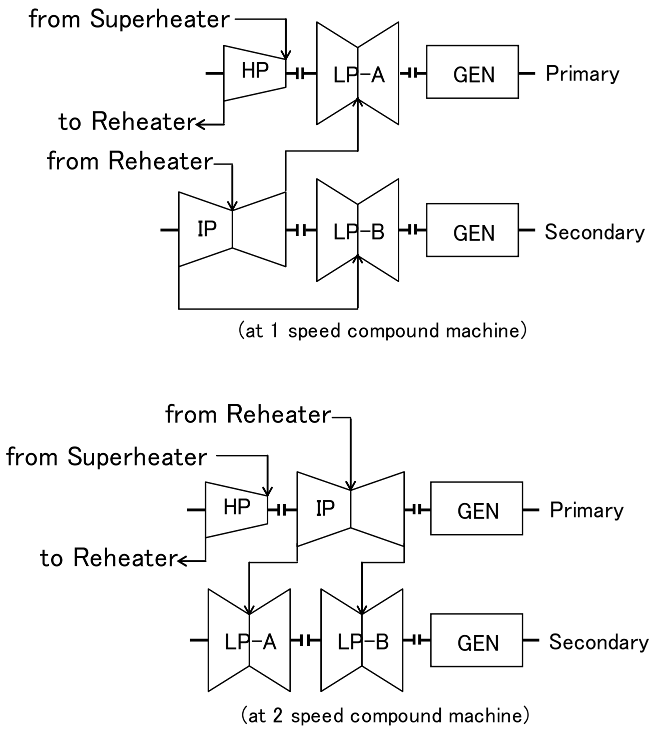
In the latest design of TC configuration for the 600MW class, a single outer casing HP/IP turbine and one double flow LP turbine type has been developed by introduction of 48 inch blades for the last stage of the LP turbine. Applying such latest design contributes to high efficiency and decreasing investment costs.

Both types of TC and CC have individual specific features illustrated in the next sub-section.



Source: Study Team

Figure 8.3-4 Tandem Compound Shaft Configuration



Source: Study Team

Figure 8.3-5 Cross Compound Shaft Configuration

(c) Comparison of Specific Features of TC and CC Shaft Configurations

The CC shaft configuration is applied to large scale units, of which the secondary shaft runs at half the speed of the primary shaft to reduce the centrifugal force imposed on the root section of the longer blades of the LP steam turbine.

The TC is also applied to the 600MW class steam turbine units as the result of development of the LP turbine longer blades to withstand the centrifugal force under the same speed as the primary speed.

Table 8.3-3 shows the comparison results between TC and CC shaft configurations of 600MW class steam turbines.

The TC shaft configuration is preferable for the Project considering advantages such as "Installation space is smaller", "Operability is simpler" and "Maintainability is easier".

Table 8.3-3 Comparison between TS and CC Shaft Configurations

Comparison Item	TC	CC
Number of axis	1	2
Shaft length	Longer	Base
Operating reliability	Similar	Base
Turbine efficiency	Same	Base
Installation space	Smaller	Base
Operability	Simpler	Base
Maintainability	Easier	Base
Construction cost	Less	Base
Running cost	Same	Base

Source: Study Team

(d) Steam Turbine Efficiency (Gross, HHV)

Steam turbine efficiencies at each partial load are mentioned below under the same steam conditions, etc. of Units 1/2.

- 100% load: 7,508 kJ/kWh (47.94%)
- 75% load: 7,583 kJ/kWh (47.47%)
- 50% load: 7,828 kJ/kWh (45.99%)
- 30% load: 8,556 kJ/kWh (42.92%)

(2) Condenser

(a) Design Concept

In thermal power plants, the purpose of a surface condenser is to condense the exhaust steam from a steam turbine into cycle water (steam condensate) so that it is reused in the boiler as boiler feed water.

There are many fabrication design variations depending on the manufacturer, the size of the steam turbine, and other site-specific conditions.

A single pass-one division of tube and shell circuit schematics is preferable, even for condenser types for large-sized turbines, being based on the HEI (Heat Exchange Institute) standard.

(b) Required amount of cooling water

The required amount of cooling water (G_w) for the condenser is calculated by the following formula.

$$G_w = Q / (\delta td \times cp \times \rho)$$

Q: Incoming heat to condenser (kcal/h)

δtd: temperature difference of cooling water between inlet and outlet of condenser (°C)

cp: specific heat of cooling water (kcal/kg °C)

ρ: specific gravity of cooling water (kg/m^3)

Based on the data of a similar power plant with the same capacity and same steam conditions, and adding an amount of bearing cooling water, etc., the total required amount of cooling water was estimated at 50 m^3/s

for two units.

(c) Condenser Vacuum

The estimate for a condenser vacuum such as 8.47 kPa (a) (saturated temperature 42.6°C) is done on the basis of the method provided in the HEI standard. The following example is provided for reference.

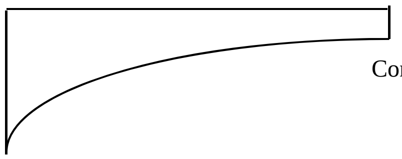
On the one hand, the condenser vacuum depends on the actual measurement data of seawater temperature, and the vacuum has been studied on the basis of a design seawater temperature of 30.0°C at the condenser inlet in accordance with Table 8.3-4 Rated Condition of steam/water cycle conditions of Clause 8.3.7 (7).

The cooling water facilities will be designed so that discharged water temperature will be 37°C, which is not considered problematic since the temperature is not higher than 40°C which is the maximum temperature allowed in the waste water quality standards of Bangladesh.

Therefore, the temperature has been set to 36.6°C, which is a lower value than the above standard. By adding the seawater temperature rise of 6.6°C in the condenser, and the estimated temperature difference of 6.0°C between the saturated temperature of condenser and condenser outlet seawater temperature, to the condenser inlet seawater temperature, the saturated temperature of condenser has been set at 42.6°C.

The saturated condenser pressure of 2.50 inch Hg abs. = 8.47 kPa (abs) equivalent to the above saturated temperature has been adopted as the design condenser vacuum.

It will sometimes be necessary to review the seawater temperature of the condenser outlet to a certain extent depending upon the conditions of yearly seawater temperature change at the power plant construction site.



Source: Study Team

Figure 8.3-6 Relationship between Saturated Temperature of Condenser and Sea Water Temperature

(d) Tube material

In general, tubes are made of stainless steel, copper alloys such as brass or bronze, cupro nickel, or titanium depending on several selection criteria. The use of copper bearing alloys, such as brass or cuprous nickel, is rare in new plants, due to environmental concerns of toxic copper alloys. Also, depending on the steam cycle water treatment for the boiler, it may be desirable to avoid tube materials containing copper. From the viewpoint of reliability and anti-corrosion, titanium is the best technical choice for the Project.

(3) Vacuum system

For water-cooled surface condensers, the shell’s internal vacuum is most commonly supplied and maintained by two types of vacuum systems, such as steam jet type air ejectors and motor driven vacuum pumps.

The motor driven vacuum pumps are preferable on the basis that they are more serviceable.

(4) Condensate demineralizer

A USC plant does not have function of boiler water blow and however it requires high quality of boiler feed water so that a condensate demineralizer shall be installed after the condensate extraction pumps. Contaminants in the condensate water are colloidal matters of iron and cupper etc., sodium ion and chloride ion. In some case the condensate demineralizer is to equip filters to remove colloidal matters. After the filters the condensate demineralizer has ion exchangers for dissolved matters.

(5) Feedwater heater

Feedwater heaters are applied to improve thermal efficiency. The source of heating is the extracted steam from the turbine. The number of heaters is determined considering economic benefits such as improved efficiency and additional investment costs, etc. In general, six to eight heaters are installed for large scale power plants over 200MW.

(a) Heat exchanger

A heat exchanger is a device built for efficient heat transfer from one fluid to another. The fluid may be separated by a solid wall, so that they are never mixed, or they may be in direct contact. Heat exchangers may be classified according to their flow arrangement.

In parallel-flow heat exchangers, two fluids enter the exchanger at the same end, and travel in parallel to the other side. In counter-flow heat exchangers the fluids enter the exchanger from opposite ends. The counter-flow design is more efficient, in that it can transfer the most heat from the heat (transfer) fluid.

1) Types of heat exchangers

The shell and tube heat exchanger is the most common type of heat exchanger in large coal fired power plants, and is suitable for higher-pressure applications.

This type of heat exchanger consists of a shell (a large pressure vessel) with a bundle of tubes inside of the shell. One fluid runs through the tubes, and another fluid flows over the tubes (through the shell) to transfer heat between the two fluids.

2) Shell and tube heat exchanger

Feed water is at a high pressure so that a shell and tube heat exchanger is applied. In this case, feed water flows inside of the tube and extracted steam and its condensate flows outside of the tube. There can be many variations on the shell and tube design. Typically, the tubes are bent in the shape of a U (called U-tubes) and the ends of each tube are connected to water boxes divided by a partition sheet.

U-tube heat exchangers are the most common type of heat exchanger in coal fired power plants.

3) Selection of tube material

To be able to transfer heat well, the tube material should have good thermal conductivity. Because heat is transferred from the hot to cold side through the tubes walls, there is a temperature difference through the width of the tubes. Because of the tendency of the tube material to thermally expand differently at various temperatures, thermal stress occurs during operation. This is in addition to any stress from high pressures from the fluids themselves. The tube material should also be compatible with both the shell and tube side fluids for long periods under the operating conditions (temperatures, pressures, pH, etc.) to minimize deterioration of the tubes, such as corrosion.

All of these requirements call for a careful selection of strong, thermally-conductive, corrosion-resistant, high quality tube materials, typically metals, including copper alloy, stainless steel, carbon steel, non-ferrous copper alloy, Inconel, nickel, hastelloy and titanium. An inadequate selection of tube material might result in a leak in the tube between the shell and tube sides causing fluid cross-contamination and possibly loss of pressure.

(b) Deaerator

A deaerator is a device that is widely used for the removal of air and other dissolved gases from the feed water to steam-generating boilers. In particular, dissolved oxygen in boiler feedwaters will cause serious corrosion damage in steam systems by the oxidizing of surfaces of metal piping and other metallic equipment. Water also combines with any dissolved carbon dioxide to form carbonic acid that causes further corrosion. Most deaerators are designed to remove oxygen down to levels of 7 ppb by weight (0.0005 cm^3/L) or less.

From technical (efficiency and operation, etc.) aspects and cost aspects, tray-type and spray-type deaerators are considered the main options for selection.

(6) Pumps

Pumps such as condensate extraction/condensate booster pumps, boiler feed /feed water booster pumps, closed cycle cooling water pumps, seawater booster pumps and circulating water pumps are installed in the plant.

(a) Condensate pump

A condensate pump is a specific type of pump used to extract the condensate (water) in the hot-well of a condenser.

Condensate pumps, as used in hydraulic systems, are usually motor-driven centrifugal pumps.

In a thermal power plant, the condensate pump is normally located adjacent to the main condenser hot-well, often directly below it.

These pumps are used in succession to provide sufficient Net Positive Suction Head (NPSH) to prevent cavitation and the subsequent damage associated with it.

(b) Boiler feed pump

A boiler feed pump is a specific type of pump used to pump feedwater into a steam boiler. The water may be freshly supplied or returning condensate produced as a result of the condensation of the steam produced by the boiler.

These pumps are normally high pressure units that use suction from a condensate return system and can be of the centrifugal pump type.

(7) Specification

The specifications of the Steam Turbine and Auxiliaries are shown in Table 8.3-4.

Table 8.3-4 Specifications of Steam Turbine and Auxiliaries

Item	Specifications
Type	Tandem compound, single reheat, ultra-supercritical, two-flow, condensing type
Power Output at generator terminals (without excitation loss)	600 MW
Rated Speed	3,000 rpm
Number of Casings	one (1) HP・ IP & one (1) LP
Steam Pressure at MSV	24.5 MPa (g)
Steam Temperature at MSV	600ºC
Steam Temperature at RSV	600ºC
Number of Extractions	8
Control System	Digital Electro-hydraulic Controller (D-EHC)
Condenser	
Type	Surface cooling, single pass-one division, shell and tube type
Condenser Vacuum	Approx. 8.47 kPa (abs)
Design Inlet CW Temperature	30.0ºC
CW Temperature Rise	7 ºC and below
Tube Cleanliness Factor	0.9
Cleaning Equipment	Ball Cleaning System
Tube Material	Titanium
Feedwater Heater	
Type	Surface cooling, shell & tube type
Number of Heaters	8 including Deaerator
Condensate Extraction Pump (CP)	
Type	Vertical Barrel, Multistage Diffuser Type (Motor driven)
Number	3 x 50% or 2 x 100%
Boiler Feed Pump (BFP)	

Item	Specifications
Type	Turbine driven (T-BFP) plus Motor driven (M-BFP) Horizontal, Multistage Diffuser Type
Number	Option 1: 3 x 50% (T-BFP) plus 1 x 30% (M-BFP) Option 2: 2 x 50% (T-BFP) plus 2 x 30% (M-BFP)
BFP Booster Pump	
Type	Horizontal, Multistage Diffuser Type (Motor driven)
Number	3 x 50% or 2 x 50%
Circulating Water Pump (CWP)	
Type	Vertical, Single Stage Type (Motor driven)
Number	3 × 50%

Source: Study Team

(8) Boiler Feed water treatment

There are three treatments for once-through boilers as shown in Table 8.3-5.

Volatile matter treatment (AVT), which uses ammonia for pH adjustment and hydrazine for deoxygenation, has historically been the primary feedwater treatment method. Here, pH adjustment (keeping the water alkaline) with ammonia is the basis of corrosion prevention to deter oxidation.

Hydrazine maintains dissolved oxygen at an extremely low concentration (less than 7 μg/l) and causes the formation of a protective film of magnetite (Fe3O4). However, it is necessary to chemically clean boilers and heaters periodically (2~3 years) because of the rapid formation of oxidized scale.

The danger of hydrazine to the human body has been pointed out, and neutral water treatment (NWT) and combined water treatment (CWT), which form a hematite film in a low-concentration oxygen state without using hydrazine, have attracted attention. Compared to magnetite, hematite has extremely low solubility and a smooth surface, which is expected to reduce the frequency of chemical cleaning and the power consumption of boiler feed water pumps.

In Japan, CWT using ammonia was adopted for large once-through boilers in 1990, and more than 56 units are currently in use with good results. Based on the above, the application of CWT for boiler feedwater treatment is technically and economically justified.

Table 8.3-5 Boiler Feedwater Treatments for once-through Boilers

Water Treatment Type	All Volatile Treatment (AVT)	Neutral Water Treatment (NWT)	Combined Water Treatment (CWT)
pH (at 25 °C)	9.0-9.7	≒7	8.0-9.3
Cation conductivity (mS/m)	≦0.025	≦0.02	≦0.02
Dissolved oxygen (μg/l)	less than 7	20-200	20-200
Chemicals	Ammonia Hydrazine	Oxygen	Ammonia Oxygen

Source: Mitsubishi Heavy Industries Technical Review Vol. 49 No. 1 (March 2012)

8.3.8 Water Treatment System

(1) Water source

Service water is utilized as the source of demineralized water for boilers, cooling water for equipment, ash disposal and firefighting, etc.

There is no source of fresh surface water in the vicinity of the site, and underground water is not suitable to draw a sufficient amount of water given possible adverse effects, such as the drying up of wells in the vicinity of the site and subsidence of the ground.

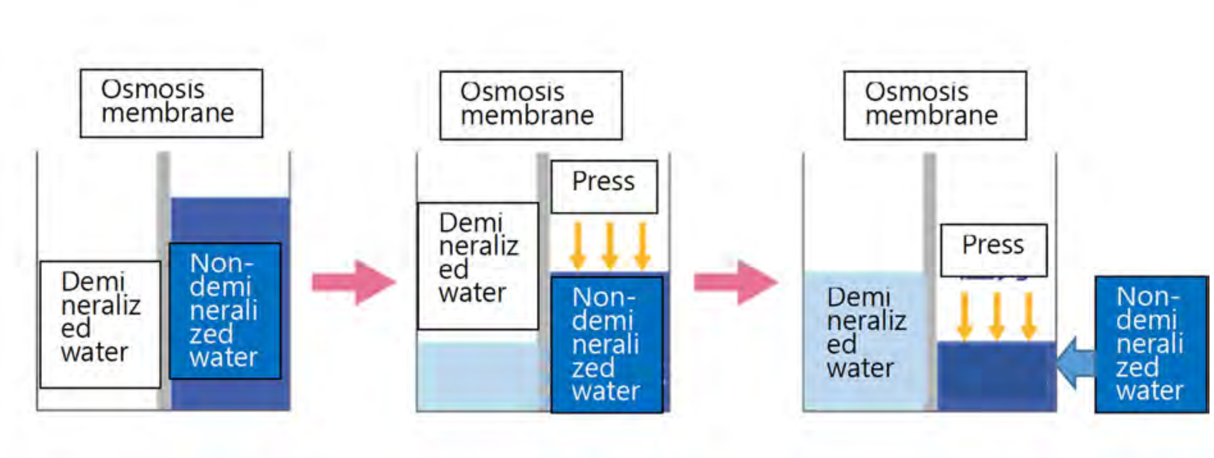
Therefore, a desalination plant is required to produce service water.

(2) Desalination Plant

(a) Comparison among MSF, MVC and RO

Desalination methods are roughly classified into three types such as Multi-Stage Flash distillation (hereinafter referred to as “MSF”), Mechanical Vapor Compression (hereinafter referred to as “MVC”) and Reverse Osmosis technology (hereinafter referred to as “RO”).

MSF applies the flash phenomenon induced when sea water decompresses under saturated pressure using steam heat. MVC applies a compressor as the heat source for vaporization. RO is a membrane separation process utilizing the principle of osmotic pressure. By pressurizing saline solution, pure water can be separated from the solutes through a membrane, as a reverse movement of normal osmosis (see Figure 8.3-7).



Source: Water Stand, website

Figure 8.3-7 Principle of Reverse Osmosis

A comparison of each type of desalination method is provided in Table 8.3-6. Indicative technical data and comparison results are dependent on sea water quality so that a detailed selection of the type of desalination method should only be made after consideration of the actual water quality, especially Total Dissolved Solids (TDS), Turbidity (NTU) and Silt Density Index (SDI).

Suspended solids and colloidal materials in sea water are one of the biggest problems in reverse osmosis (RO) systems. Even though most systems have some pretreatment, including 5 micron pre-filters, these fine particles are responsible for the fouling of reverse osmosis membranes.

In order to evaluate the degree of this fouling, the Silt Density Index (SDI or Fouling Index, FI) is measured. This method is standardized as ASTM D4189-07 Standard Test Method for Silt Density Index (SDI) of Water.

To measure the SDI, a 0.45 micron filter is exposed to the feedwater under pressure (2.07 bar) and flow rates are measured during the collection of 500 mL samples at the start of the test (T0) and after 15 minutes (T). Calculation of SDI is as follows.

SDI = (1-T0/T) x 100/15

An SDI of less than 5 is considered acceptable for the reverse osmosis systems. This means that at values of SDI of less than 5, the membranes should foul at a very low rate. Even though the index works most of the time, there are exceptions when a lower SDI (less than 3) is desirable due to the nature of the suspended solids in that feedwater.

If sea water quality is acceptable and not very contaminated, applying the RO system is feasible as it is mature technology and has recently been viewed as economically efficient.

Table 8.3-6 Comparison between MSF, MVC and RO

	MSF	MVC	RO
Total dissolved substance (TDS) of produced water *1	10	5	10 (by two stages treatment)

	MSF	MVC	RO
Investment cost *1	Higher	Higher	Base
Energy Consumption *1	25 kWh/m^3 (incl. steam energy)	11 kWh/m^3	5 kWh/m^3
O&M cost *1 (excl. energy cost)	Cheaper	Cheaper	Base
Raw Water Consumption (per produced water m3) *1	6-8 m^3/m^3	3 m^3/m^3	2 m^3/m^3
Characteristics	- High reliability - Considerable experience for large capacity plants - Suitable for sea water desalination - Corrosion, scale problems	- Simple system - High reliability - Has become a possible process - Suitable for sea/river water desalination - Lower temperature operation than MSF - Less corrosion, scale problems than MSF	- Simple system - Least energy consumption - Has become a major process - Suitable for sea/river water desalination - Short life of membrane (about 5 years) - Sensitive to sea water quality

*1：Depending on sea water quality
Source: Study Team

(b) Pre-treatment Facilities

Processes that rely on microporous membranes must be protected from fouling. Membrane fouling causes a loss of water production (flux), reduced permeate quality and increased trans-membrane pressure drop.

Membrane fouling is typically caused by precipitation of inorganic salts, particulates of metal oxides, colloidal silt, and the accumulation or growth of microbiological organisms on the membrane surface. These fouling problems can lead to serious damage and necessitate more frequent replacement of membranes.

Pre-treatment facilities, including chemical treatment, clarifier (if required) and filters, are required to remove suspended solids to avoid membrane fouling.

(3) Demineralization Plant

The demineralization plant is designed based on the latest cost effective ion exchange technique of counter current regeneration. The units consist of corrosion free pressure vessels internally connected in series. There is a column containing cation absorbing exchanger and another column is charged with an anion absorbing exchanger. Generally, in the final stage a mixed bed exchanger is equipped as back-up use against leaked ion.

Therefore the plant removes dissolved chemical impurities/salts from water to a specified degree. At certain regular intervals, the cation exchanger is regenerated with an acid and the anion exchanger resin is regenerated with an alkali solution.

(4) Potable Water Production Plant

Desalinated water will be used to produce potable water. To sterilize the water, hypochlorite dosing or ultraviolet (UV) disinfection will be applied.

(5) Scope of supply

(a) Desalination Plant

Raw water intake strainer:	1 set/unit
Raw water supply pump:	1 set/unit
Raw water storage tank	1 set/unit
Raw water transfer pump:	1 set/unit
Initial Filtration device:	1 complete set

Intermediate Filtration device:	1 complete set
Reverse Osmosis (RO) device:	1 complete set
Chemical injection equipment:	1 complete set
Desalination water storage tank:	2 sets (100% x 2)

(b) Demineralization Plant

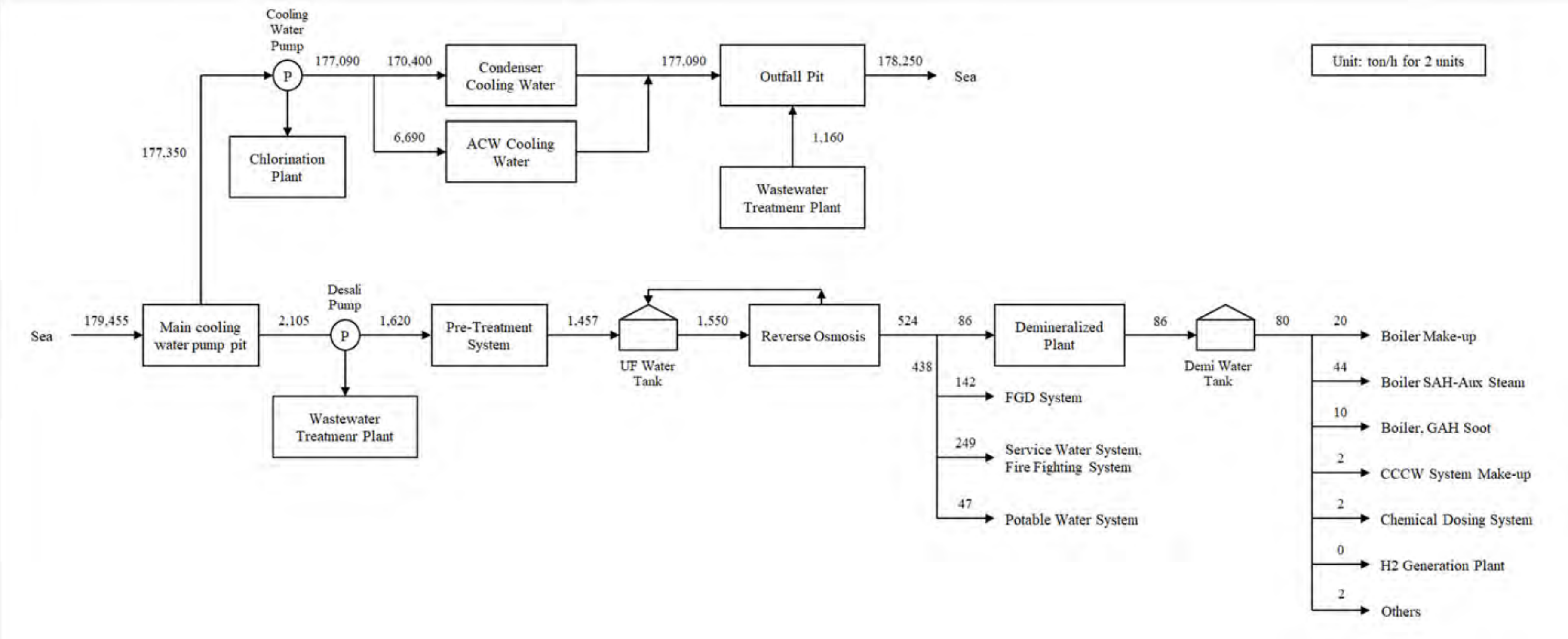
Raw water supply pump:	1 set/unit
Filter:	1 set/unit
Anion tower (if required):	1 set/unit
Cation tower (if required):	1 set/unit
Mixed bed type ion exchange tower:	1 set/unit
Intermediate pump:	1 set/unit
Waste water regenerating pump:	1 set/unit
Blower:	1 set/unit
Hydrochloric acid storage tank:	1 set
Caustic soda storage tank:	1 set
Various dilution tanks:	1 complete set
Demineralized storage tank:	2 sets (100% x 2)
Make-up pump:	2 sets (100% x 2)

(c) Potable water production plant

Pump:	2 sets/unit
Carbon filter:	2 sets/unit
Disinfection system (Hypochlorite dosing or UV)	1 set/common (100% x 1)
Potable water storage tank:	1 set/common (100% x 1)

(6) Conceptual schematic diagram of water treatment system

Figure 8.3-8 shows the flow diagram of water treatment system.



Source: Study Team

Figure 8.3-8 Flow Diagram of Water Treatment System

8.3.9 Wastewater Treatment System

(1) Overview Specifications

(a) General

The general treatment concepts of the various effluent streams are as follows:

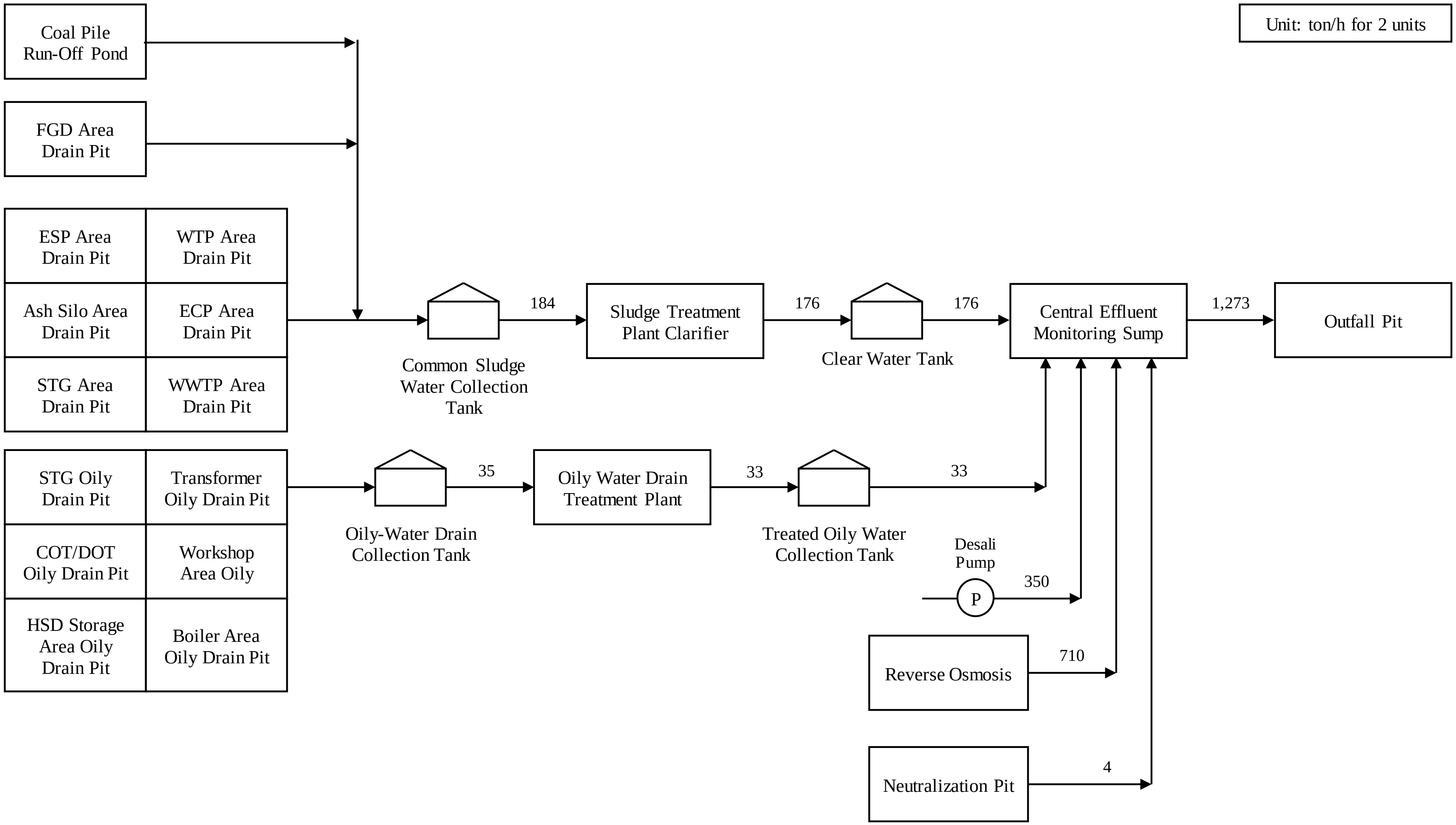
1) The process wastewater shall be treated in the wastewater treatment plant, after which it shall be discharged into the cooling water discharge line with quality satisfying standards stipulated in Section 8.3.5 Environmental Requirements. The process wastewater includes waste streams from plant oily waste, drains, and other miscellaneous streams. Wastewater sample points shall be provided in the plant.
2) Boiler blowdown shall be directed to the boiler blowdown tank with quenching by cooling water, after which it shall be directed into the boiler sump pit.
3) Oil-contaminated effluent shall be treated in an oil/water separator. After which the effluent shall be routed into the wastewater storage pit.
4) Wastewater from the water treatment plant shall be routed into the wastewater storage pit.
5) In no case shall the untreated effluent be discharged either directly or indirectly to any surface or ground water source.
6) Sludge collected by the wastewater treatment plant shall be transferred to an appropriate disposal site.
7) Sanitary wastewater from buildings in the plant shall be routed directly to an on-site sewage treatment plant.
8) Roof drain, storm water and water tanks overflow shall be conveyed into a check pit and discharged into the cooling water discharge line after checking water quality (at least pH value and oil content).
9) Coal yard rainwater shall be treated separately using the coagulation and filtration method.
10) Wastewater from the coal conveyer cleaning system shall be treated separately using the coagulation and sedimentation method. Concentrated coal slurry shall be returned to the coal yard.
11) Ash pond wastewater shall be treated separately using the sedimentation and neutralization method.

(b) Scope of supply

Wastewater storage pit	1 set
pH regulator pit	2 sets
Coagulation pit	2 sets
Sedimentation pit	2 sets
Intermediate pit	1 set
Sludge storage pit	1 set
Neutralization pit	1 set
Filter	2 sets
Dehydration equipment	1 complete set
Supply pump	2 sets
Intermediate pump	2 sets
Sludge discharge pump	2 sets x 2
Dehydrator supply pump	2 sets

(2) Conceptual schematic diagram of the wastewater system

Figure 8.3-9 shows the flow diagram of the wastewater system



Source: Study Team

Figure 8.3-9 Flow Diagram of Wastewater System

8.3.10 Flue Gas Treatment System

(1) Electrostatic Precipitators

The flue gas dust collection system for each boiler shall consist of a two pass electrostatic precipitator (ESP). The electrostatic precipitator ash collection hoppers will have a capacity sufficient for twelve hours operations at the maximum collection rate in any section of the electrostatic precipitator. The ESPs will be provided complete with motorized rapping mechanisms, rectifier transformers, hoppers and their heaters and all associated auxiliaries. The hopper outlet shall be provided with a diversion gate for Dry Fly Ash collection System.

The dust reduction efficiency of ESP is 99.7%. The stack outlet emission concentration of Units 3/4 shall be below 25mg/Nm^3 according to IFC/WB EHS Guideline (Thermal Power Station; 2017 draft).

(2) Flue Gas Desulfurization System (FGD)

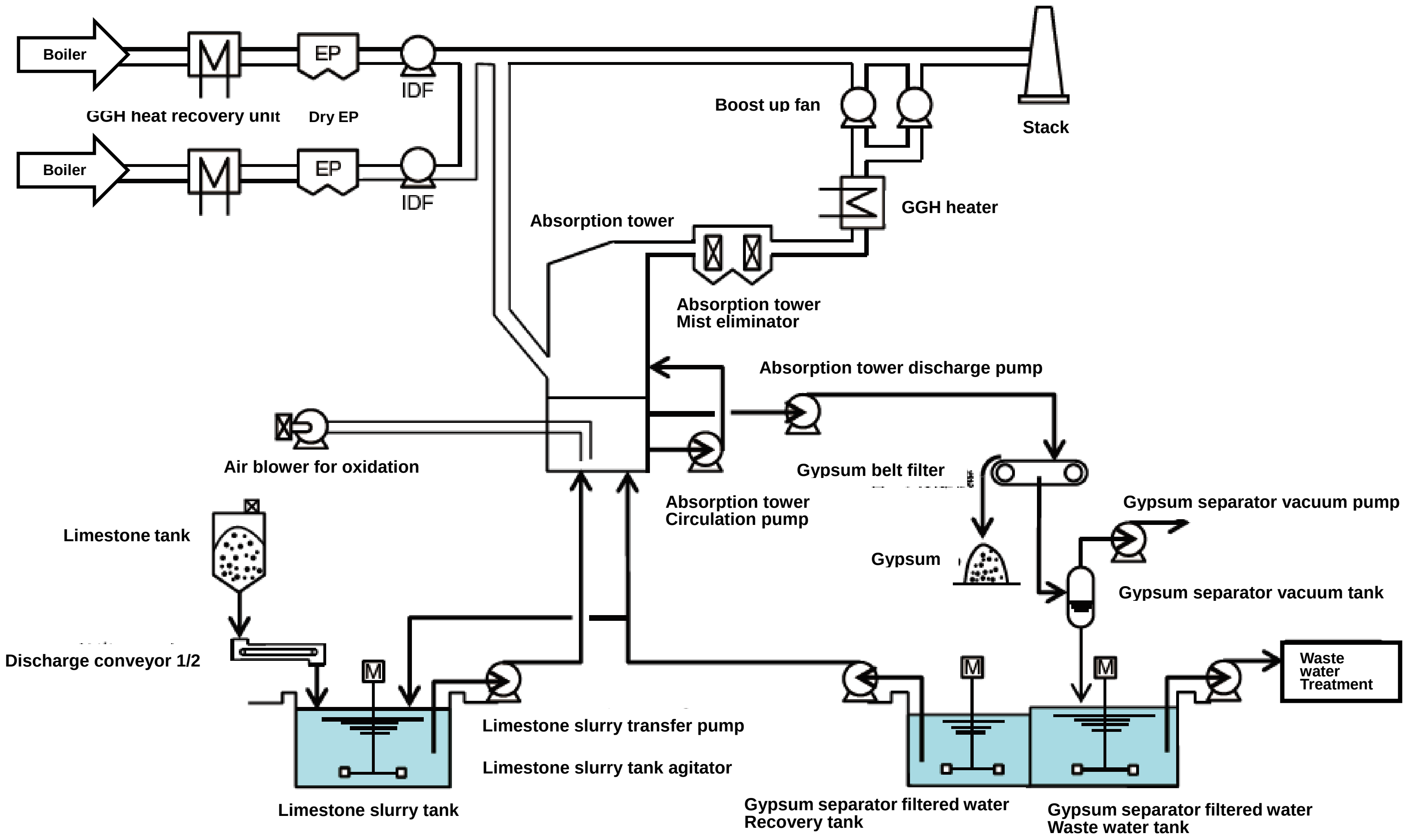
(a) Type of FGD

Two types of desulfurization methods are applicable to this project: one is the wet limestone/gypsum method and the other is the seawater method. In this project, the wet limestone/gypsum method is used as described in Section 8.1.1 (6).

A typical system diagram of this method is shown in Figure 8.3-10. This desulfurization plant consists of four processes: a limestone supply process to supply limestone, an alkaline absorbent; an absorption process to remove SO_2 from the flue gas; a gypsum recovery process to recover gypsum as a byproduct; and a ventilation process to introduce the flue gas and reheat the gas.

The SO_2 in the exhaust gas reacts with limestone and is oxidized by the oxygen in the air to form gypsum. The chemical equation for the desulfurization reaction is shown below.

$$SO_2 + 2\ H_2O + CaCO_3 + 1/2\ O_2 \rightarrow CaSO_4 \cdot 2\ H_2O + CO_2$$



Source: Thermal and Nuclear Power Generation Association, Introductory Course (Auxiliary Equipment for Thermal Power Plants) IV. Auxiliary equipment in flue gas treatment system

Figure 8.3-10 Flue-Gas Desulfurization Equipment System Diagram

(b) List of FGD Equipment

The FGD consists of the following equipment/facilities

- Sulfurous acid gas absorption tower (1 unit)
- One regenerative rotary gas and gas heater
- Freshwater pressure booster pumps (several units)
- Water piping and valves
- Exhaust gas booster fan (2 units)
- Flue gas bypass system (1 unit)
- Inlet and outlet exhaust gas ducts
- Oxidation air blower
- Oxidation tank (shared by two boilers)
- Power supply system
- Instrumentation and control equipment

(c) Performance of FGD

The FGD will be installed in order to reduce the sulfurous acid gas (SO_2) concentration in the flue gas to 200 mg/Nm^3 or less in order to meet the regulations of international standards such as those of the World Health Organization. Assuming that the properties of the coal used in this project are the same as those used in Units 1/2, the SO_2 concentration in the flue gas from the FGD inlet is 2,500 mg/Nm^3 or less at BMCR (1.0% sulfur content in coal) using performance coal, so the SO_2 removal efficiency must be 91% or higher.

In addition, the FGD is assumed to reduce the dust in the exhaust gas to 25 mg/Nm^3 or less.

As a result of the simulation of atmospheric diffusion of exhaust gas, the temperature of the exhaust gas at the stack outlet must be 90ºC or higher in order for the exhaust gas to diffuse sufficiently into the atmosphere. Each FGD shall be equipped with a regenerative rotary gas/gas heater.

The exhaust gas properties at the EP outlet (FGD inlet) are shown in Table 8.3-7.

Table 8.3-7 Exhaust gas properties at outlet of EP (inlet of FGD)

Items	Unit	Performance Coal	Design Coal (Max. Ash)	Design Coal (Max. Flue Gas)	Remarks
Boiler Load		BMCR	BMCR	BMCR	Per 1 unit
Flue Gas Flow Rate	Nm^3/h	1,992,177	1,859,318	2,228,822	
Flue Gas Temperature	ºC	134	134	134	
H_2O (wet)	vol %	14.17	12.64	16.49	
O_2 (dry)	vol %	4.45	3.85	3.91	
Pollutant Matters Concentration (dry, 6%O_2)					
NOx (as NO_2)	mg/Nm^3	62	62	62	
SO_2	mg/Nm^3	≦2,759	≦2,898	≦2,500	
PM	mg/Nm^3	25	25	25	
Pollutant Matters Volume					
NOx (as NO_2)	kg/h	124	115	138	Per 1 unit
SO_2	kg/h	5,496	5,388	5,572	Per 1 unit
PM	kg/h	50	46	56	Per 1 unit

Source: Study Team from Units 1/2 Design Document

The dust concentration standard in the exhaust gas applied to Units 3/4 is 25 mg/Nm^3 (6% O_2) or less at the stack outlet, and based on the given data on coal characteristics and limestone concentration, the system with electrostatic precipitator and other related equipment will be designed to keep the dust concentration below this standard and the gypsum purity above 95%. The desulfurization plant is designed with electrostatic precipitator and other related equipment.

The desulfurization plant will be installed downstream of the electrostatic precipitator, and the wet limestone and gypsum process, which is widely used in the world, will be adopted for the desulfurization plant in the Units 3/4 expansion project.

(3) Limestone and Gypsum Handling Equipment

Limestone equipment is used for unloading, storing, and supplying limestone from ships to the FGD equipment. Gypsum handling equipment is used for storing the gypsum produced by the FGD equipment and loading it onto trucks for transport by road. Gypsum could also be delivered to local industries by small vessel.

(a) Loading method of limestone

Limestone will be unloaded from the ship by ship loader at the unloading jetty and transported by conveyor belt from the jetty to the limestone storage area. Limestone in the limestone storage area will be transported by belt conveyor to the limestone storage silos (1,000 m^3 x 2). At present, limestone is planned to unload at the berth which is located at north-west in the area of Units 3/4 (refer to Figure 8.3-1).

(b) Conditions for equipment study

The specifications and capacities of the limestone and gypsum facilities in Units 3/4 were reviewed based on the applicable design coals as follows. The conditions of the study are shown below.

- SO_2 at the inlet of the desulfurization unit: 5,496 kg/h-unit
- S content of coal: 1% (Performance Coal)
- Limestone utilization rate : 95%
- Limestone purity: 90%
- Limestone jetty: 2,000 DWT

(c) Results of the study

The S content of the applied coal varies, and the maximum value is 1%. Therefore, when the S content in coal is 1%, the required amount of limestone is 359 tons/day for 2 units (100% load), and 2,000DWT class ship needs to accept limestone in a 5-day cycle.

Limestone consumption and gypsum production (when using coal with 1% S content)

Coal consumption per hour (for 2 units as per 100% load at MCR):
600,000 kW x 860 kcal/kW x 2 ÷ 4,600 kcal/kg ÷ 0.411 (plant efficiency) x 1.0385 (MCR/ECR)
= 566.9 ton/h
Amount of SO_2 removed per hour:
Amount of SO_2 generated in boiler - Amount of SO_2 in flue gas after desulfurization process
(5,496 kg/h - 377 kg/h) x 2 = 10,238 kg/h
$CaCO_3$ reacting with SO_2 in 1 hour (theoretical reaction amount): 10,238 kg/h x 100 / 64 = 15,997 kg/h
$CaSO_4 \cdot 2H_2O$ produced in 1 hour (theoretical reaction volume): 10,238 kg/h x 172 / 64 = 27,515 kg/h
Limestone consumption per day: 15,997 kg/h x 24 h/day x 0.8 / 0.95 / 0.90 = 359 ton/day
Number of operable days for a 2,000 DWT class carrier: 2,000 ton / 359 ton/day = 5.8 days

Therefore, if the ship is delivered once every 5 days, there will be no shortage in limestone.

Amount of gypsum produced per day: 27,515 kg/h x 24 h/day x 0.8 = 528 ton/day

(d) Procurement of limestone

Limestone is not mined in Bangladesh, and cement companies that use limestone as a raw material import it from abroad.

According to Metro Cement Co Ltd, the major limestone importers in Bangladesh are as follows.

a) BIROTI-Rumki Ltd
b) Abden CEO Peakard Ltd.
c) Shahieen Lafrag Company
d) PW-FIDA

According to Shahieen Lafarg, 40% of its imports come from Vietnam, 50% from the UAE, and 10% from Oman, and the CIF price for cargoes received at Chittagong is about USD 25 per ton (excluding import duties and VAT).

According to PW-FIDA, they have a branch office in Singapore (Rubina Resources Pte Ltd.) and import from Vietnam, UAE, Oman, etc. BIROTI-Rumki had similar interview results.

The hearing results of BIROTI-Rumki were similar.

(e) Offtake of gypsum

Gypsum is used as a raw material for cement, so cement plants consider gypsum produced from FGD of Matarbari coal-fired power plant become a possible source of gypsum. Gypsum is a raw material for cement, which requires 3% of the cement production volume. 85% of total amount of gypsum must be procured. Table 8.3-8 shows the cement production capacity, gypsum requirements, and the amount of gypsum that can be procured by cement factories in Bangladesh.

The total amount of gypsum required to be procured by cement plants in Bangladesh is 1,771,511 ton/year. Since the amount of gypsum discharged from Matarbari Units 3/4 is 435 tons/day x 365 days = 158,775 tons/year, which is about 9% of the total amount of gypsum required to be procured by cement plants. Therefore, there is a possibility that cement plants in Bangladesh will take over gypsum from Units 3/4.

On the other hand, the quality of gypsum is also important. Table 8.3-9 shows the properties of natural gypsum. There is a possibility that the gypsum discharged from Units 3/4 will be required to be of similar quality.

Table 8.3-8 Statement of Installed Capacity of Different Cement Plants of BD which are under operation

Sl. No.	*Name of the Company*	*Plant Location*	*Plant Facilities for Production (Ball Mill, Roller Press & VRM)*	*Total Installaion Capacity (Metric Ton per Day)*	*Total Installation Capacity per Annum in Metric Ton (Considering 300 day / year)*
1	Anower Cement	Gozaria, Munshigonj	Ball Mill-1: 300 TPD, Ball Mill-2: 300 TPD, Ball Mill-3: 1800 TPD	2,400	720,000
2	Aman Cement	Ullapara, Sirajgonj	Ball Mill-1: 350 TPD, Ball Mill-2: 350 TPD	700	210,000
3	Aman Cement	Sonargoan, N-Gonj	VRM-1: 5000 TPD, VRM-2: 5000 TPD	10,000	3,000,000
4	Akij Cement	Bandar, N-Gonj	VRM-1: 3000 TPD, VRM-2: 5000 TPD	8,000	2,400,000
5	Aramit Cement	Kalurghat, CTG	Ball-1: 700 TPD, Ball Mill-2: 1000 TPD	1,700	510,000
6	Al-Haj Mostofa Hakim	Kumira, CTG	Ball Mill-1: 600 TPD	600	180,000
7	AR Cement	Noapara, Jessore	Ball Mill 1-8: 50 x 8 TPD = 400 TPD	400	120,000
8	AR Cement	Pabna	Ball Mill-1: 250 TPD, Ball Mill-2: 250 TPD	500	150,000
9	Bashundhara Cement	Madongonj, N-Gonj	Ball Mill-1: 2300 TPD, VRM-1: 6000 TPD	8,300	2,490,000
10	Bashundhara Cement	Mongla, Bagerhat	Ball Mill-1: 720 TPD, Ball Mill-2: 720 TPD, Ball Mill-3: 720 TPD, Ball Mill-4: 720 TPD, VRM-1: 6000 TPD, VRM-2: 10800 TPD	19,680	5,904,000
11	Bengal Cement	Sonargoan, N-Gonj	Ball Mill-1: 1800 TPD, Ball Mill-2: 1800 TPD	3,600	1,080,000
12	Bengal Tiger Cement (Japan Bangla)	Ghorashal, Narsingdi	Ball Mill-1: 600 TPD	600	180,000
13	Confidence Cement	Sitakundu, CTG	Ball Mill-1: 1600 TPD, Ball Mill-2: 2000 TPD	3,600	1,080,000
14	Crown Cement	Mukterpur, Munshigonj	Ball Mill-1: 600 TPD, Ball Mir-2: 800 TPD, Ball Mill-3: 1400 TPD, Ball Mill-4: 3000 TPD, VRM-1: 5280 TPD	11,080	3,324,000
15	Chatak Cement Ltd	Chatak, Sunamgonj	Ball Mill-1: 600 TPD	600	180,000
16	Diamond Cement	Chattogram	Ball Mill-1: 600 TPD, Ball Mill-2: 1000 TPD, Ball Mill-3: 2000 TPD	3,600	1,080,000
17	Desh Bandhu Cement	Ullapara, Sirajgonj	Ball Mill-1: 350 TPD, Ball Mill-2: 350 TPD	700	210,000
18	Dubai Bangla Cement	Mongla, Bagerhat	Ball Mill-1: 900 TPD, Ball Mill-2: 900 TPD, Ball Mill-3: 2000 TPD	3,800	1,140,000
19	Fresh Cement (Unique)	Meghnaghat, N-Gonj	Ball Mill-1: 800 TPD, Ball Mill-2: 800 TPD, Ball Mill-3 with Roller Press: 3000 TPD, Ball Mill-4 with Press: 6000 TPD, Ball Mill-5 with Roller Press: 6400 TPD	17,000	5,100,000
20	Gazi Cement	Rupgonj, N-Gonj	Ball Mill-1: 300 TPD, Ball Mill-2: 600 TPD	900	270,000
21	Holcim Lafarge	Meghnaghat, N-Gonj	Ball Mill-1: 720 TPD, Ball Mill-2: 720 TPD, Ball Mill-3: 720 TPD, Ball Mill-4: 720 TPD, Ball Mill-5: 720 TPD, Ball Mill-6 : 3360 TPD	6,960	2,088,000
22	Holcim Lafarge	Chatak, Sunamgonj	Ball Mill-1: 2400 TPD, Ball Mill-2: 2400 TPD	4,800	1,440,000
23	Holcim Lafarge	Mongla, Bagerhat	Ball Mill-1: 720 TPD	720	216,000
24	Insee	Madangonj, N-Gonj	Ball Mill-1: 2000 TPD	2,000	600,000
25	Metrocem Cement	Mukterpur, Munshigonj	Ball Mill-1: 800 TPD, Ball Mill-2: 1800 TPD, VRM (upcoming): 5000 TPD	2,600	780,000
26	Mongla Cement (Elephant Brand)-Sena Cement	Mongla, Bagerhat	Ball Mill-1: 2000 TPD, Ball Mill-2: 2000 TPD, Ball Mill-3: 2400 TPD	6,400	1,920,000
27	Mir Cement	Rupgonj, N-Gonj	Ball Mill-1: 600 TPD, Ball Mill-2: 1800 TPD	2,400	720,000
28	Modina Cement (Tiger & 3 -Rings Brand)	Meghnaghat, N-Gonj	Ball Mill-1: 200 TPD, Ball Mill-2: 200 TPD, Ball Mill-3: 200 TPD, Ball Mill-4: 200 TPD, Ball Mill-5: 3000 TPD	3,800	1,140,000
29	Modina Cement (Tiger Brand)	Pagla, N-Gonj	Ball Mill-1: 200 TPD, Ball Mill-2: 200 TPD	400	120,000
30	NGS Cement	Chattogram	Ball Mill-1: 500 TPD, Ball Mill-2: 1000 TPD	1,500	450,000
31	National Cement (**Premier** Brand)	Chattogram	Ball Mill-1: 720 TPD, Ball Mill-2: 720 TPD, VRM-1: 6480 TPD under construction	7,920	2,376,000
32	Olympic Cement (Anchor)	Barishal	Ball Mill-1: 600 TPD, Ball Mill-2: 600 TPD, Ball Mill-3 with Roller Press: 2800 TPD	4,000	1,200,000
33	Premier Cement	Mukterpur, Munshigonj	Ball Mill-1: 2000 TPD, Ball Mill-2: 2000 TPD, Ball Mill-3: 2000 TPD, Ball Mill-4: 2000 TPD, VRM-1: 11000 TPD under construction	19,000	5,700,000
34	Scan Cement (Scan)	Kanchpur, N-Gonj	Ball Mill-1: 2400 TPD, Ball Mill-2: 1080 TPD, Ball Mill-3: 2000 TPD	5,480	1,644,000
35	Scan Cement (Rubby)	Chattagram	Ball Mill-1: 1200 TPD, Ball Mill-2: 2800 TPD	4,000	1,200,000
36	Scan Cement (Scan)	Mukterpur, Munshigonj	Ball Mill-1: 2000 TPD	2,000	600,000
37	Seven Rings Cement	Kaligong, Gazipur	Ball Mill-1: 960 TPD, Ball Mill-2: 960 TPD, Ball Mill-3: 1800 TPD, Ball Mill-4: 1800 TPD, VRM-1: 9600 TPD	15,120	4,536,000
38	Seven Rings Cement (Shun Shing)	Khulna	Ball Mill-1 with Roller Press: 4320 TPD	4,320	1,296,000
39	Seven Rings Cement (Shun Shing)	Chattogram	VRM-1: 3840 TPD	4,320	1,296,000
40	Seven Horse (Eastern)	Siddirgonj, Narayangonj	Ball Mill-1: 350 TPD, Ball Mill-2: 350 TPD, Ball Mill-3: 350 TPD, Ball Mill-4: 600 TPD, Ball Mill-5: 600 TPD	2,250	675,000
41	Shah Cement	Mukterpur, Munshigonj	Ball Mill-1 with Polycon: 6000 TPD, Ball Mill-2: 1680 TPD, Ball Mill-3: 1680 TPD, Ball Mill-4 with Roller Press: 7500 TPD, VRM-1: 15360 TPD	32,220	9,666,000
42	S. Alam Cement	Chattogram	Ball Mill-1: 1200 TPD	1,200	360,000
43	Sheikh Cement	Khulna	Ball Mill: 400 TPD	400	120,000
				Total:	69,471,000
				Required gypsum quantity	2,084,130
				Gypsum quantity to be procured	1,771,511

Source: Metrocem Cement Ltd, West Mukterpur, Munshigonj

Table 8.3-9 Specification of Natural Gypsum (for reference)

No.	Key Indicator	Unit	Percent Level / Range
1	CaO	%	30 – 32
2	SiO_2	%	2.50% Max.
3	$Al_2O_3 + Fe_2O_3$	%	< 0.50%
4	MgO	%	1.50% Max.
5	SO_2	%	> 40%
6	Moisture	%	< 5.0%
7	Putiry	%	90% Min.

Source: Study Team

(f) Outline of main facilities

1) Ash treatment facilities
- Furnace bottom ash system: 1 unit/unit
- Ash collection system: 1 unit/unit
- Fly ash storage and discharge system: 2 units/2 units

2) Desulfurization equipment
- Air compressor system for oxidized air: 50 % x 3 units
- Service water pump and related equipment: 100 % x 2 units
- Absorption tower system (with internal corrosion protection): 1 unit
- Mist eliminator: 1 unit
- Limestone slurry system: 1 unit
- Dewatering system/vacuum filter system: 1 unit
- Other related equipment: 1 set

3) Limestone and Gypsum Equipment
- Lime stone unloader: 1 unit / 2 units
- Limestone receiving conveyor: 1 line / 2 units
- Lime stone storage silo: 1,000m^3 x 2 / 2 units
- Gypsum discharge facility: 1 unit/2 units

4) Ash dumping site
- Ash handling vehicle: 1 set

5) Fuel oil storage and processing facilities
- Trailer oil pumping equipment: 1 unit/unit
- Diesel oil storage tank: 1 unit
- Pump for diesel oil igniter: 30% B-MCR/2 units

(4) Flue Gas Denitration System (DeNOx)

(a) Denitration principle

Currently, the selective catalytic reduction method is widely used for denitration equipment in thermal power plants, and this method will also be used in this project.

The principle of the denitration system is to add a reductant in the presence of a catalyst to reduce NOx to N_2. Ammonia (NH_3) is commonly used as the reductant, and NOx in the exhaust gas is decomposed into N_2 and H_2O based on the following chemical reaction equation, which is then sent to the equipment downstream.

$$4NO + 4NH_3 + O_2 \rightarrow 4N_2 + 6H_2O$$
$$NO + NO_2 + 2NH3 \rightarrow 2N_2 + 3H_2O$$

In some cases, urea is used as a reducing agent instead of ammonia (which is highly irritating) for safety reasons.

This method is characterized by simple equipment, no by-products, and no need for post-processing.

(b) Main equipment configuration

The De-NOx system consists of three major components: the "De-NOx catalyst" for the De-NOx reaction, the "De-NOx reactor" that houses the catalyst, and the "ammonia injector" for injecting ammonia, a reducing agent, into the exhaust gas.

1) De-NOx catalyst

The De-NOx catalyst consists of the active ingredients to promote the De-NOx reaction, the substrate to support the active ingredients, and the auxiliary materials. The conditions required for a De-NOx catalyst are as follows.

- ✓ High denitration performance in the temperature range used.
- ✓ Low side reaction such as conversion rate from SO_2 to SO_3.
- ✓ High durability.
- ✓ Sufficient mechanical strength and heat resistance.
- ✓ When handling exhaust gas containing highly abrasive dust, such as coal combustion gas, it should be designed to be abrasion resistant and not easily blocked.

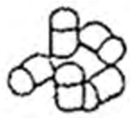
The main catalysts that meet these conditions and are currently in use are porous ceramics such as titanium and aluminum as supports, and several metal oxides as active components.

Catalyst shapes include granular, lattice, and plate shapes as shown in Figure 8.3-11. De-NOx catalysts are generally packed in catalyst containers (called packs, modules, baskets, units, flocks, etc.).

Board type is superior for wear resistance, ash buildup resistance, low pressure drop and durable performance.

Honeycomb is superior for initial amount of packed catalyst.

Granular is not applicable in the case of coal fired power plant.

	Board	Honeycomb	Granular
Feature	It has excellent resistance to catalyst wear and ash deposition, and is the best catalyst for high dust conditions such as coal-fired plants. Smaller effective area and larger amount of catalyst required compared to honeycomb catalyst	Although there is a concern about catalyst clogging in plants with large amounts of dust, the effective area is large and the amount of catalyst required is small (optimal catalyst for low dust conditions)	There is a possibility to make the reactor volume compact, but it cannot be used in a plant with dust. Also, the pressure drop of the catalyst bed is high.
Shape			
Wear resistance	◎	○	Not applicable in the case of coal fired power plant Applicable to Clean Gas
Ash buildup resistance	◎ (Large hydraulic diameter)	○	
Low pressure drop	◎ (Large hydraulic diameter))	○	
Initial amount of packed catalyst	○	◎ (Large specific surface area)	
Durable performance	◎	○	

Note: ◎: excellent, ○: good

Source: Study Team

Figure 8.3-11 Types, advantage and disadvantage of catalysts for practical use

2) Denitration reactor

In the case of coal-fired boilers, a denitration reactor structure such as that shown in Figure 8.3-11, in which the exhaust gas flows vertically, is generally used to prevent ash blockage. Ammonia is blown into the exhaust gas from the boiler and introduced into the denitration reactor.

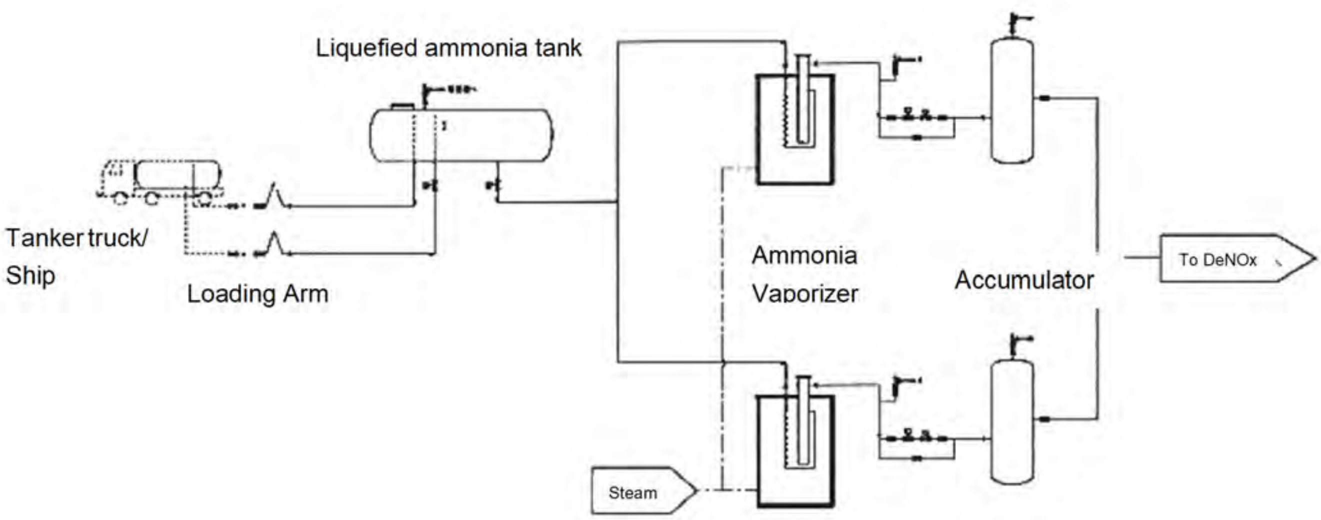
In the design of the De-NOx reactor, it is necessary to prevent the exhaust gas from being deflected and the catalyst from being blocked so that the De-NOx reaction can be carried out efficiently. Measures such as installing guide vanes upstream of the reactor are taken to prevent uneven flow. In addition, coal-fired boilers contain a lot of dust in the exhaust gas, which may block the catalyst, so a soot blower may be installed in the denitration reactor.

3) Ammonia injection system

a) Overview of ammonia injection system

Ammonia is generally received and stored in tanks as liquefied ammonia. When ammonia is sprayed into the flue gas, it is vaporized in an ammonia vaporizer, passed through an accumulator, diluted to a predetermined concentration with air, and then uniformly injected by ammonia injection nozzles. The number, size and shape of the injection nozzles located upstream of the denitration reactor are also determined to ensure that ammonia is uniformly injected into the exhaust gas. The criteria for these decisions vary from manufacturer to manufacturer of each denitration system, but the final ammonia adjustment can be made during commissioning.

Figure 8.3-12 shows the basic system of an ammonia supply facility.



Source: Thermal and Nuclear Power Engineering Association Introductory Course [Thermal Power Plant (Overall Plan and Auxiliary Facilities)] (Revised Edition) III. Environmental measures

Figure 8.3-12 Basic system of ammonia supply system

b) Trial calculation of the amount of ammonia for denitration

The table below shows the values, etc. for the estimated amount of ammonia to be injected into the denitration system of Units 3/4, based on the properties of the flue gas from Units 1/2.

Table 8.3-10 Conditions for calculating ammonia consumption

Items	Unit	Value	Remarks
Boiler Load	—	BMCR	
Exhaust Gas Volume	Nm^3/h, wet	2,228,822	Based on Max. Flue Gas Coal of Units 1/2
NOx at Inlet of DeNOx	ppmvd@6% O_2	150	
NOx at Outlet of DeNOx	ppmvd@6% O_2	30	As of NO_2
DeNOx Ratio	%	80	
Leak Volume of Ammonia	ppmvd@6% O_2	3.0	Assumed value

Source: Study Team

Table 8.3-11 Ammonia Consumption

Item	Unit	Value	Remarks
Ammonia Consumption /unit	m^3N / hr	230	Based on 80% utilization Density: 0.771 kg/m^3
Ammonia Consumption (gas base) /unit	kg/h, wet	178	Based on 80% utilization

Source: Study Team

c) Receiving of ammonia for DeNOx

Liquified ammonia will be transported by ocean transportation and unloaded at the temporary unloading berth where is located north-west of power plant area And then liquid ammonia will be transported by truck or pipeline to the ammonia storage tank located near DeNOx.

Alternatively, liquid ammonia is procured from the fertilizers in Bangladesh and transport it by truck to supply ammonia storage tanks.

Table 8.3-12 Receiving method of liquid ammonia

	Transportation by Truck	Transportation by pipeline	Remark
Receiving method	Ammonia will be received through unloading arm to truck and will be transported to the ammonia storage tank.	Ammonia will be received through unloading arm and pipeline and to will be transported to the ammonia storage tank.	
Construction cost	Base	Higher	
O&M cost	Base	Cheaper	
Evaluation	Recommendable		

Source: Study Team

d) Procurement and receiving of ammonia for denitrification

According to BCIC (Bangladesh Chemical Industries Corporation), all fertilizer factories in Bangladesh will sell liquid ammonia in cylinders or containers if there is a surplus of ammonia. The price is 32,632 taka/ton = JPY 42,307/ton (BDT 1 = JPY 1.2965 equivalent) ex-factory, which is the price applicable to all fertilizer plants.

In case that it is difficult to procure ammonia within Bangladesh, it is necessary to import ammonia from Singapore, Vietnam or Indonesia, etc.

(c) Design consideration

1) Planning conditions

This section describes the main planning conditions for planning a denitration system: denitration performance, exhaust gas volume, exhaust gas temperature, exhaust gas composition, aging of the catalyst, and selection of the catalyst.

a) Denitration performance

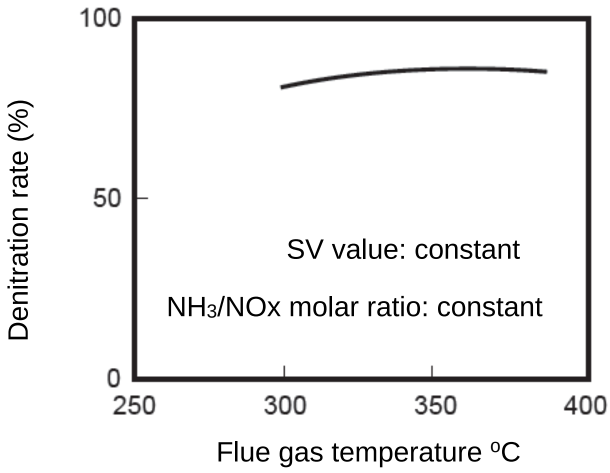
Denitration performance should be set in consideration of NOx concentration in exhaust gas, discharged NOx concentration and leaked ammonia.

b) Flue gas volume

The amount of exhaust gas is a major factor in determining the volume of the denitration reactor, and generally the amount of exhaust gas at MCR (Maximum Continuous Rating), when the boiler load is at its maximum, is used as the design condition.

c) Flue gas temperature

The exhaust gas temperature has a significant effect on the De-NOx performance. The relationship between De-NOx performance and exhaust gas temperature varies depending on the type of De-NOx catalyst, and an example is shown in Figure 8.3-13. When SOx is contained in the exhaust gas, a lower limit on the applicable temperature of the De-NOx system is necessary because a low exhaust gas temperature will cause acidic ammonium sulfate to be generated in the catalyst, resulting in a decrease in activity and other problems. In order to maintain the exhaust gas temperature at the applicable temperature, an economizer bypass may be installed.



Source: Thermal and Nuclear Power Engineering Association, Introductory Course [Auxiliary Equipment for Thermal Power Plants] IV. Auxiliary equipment measures for flue gas treatment system

Figure 8.3-13 Relationship between flue gas temperature and denitration rate

d) Exhaust gas composition

Various substances are contained in the exhaust gas, but NOx, SOx, and soot, which are particularly relevant to denitrification performance, are explained in this section.

➢ NOx

The concentration of NOx in exhaust gas varies depending on fuel properties, combustion conditions, etc., but generally the maximum concentration is about several hundred ppm, and within this range, there is almost no change in the denitration rate due to high or low concentrations.

➢ SOx

The concentration of SOx in the exhaust gas varies mainly depending on the sulfur content in the fuel. In the case of coal-fired boilers, the concentration of SOx in the exhaust gas varies from several hundred to several thousand ppm, and since alumina-based catalysts cause problems such as sulfuric acid chlorination of the catalyst, titanium-based catalysts are usually used for the exhaust gas from coal-fired boilers containing SOx.

➢ Soot and dust

The amount of soot and dust in the exhaust gas varies depending on the fuel and operating conditions. In the case of coal-fired boilers, it ranges from a few g/m^3N to several tens of g/m^3N. It is mainly responsible for catalyst wear, blockage and performance degradation.

2) Catalyst degradation over time and catalyst selection

The activity of a catalyst generally degrades over time due to poisoning. The main causes are as follows

- The activity of the catalyst decreases due to scientific bonding between the catalyst and components (alkali metals, etc.) in the exhaust gas.
- The components in the exhaust gas (e.g., dust) adhere to the catalyst surface, and the catalyst activity decreases. The activity of the catalyst decreases.
- Sintering of the catalyst at high temperature, resulting in loss of catalytic activity.

The above factors and characteristics of catalyst degradation over time must be fully taken into account when selecting the most important "appropriate catalyst.

The selection of appropriate catalyst includes the following

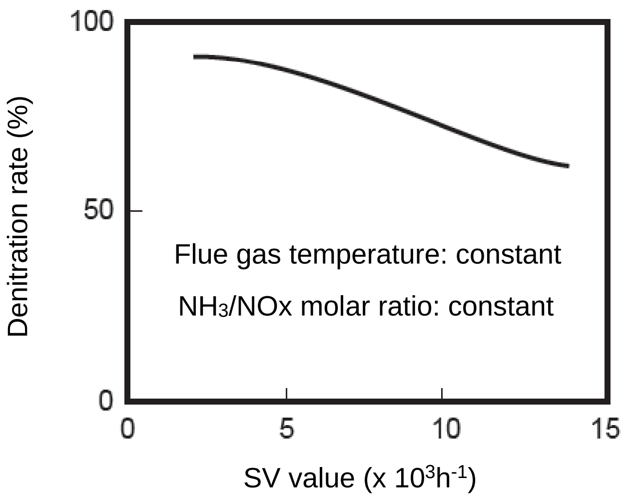
- Selection of catalyst type

- Selection of catalyst amount (SV value)
- Selection of operating conditions (molar ratio)

It is necessary to do these things properly. The following is a description of each.

- Selection of catalyst type
  In the case of coal-fired systems, it is necessary to use a catalyst with a low SO_2 conversion rate because SOx formation in the catalyst bed can damage the air preheater in the backflow. Furthermore, in coal-fired high soot De-NOx systems, it is necessary to select a catalyst with sufficient wear resistance. Nowadays, catalysts suitable for each fuel have been developed, and it is possible to select a catalyst suitable for each fuel type as catalyst retirement.

- Selection of catalyst amount (SV value)
  It is necessary to select the amount of catalyst (SV value: Space Velocity: amount of waste to be treated / amount of catalyst) to obtain the denitration performance that meets the design conditions. The denitration rate tends to decrease as the SV value increases, and this relationship is shown in Figure 8.3-14. The catalyst amount should be set based on this relationship. It is not advisable to fill more catalyst than necessary because it will increase the pressure drop, and it is necessary to select an appropriate amount of catalyst.



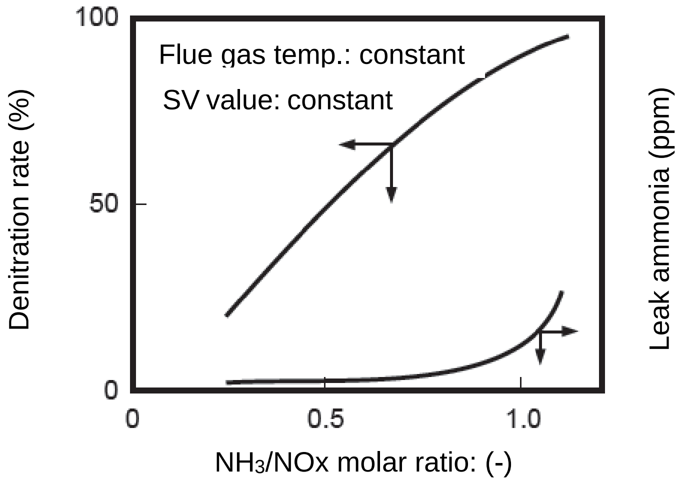
Source: Thermal and Nuclear Power Engineering Association, Introductory Course [Auxiliary Equipment for Thermal Power Plants] IV. Auxiliary equipment measures for flue gas treatment system

Figure 8.3-14 Relationship between flue gas temperature and denitration rate

- Selection of operating conditions (molar ratio)
  It is necessary to set the NH_3 / NOx molar ratio so that the target denitration rate can be obtained, taking into account the amount of leaked ammonia. The main reaction of denitration is expressed by the following equation.

$$4NO + 4NH_3 + O_2 \rightarrow 4N_2 + 6H_2O$$

Therefore, one mole of NH_3 is required for each mole of NOx, and the denitration rate is greatly affected by the amount of NH_3 injected.
Figure 8.3-15 shows the relationship between the molar ratio and the denitration rate. Based on this graph, select appropriate molar ratio.



Source: Thermal and Nuclear Power Engineering Association, Introductory Course [Auxiliary Equipment for Thermal Power Plants] IV. Auxiliary equipment measures for flue gas treatment system

Figure 8.3-15 Relationship between NH_3 / NOx molar ratio and denitration rate

(d) Maintenance Management of Catalyst

In the case of coal-fired power plants in Japan, if the De-NOx catalyst is a honeycomb type, the life of the catalyst is generally considered to be about 6 years. The frequency of catalyst replacement is based on the method of replacing half of the catalyst every three years. The cost of the catalyst is approximately 240 million yen/year/unit and 480 million yen/year/2units if half of the catalyst (160m^3) is replaced every three years (half of the total 327m^3 of catalyst).

8.3.11 Comparison Summary for Each Design Option

Table 8.3-13 summarizes a comparison for each design option evaluated in this chapter. The reasons why those options are selected for evaluation are follows.

(1) Steam Cycle

Steam cycle for thermal power plant is classified broadly into three types. Therefore it is selected typical steam conditions (temperature, pressure) for evaluation.

(2) Flue Gas Desulfurization (FGD)

These options are typical system commercially available for FGD of thermal power plants.

(3) Steam Turbine Shaft Configuration

In view point of steam turbine shaft configuration is classified broadly into two types.

(4) Desalination Plant

There are several systems to be commercially used for a desalination plant. MSF and RO are top two major system and MVC has become possible for selection.

Table 8.3-13 Comparison Summary for Each Design Option

Steam Cycle						
	Subcritical (16.6MPag, 538/538ºC)		Supercritical (24.1MPag, 538/566ºC)		Ultra Supercritical (USC) (24.5MPag, 600/600ºC)	
Record of application	Many	◎	Moderate	◎	Increasing rapidly	○
Reliability	High	◎	High	◎	High	◎
Thermal efficiency	39.15%	△	40.32%	○	41.1%	◎
CO2 emission	Base	△	110,500 ton/year Less	○	198,300 ton/year Less	◎
Economic evaluation	Base	△	NA	○	98 to 158 million USD, more economical	◎
Total evaluation	△		○		◎	
Flue Gas Desulfurization (FGD)						
	Limestone – gypsum FGD		Seawater FGD			
FGD efficiency	90～99%	◎	90～95%	○		
Absorbent	Limestone (required to install limestone unloading / handling facilities)	△	Seawater	◎		
Byproduct (Waste)	Gypsum (required to dispose or to establish recycle chain)	△	Sulfate ion (discharge to the sea)	○		
Waste water treatment	Wastewater treatment plant is required	○	Only oxidation in seawater aeration pond	◎		
Plant space	Large	○	Smaller	◎		
Service water consumption	Much	△	Little	◎		
Availability	Very high	◎	Higher (no limestone/ gypsum handling)	◎		
Levelized cost	Base	○	Cheaper	◎		
Record of application	Since 1990s, world share 83%	◎	Since 1990s, world share 3%	△		
Total evaluation	◎		○			
Flue Gas Denitration System (DeNOx)						
	Board Type Catalyst		Honeycomb Type Catalyst		Granular Type Catalyst	
Wear Resistance	High	◎	Base	○	Not applicable in the case of coal fired power plant.	
Ash Buildup Resistance	High	◎	Base	○		
Pressure Drop	Low	◎	Base	○		
Initial Amount of Packed Catalyst	Base	○	Small	◎		
Durable Performance	High	◎	Base	○		
Initial/Running Cost	Base	○	Almost Same Level with Board Type	○		
Total Evaluation	○		○		X	
Steam Turbine Shaft Configuration						

	Tandem Compound (TC)		Cross Compound (CC)			
Shaft length	Longer	○	Base	◎		
Reliability	Similar	◎	Base	◎		
Turbine efficiency	Same	◎	Base	◎		
Installation space	Smaller	◎	Base	○		
Operability	Simple	◎	Base	○		
Maintainability	Easier	◎	Base	○		
Construction cost	Less	◎	Base	○		
Running cost	Same	◎	Base	◎		
Total evaluation	◎		○			
Desalination Plant						
	Multi Stage Flash (MSF)		Mechanical Vapor Compression (MVC)		Reverse Osmosis (RO)	
Total dissolved substance (TDS)	10	○	5	◎	10 (by two stages treatment)	○
Investment cost	Higher	○	Higher	○	Base	◎
Energy consumption	25kWh/m3 (including steam energy)	△	11kWh/m3	○	5kWh/m3	◎
O&M cost (excluding energy cost)	Cheaper	◎	Cheaper	◎	Base	○
Raw water consumption	6～8 m3/m3	△	3 m3/m3	○	2 m3/m3	◎
Record of application	Considerable experience for large capacity plants	◎	Has become a possible process	○	Has become a major process	◎
Reliability	High reliability Corrosion, scale problems	◎	Simple system Lower temperature operation than MSF	◎	Simple system	◎
Operability		◎	Simple system	◎	Simple system	◎
Total evaluation	○		△		◎	

Legend: ◎Excellent, ○Good, △Poor
Source: Study Team

8.3.12 Fuel and Coal Facility

(1) Study Concept

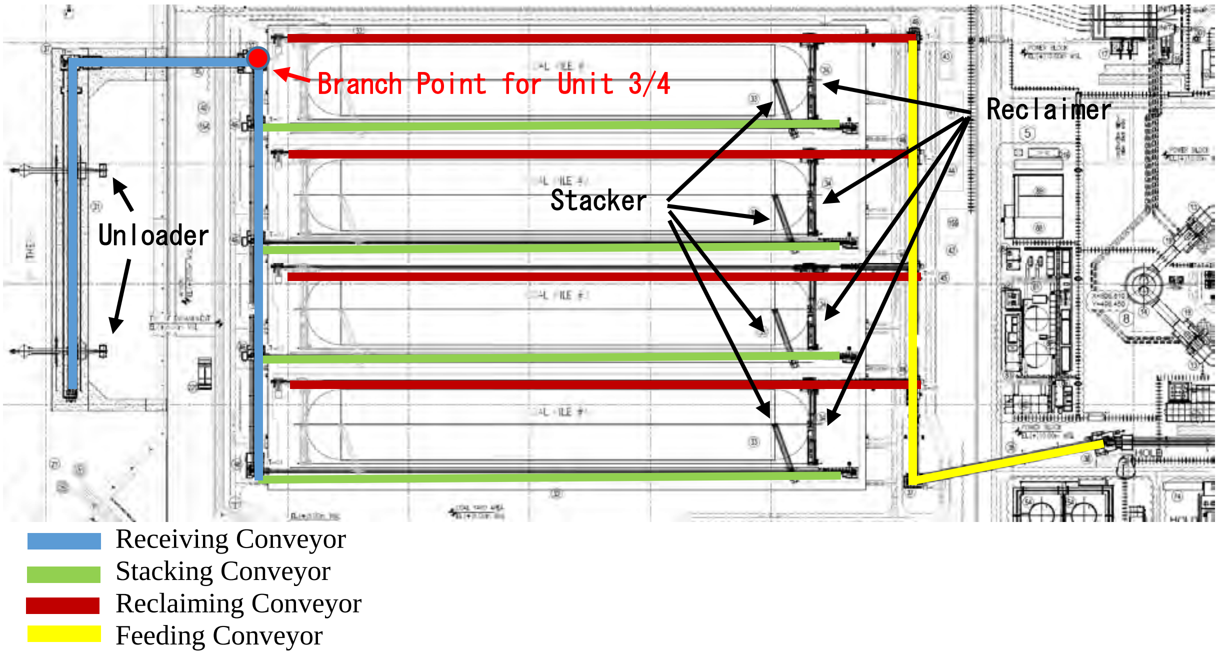
At Units 1/2 Project which is under construction project, the design for a part of the coal handling facility is considered with the expansion for this project. Basically, the following for Units 1/2 Project design is better to optimize the operation system of all of the station of Matarbari. And also it will contribute for easy maintenance and operation.

(2) Coal Facility of Units 1/2 Project

The main facility of Units 1/2 Project is shown as follows;

Table 8.3-14 Main Facility of Units 1/2 Project

Unloader	Type	Continuous Bucket Type
	Capacity	1,500 t/h
	Units	2 Unit
Coal Yard	Type	Indoor Type
	Pile Number	4 piles
	Capacity	For 60 days
Conveyor	Type	Flat type Belt Conveyor
	Load Factor	80%
	Capacity	Receiving / Stacking Conveyor 3,000 t/h Reclaiming / Feeding Conveyor 1,450 t/h
	Angle	Line for Unloader / Stacker Maximum 17 degree Other Line Maximum 14 degree
	Numbers	Receiving Conveyor 100 % x 2 Line Stacking Conveyor 100 % x 4 Line (1 Line for each pile) Reclaiming Conveyor 100 % x 4 Line (1 Line for each pile) Feeding Conveyor 100 % x 2 Line
Stacker	Type	Travelling, slewing and luffing stacker
	Units	4 Unit
	Capacity	3,000 t/h per 1 unit
Reclaimer	Type	Portal scraper reclaimer
	Units	4 Unit
	Capacity	1,000 t/h per 1 unit

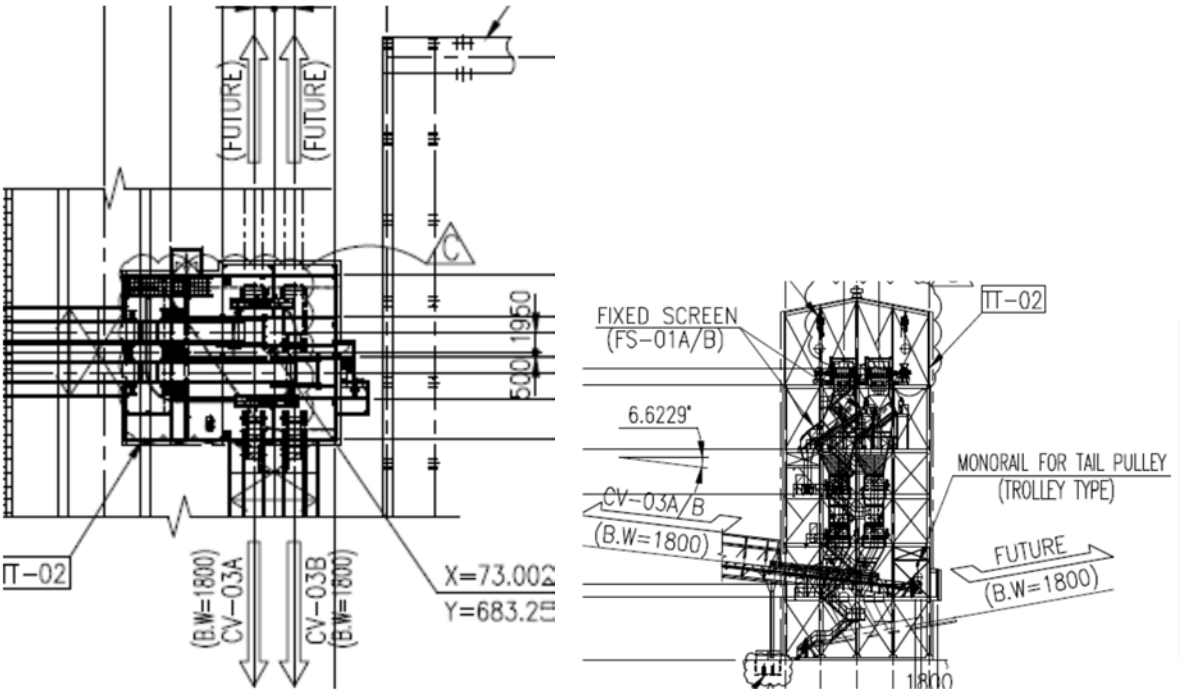


Source: Study Team from Units 1/2 Design Document

Figure 8.3-16 Layout for Coal Handling Facility of Units 1/2 Project

The coal carrier capacity is assumed as 80,000DWT (Deadweight tonnage) class for this plant. The coal will be unloaded while 2 or 3 days. From Unloader to Coal Yard, the two line conveyors which have 3,000 t/h capacity with the redundancy consideration are planned. The coal yard is divided as 4 indoor type piles which have the system for prevent of coal combustion. And by the stackers which are set for each plie, the coal will be stacked at the plie. The reclaimers are also set for each pile. The coal mixing on the feeding conveyor is planned. The way can mix the coal as designed percentage of coals by the speed control of reclaimer and conveyor. However, the coal of same pile cannot be mixed and the coal cannot be piled up other pile due to conveyor's direction. And there is constraint for the layout. There are 5 m of the height difference between the coal yard area and the power plant area and 60 m of the coal banker height. So the layout should be considered with conveyor angle as allowable angle of the vendor's specification.

The branch point for Units 3/4 facility is considered at No.2 transfer tower. And the point direction can be changed by the chute operation control.



Source: Units 1/2 Design Document

Figure 8.3-17 Branch Point of No.2 Transfer Tower

Each unit number and capacity of Units 1/2 Project is designed based on the following concept which is assumed on Basic Design Report of Units 1/2 Project.

The unloading capacity shall be sufficient enough to cover the full coal demand for 4 units of 600 MW with a Plant Capacity factor (CF) of 80 %. The hourly coal consumption would rise up to 877 t/h for a HHV of 5,700 kcal/kg or 1,064 t/h with a HHV of 4,700 kcal/kg as originally given in the feasibility study. For an HHV of 4,200 kcal/kg even 1190 T/h would be required. Considering furthers the limited navigation time and maintenance of the unloading facilities – a minimum capacity of 1,500 t/h per unloader is necessary. With reference to the aforesaid the nominal transport capacity of the receiving conveyors must be enlarged up to 3,000 t/h too.

From the above, the capacity is designed for 4 units of 600 MW as 80 % plant availability. Focused for the unloader, the capacity is almost twice the amount of capacity 1,500 t/h from the value of Units 1/2 Feasibility Study which is 800 t/h as assumed. Therefore, the shortening of unloading duration is expected from 4 days to 2.3 days. Of course, the capacity of other facility is also augmented.

Additionally, the load factor of unloading facility is estimated as follows;

With other words the equipment-using coefficient would be 50% for 5,700 kcal/kg or 61 % for 4,700 kcal/kg and 68 % for 4,200 kcal/kg with 4 unties.

The important points for the expansion of the coal handling facility are the capacity of each facility, the coal receiving schedule through the year, and the concept of the connection between Units 1/2 and Units 3/4.

(3) Study for the coal handling facility and operation

The operation hour for the unloading work which is including the works of berthing and un-berth is calculated with the method of the report "Preparatory Survey for the Construction and Operation of Imported Coal Transshipment Terminal Project in Matarbari Area; 2016, JICA" (CTT Report) which was conducted after the Unit 1/2 FS. The estimation will be done as 4 units operation (Units 1/2 and Units 3/4).

Table 8.3-15 Conditions for Estimation

Total Generation Output	2,400 MW (Gross) 600MW x 4 units
Thermal Efficiency (Units 1/2)	41.1% (HHV, Gross)

	Same as mentioned on 8.1.1 (4)
Thermal Efficiency (Units 3/4)	41.1% (HHV, Gross) Same as mentioned on 8.1.1 (4)
Plant Availability	80 %
Rated power factor (BMCR/ECR)	3.85% Source : Unit 1/2 EPC Design Document
Performance Coal	4,600 kcal/kg (HHV) Source : Unit 1/2 EPC Design Document
Design Coal (Lowest Calorie)	4,200 kcal/kg (HHV) Source : Unit 1/2 EPC Design Document
Unloading Capacity	3,000 t/h 1,500 t/h x 2 units Source : Unit 1/2 EPC Design Document
Unloading Efficiency	70 % (Minimum) Source : Unit 1/2 EPC Design Document
Coal Carrier Capacity	80,000 DWT class (working capacity) Source : Unit 1/2 EPC Design Document
Operation Shift	3 shifts Same as CTT Report
Working hour per shift	6 hours Same as CTT Report
Preparation hour per shift	2 hours Same as CTT Report
Assumed shut down period (CTT Report)	15 days per year Same as CTT Report
Assumed shut down period (Units 1/2 FS Report)	50 days per year Same as Units 1/2 FS Report
Berthing Working Hours / Unloading Preparation Hours	6 hours Same as CTT Report

(a) Fuel Consumption

The formula for the fuel consumption is below. The unit transformation is omitted on this formula.

Fuel consumption＝(Total Generation Output x Rated power factor / Fuel Calorie / Thermal efficiency)

Annual consumption＝Fuel consumption x Plant Availability x 24 hours x 365 days

- Performance Coal
  Units 1/2 coal consumption: 566.9 t/h
  Units 3/4 coal consumption: 566.9 t/h
  Yearly consumption: 7,945,904 t/year
  Necessary vessels: 100 vessels

- Design Coal (Lowest Calorie)
  Units 1/2 coal consumption: 620.9 t/h
  Units 3/4 coal consumption: 620.9 t/h
  Yearly consumption: 8,702,768 t/year
  Necessary vessels: 109 vessels

(b) Operation hours per 1 vessel

For the 80,000DWT class (working capacity), the unloading hours will be calculated with following formula;

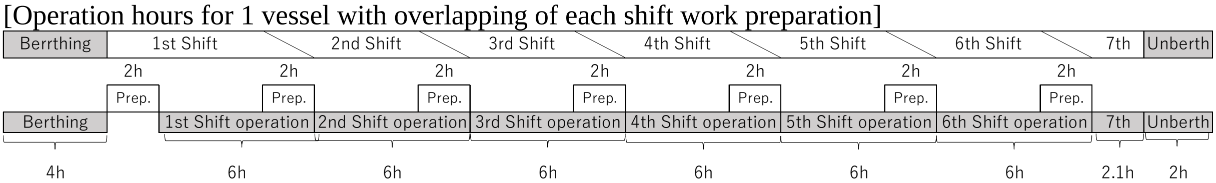
Unloading hours＝(Working capacity of vessel / (Unloading capacity x Unloading efficiency))
＝(80,000 ton / (3,000 t/h x 70%))
＝38.1 hours ＝ 6.34 shifts

Thus, with the additions of each preparation of shift and berthing hours, total operation hours will be calculated to 58.1 hours. And also, by the overlapping of each shift work and/or increase of shift numbers, 12 hours for preparations which is occurred with intervals of shifts would be reduced and the operation could be continued without any suspension. In this case, total operation hours will be calculated to 46.1 hours.

[Operation hours for 1 vessel]

Berthing	1st Shift		2nd Shift		3rd Shift		4th Shift		5th Shift		6th Shift		7th Shift		Unberth
4h	2h	6h	2h	6h	2h	6h	2h	6h	2h	6h	2h	6h	2h	2.1h	2h

[Operation hours for 1 vessel with overlapping of each shift work preparation]



Source: Study Team

Figure 8.3-18 Structure of operation hours

(c) Berth occupancy ratio in Case A, assumed shut down period: 15 days, 46.1 operation hours for 1 vessel

The formula for the operation day and load factor is below. The unit transformation is omitted on this formula.

Operation day＝(Necessary vessels x Operation hours)

Load factor＝(Operation day) / (365 days－Shutdown period)

- Performance Coal
  Operation days per year: 192 days
  Berth occupancy ratio: 54.9 %

- Design Coal (Lowest Calorie)
  Operation days per year: 209 days
  Berth occupancy ratio: 59.8 %

(d) Berth occupancy ratio in Case B, assumed shut down period: 50 days, 46.1 operation hours for 1 vessel

- Performance Coal
  Operation days per year: 192 days
  Berth occupancy ratio: 61.0 %

- Design Coal (Lowest Calorie)
  Operation days per year: 209 days
  Berth occupancy ratio: 66.4 %

(e) Berth occupancy ratio in Case C, assumed shut down period: 15 days, 58.1 operation hours for 1 vessel

- Performance Coal
  Operation days per year: 242 days
  Berth occupancy ratio: 69.2 %

- Design Coal (Lowest Calorie)
  Operation days per year: 264 days
  Berth occupancy ratio: 75.4 %

(f) Berth occupancy ratio in Case D, assumed shut down period: 50 days, 58.1 operation hours for 1 vessel

- Performance Coal
  Operation days per year: 242 days
  Berth occupancy ratio: 76.8 %

- Design Coal (Lowest Calorie)

Operation days per year:	264 days
Berth occupancy ratio:	83.8 %

From the above, if the performance coal is applied, the berth occupancy ratio will be 54.9 % (Case A), and 61.0 % (Case B). According to the evaluation of harbor calmness of Unit 1/2 FS report, with the design of excavated port, the harbor calmness (under 1.5m wave height in the entrance of channel) will be secured in 99.4% per years. Thus, the interruption due to the wave condition will be few with the consideration. In case of Japanese power plant, the factor is set around 50%. And also, according to the report by Ministry of Transport, Japan, currently called Ministry of Land, Infrastructure, Transport and Tourism, Japan on the 45th meeting of Japan Society of Civil Engineers (Harbor availability and mooring vessels motions). The report showed the percentages of the failure of berthing in the Pacific Ocean port in Japan. It shows that the 14.6% vessels were postponed or canceled to berthing the port in the year. Compared with this report and based on the evaluation of harbor calmness of Unit 1/2 FS report, the considering of 50 days shut down period is appropriate duration. According to UNCTAD guideline, for the dry bulk cargo including the coal, the specific load factor is not mentioned. But the guideline recommend to struggle to keep the lower load factor.

On the other hand, the assumption is including the navigation work from the entrance of the port with the operation pilot and tag boat. So, virtually the operation hour will be the equivalent hour with the above. As for the work on the navigation channel, the works can be done in parallel.

(4) Unloader

Units 1/2 facility will be utilized. The maximum design capacity of unloader is 120% of the nominal capacity normally. At the Units 1/2 facility's design, the design capacity is also considered as 1,800 t/h (Nominal Capacity is 1,500 t/h).

(5) Receiving Conveyor

The capacity will be matched for the unloader capacity. Thus, the conveyor capacity will be estimated based on 2 units unloader nominal capacity. As mentioned at (2), the receiving conveyor has two line of the conveyors for the redundancy. Even if the one line is stopped due to some trouble or maintenance, the other line will work for the continuous operation. For Units 3/4 facility, the redundancy concept also shall be considered.

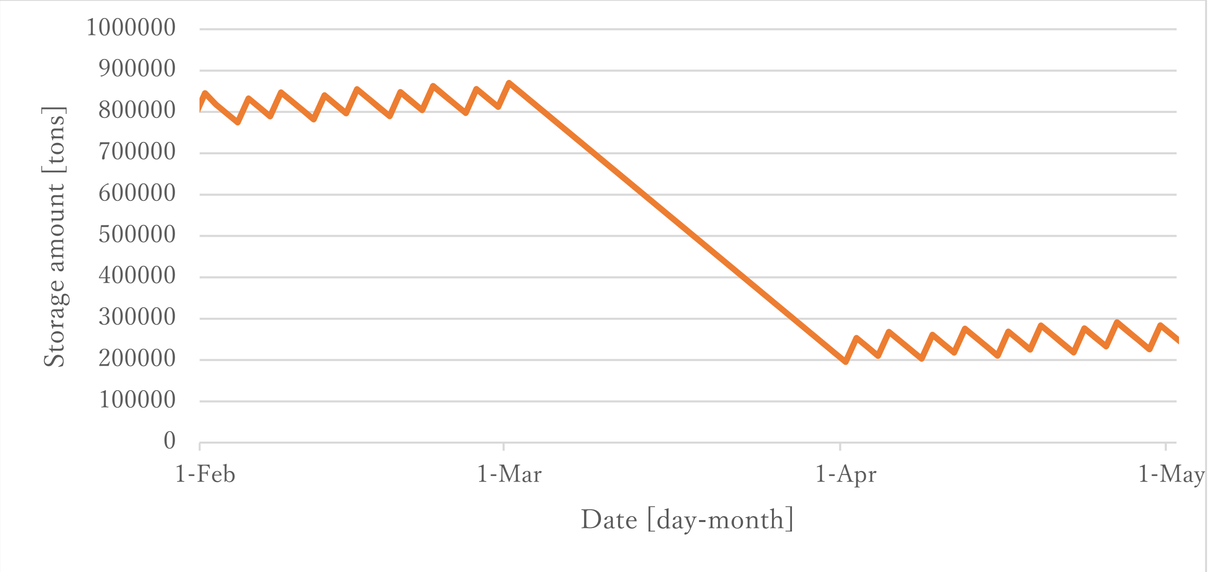
(6) Coal Yard

The same type of coal yard of Units 1/2 is better. The capacity also will be considered 60 days operation for 2 unit of 600 MW plant as same as Units 1/2 coal yard. For the Unit 3/4 also, the same levels of capacity should be considered. This is the capacity for the countermeasure for the stop of the shipping and transportation operation to Matarbari site due to the accident of the coal supplier or the disaster. The capacity is assumed as 830,000 tons. And the pile number is also same as Units 1/2.

Although the area for Unit 3/4 coal yard is slightly narrow than Unit 1/2 one, by the adjustment of the load layout, Unit 3/4 also will have the same capacity.

For the coal carrier vessels, based on the long term supply contracts, the several vessels will be operated. So, in case of trouble of one supplier, the other supplier can cover. If the only one supplier will be contracted for the coal supply, the period to solve the supplier problem cannot supply the all of coal if the serious trouble will occur.

The following figure is the case study that the storage amount will start from 50 % capacity of coal storage capacity of coal yard through unit 1 to 4, almost 800,000 tons, and the all of supply will stop during 30 days to solve the supplier problem. In this figure, the plant availability is assumed as 80 % and levelized.



Source: Study Team

Figure 8.3-19 Coal storage transition (30 days coal supply suspension case)

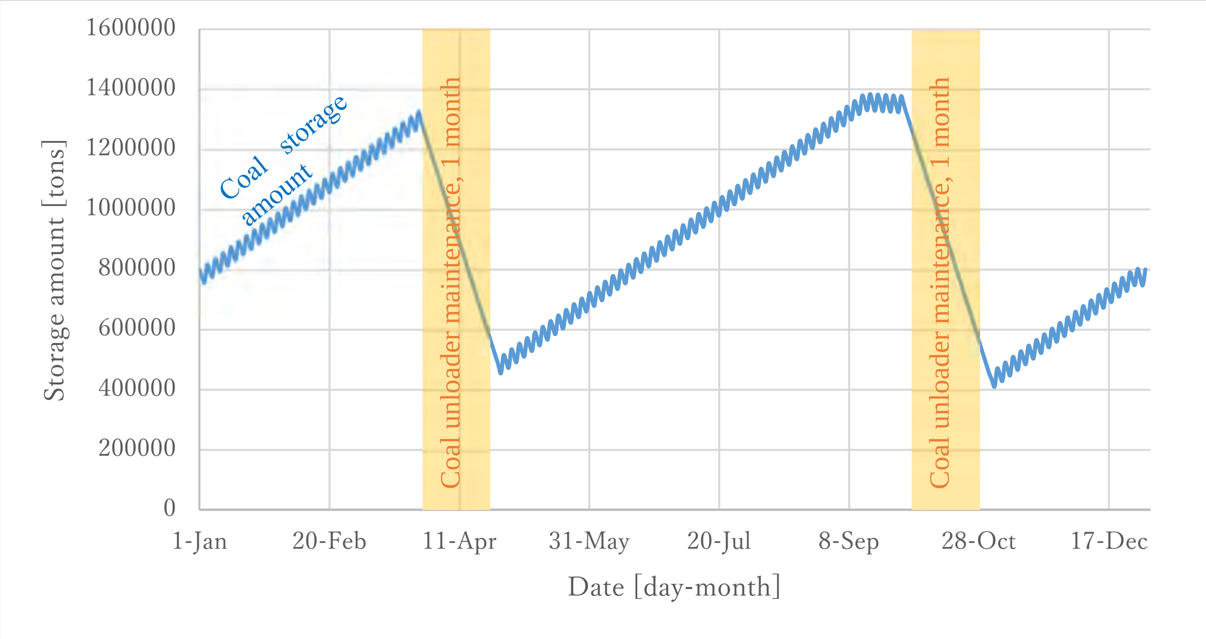
In this case, the storage amount will be decrease to 150,000 tons.

For the consideration of coal yard capacity, the coal supply contract is the key factor to verify the capacity. However, even though the contract is under discussion for Units 1/2, the capacity should be set as safety value at this time. If the yard will be made the size smaller, the several supply contract should be considered.

And this is the point of consideration, the coal yard will not storage the 100 % amount of coal in the operation. So, all of margin cannot be utilize for the operation.

For the next, the yearly coal transition is show based on the assumption of availability and coal supply vessels. This is the imaginal case study, so the overlapping of maintenance or detail schedule assumption and adjustment are not considered. At this study, the maintenance for power plant and coal jetty will be taken sequential with follow assumptions.

Yearly coal vessels: 100 vessels
Unloading operation period: 3 days
Unit 1 to 4 regular maintenance: 1 month for each
Unit 1 to 4 other shutdown period: 40 days for each
Unit 1 to 4 availability: 80 % considered (Totally 70 days shutdown)
Coal jetty maintenance: 2 months



Source: Study Team

Figure 8.3-20 Yearly coal transition

At the start, the storage is 800,000 tons and the end, the storage is 800,274 tones in this assumption. Maximum drop of storage is 1,000,000 tons in this case. If the total capacity is designed as 30 days storage, it will be minas. From this case study also, the 60 days capacity is recommended.

(7) Stacker and Reclaimer

(a) Capacity of Stacker

The capacity of stackers will be same as the receiving conveyor.

(b) Capacity of Reclaimer

24 hours Coal Handling Operation by 8 hours working shift is assumed. And the working shift can be divided into 2 hours preparation work and 6 hours coal handling work as assumed. Thus, the capacity of reclaimers will be designed as 18 hours operation for the total coal consumption per day. The estimations of Units 1/2 Feasibility Study are follows;

- Actual operation time : 18 hours (6 hours x 3 shifts)
- Work preparation time : 6 hours (2 hours x 3 shifts)
- Loading efficiency : 0.8
- Nominal Capacity of the Reclaimer = 13,783 ton/day / 18 hours / 0.8 = 957 ton/hour < 1,000 ton/hour
- Reclaimer Nominal Capacity : 1,000 ton/hour

At the construction stage of Units 1/2, the same capacity is used for the design. And several reclaimer can be operated as parallel operation. Total reclaiming capacity which is same as coal supply capacity is designed as 1,450 t/h for Units 1/2. For Units 3/4, the capacity is enough for the continuous operation.

(c) Unit numbers

Stacker and reclaimer type which has the function of each equipment is better from the point of view of layout consideration. However, in the case of the applying that type which is different from Units 1/2, the operator have to study the different type as newly for Units 3/4. It may be a cause of confusion and human error. Therefore, the same facility from Units 1/2 is better for Units 3/4 operation. 4 stackers and 4 reclaimers will be set for each pile respectively.

(8) Feeding Conveyor

The capacity of the feeding conveyor will be designed with a margin from the capacity of the reclaimer.

At Units 1/2 design, the capacity is designed as 1,450 t/h. And the conveyor has two line for the redundancy. The coal mixing will be done on this conveyer.

(9) Miscellaneous facility for coal handling

Units 3/4 also should have the equivalent miscellaneous with Units 1/2. Not limited to the following, the miscellaneous will be assumed in the following;

- Coal screen
- Coal crusher
- Measurement equipment on the conveyor
- Dust extractor
- Fire fighting system
- And etc.

Each requirement of equipment should be considered in the basic design stage.

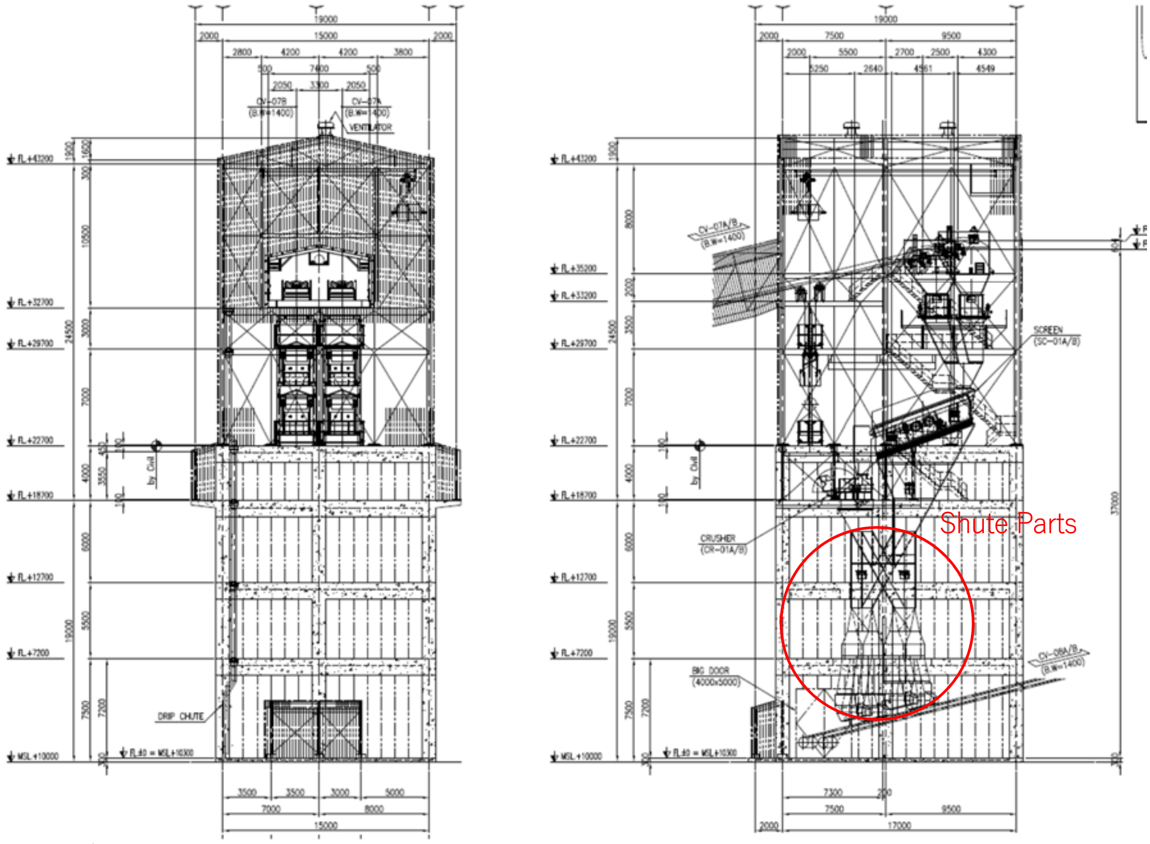
(10) Sharing of Coal Handling Facility

The sharing of the coal handling facility between Units 1/2 and 3/4 is better for the coal stock management and the operation planning of Matarbari power plant. The purpose of the sharing is shown below;

- Each brand of the coal can be managed respectively as all of power plant. It will make a simplification of the coal handling operation.
- The changeover the operation to distribute the coal for each stock pile is not necessary.
- In the case of the disaster or etc., when the coal yard of Units 1/2 cannot operate, the power plant can be operated continuously by the feeding coal from Units 3/4.

However, there are demerits for the sharing. It should be noted.

- Because there are the time lags of the coal supply flow rate for coal banker, coal feeder, and combustion flow rate, the actual coal consumption for Units 1/2 and 3/4 will be difficult to clarify as timely. If the operation company is different, the basis of payment calculation for fuel consumption should be designated clearly.
- Due to the constraint of Units 1/2 conveyor operation direction, the modification of the transfer tower to branch to lines for Units 3/4 will be necessary. It’ll be additional cost for Units 3/4 project. The candidate modification place is expected on Transfer Tower – 04 which has sufficient height. The assumed modification is an addition of branch point to shute parts of the tower. The section drawing of the tower is shown below;



Source: Units 1/2 Design Document

Figure 8.3-21 Transfer Tower -04 Section Drawing

- The road and embankment which is located between Units 1/2 area and Units 3/4 area is high from Coal Yard area. So, the road will be an obstacle for the conveyor connection. The countermeasure such as the underground or high elevated connection will be needed. To avoid the modifying of the dike, the high elevated connection is better.
- The workload of the operators will increase due to increasing the control work for the exchange lines and covered area and stock amount including coal management for each coal type.
- The timing of the work for the connection between Unit 1/2 and Unit 3/4 can be selected as optionally. So, it can be included in Unit 3/4 scope or the further work scope.

(11) Assumed main coal handling equipment for Units 3/4

As from the above, the equipment is summarized as below table;

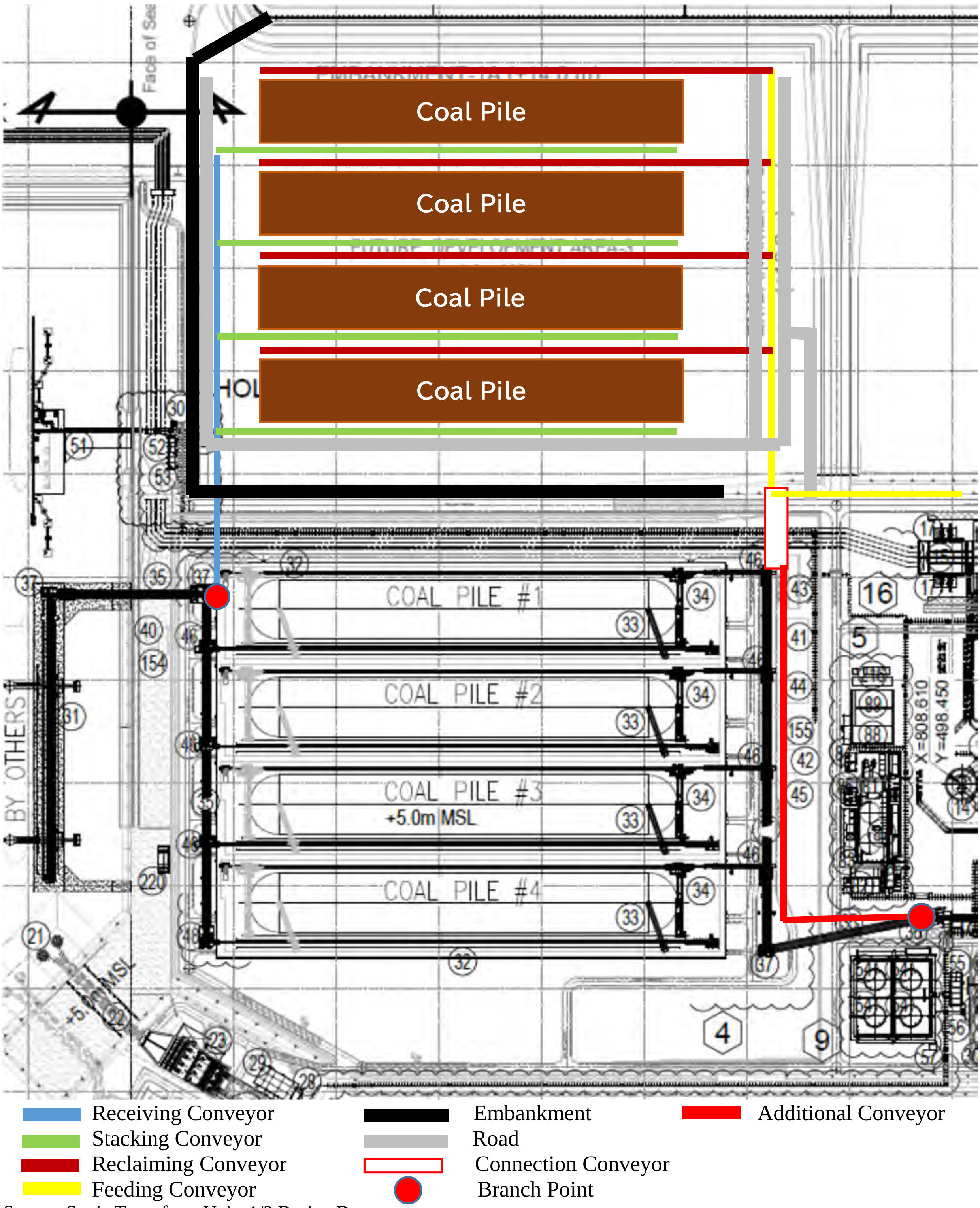
Coal Yard	Type	Indoor Type
	Pile Number	4 piles
	Capacity	For 60 days
Conveyor	Type	Flat type Belt Conveyor
	Load Factor	80%
	Capacity	Receiving / Stacking Conveyor 3,000 t/h Reclaiming / Feeding Conveyor 1,450 t/h
	Angle	Line for Unloader / Stacker Maximum 17 degree Other Line Maximum 14 degree
	Numbers	Receiving Conveyor 100 % x 2 Line Stacking Conveyor 100 % x 4 Line (1 Line for each pile) Reclaiming Conveyor 100 % x 4 Line (1 Line for each pile) Feeding Conveyor 100 % x 2 Line Connection conveyer 100 % x 2 Line
Stacker	Type	Travelling, slewing and luffing stacker

	Units	4 Unit
	Capacity	3,000 t/h per 1 unit
Reclaimer	Type	Portal scraper reclaimer
	Units	4 Unit
	Capacity	1,000 t/h per 1 unit

(12) Assumed Layout

With the above and following assumptions, the coal yard layout for Units 3/4 is prepared.

- Unit 1/2 layout will be followed.
- The embankment height is + 8 m and it will be connect to the embankment of ash pond (+14m).
- The road slope gradient will be 3/100 m as same as Units 1/2.
- The connection between Units 1/2 and 3/4 will be connected by using the vertical conveyor.
- The additional conveyor for connection line from Units 1/2 yard to Units 3/4 yard will be installed next to existing line.



Source: Study Team from Units 1/2 Design Document

Figure 8.3-22 Assumed Layout of Units 3/4 Coal Yard

(13) Light oil supply facility

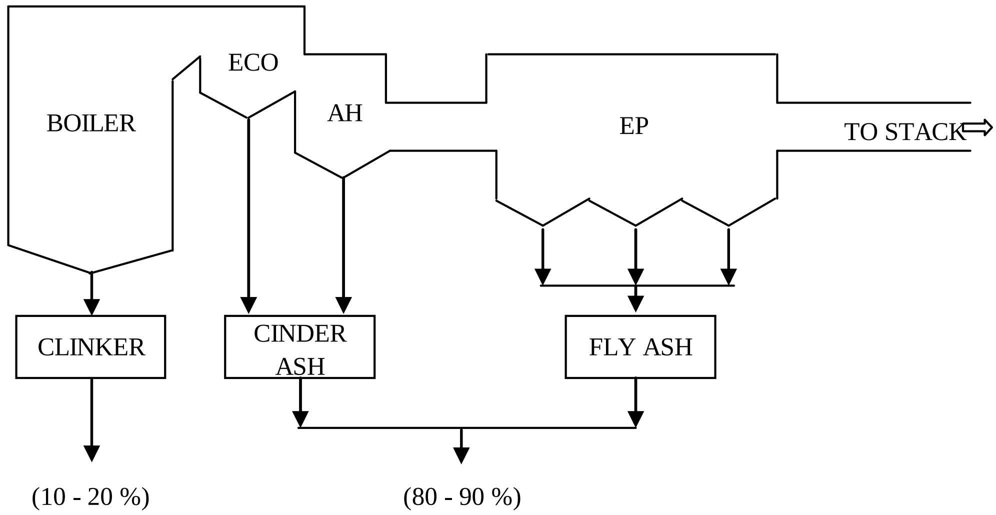
For Units 3/4 facility, the light oil storage tank of Units 1/2 facilities will be utilized. The tank of Units 1/2 has 4,000 m^3 capacity for each. Total capacity of storage tank under Units 1/2 is 16,000 m^3 (4,000 m^3 x 4). It is sufficient storage as coal fired power plant.

In Units 3/4 scope, two of service tanks and light oil pumps yard will be considered mainly. And additionally, the brunch piping, valves and transfer pump from the tank of Units 1/2, and measurement equipment will be necessary. Mostly, the facility of Units 1/2 including the unloading facility will be utilized.

8.3.13 Ash Handling Facilities

Figure 8.3-23 shows an example of the distribution of ash in the various parts of the coal fired boiler.
In general, ash in coal is captured in various parts in the flue gas flow (outlined below) in the course of the combustion of coal in the boiler until the flue gas is discharged from the stack.

- The ash which is melted by the coal combustion falls to the bottom hopper of the boiler furnace and is captured. This is called clinker. About 10 - 20% of the amount of all ash is captured in this way.
- A part of the combustion ash which floats in the flue gas falls to the bottom hopper of the economizer and the air heater in the downstream of flue gas and is captured. This combustion ash is called cinder ash. 5% or less of the amount of all ash is captured here.
- The combustion ash which is captured by the electrostatic precipitator is caught in the bottom hopper of the electrostatic precipitator. It is called fly ash. In general, 80 - 90% of the amount of all ash is captured here.

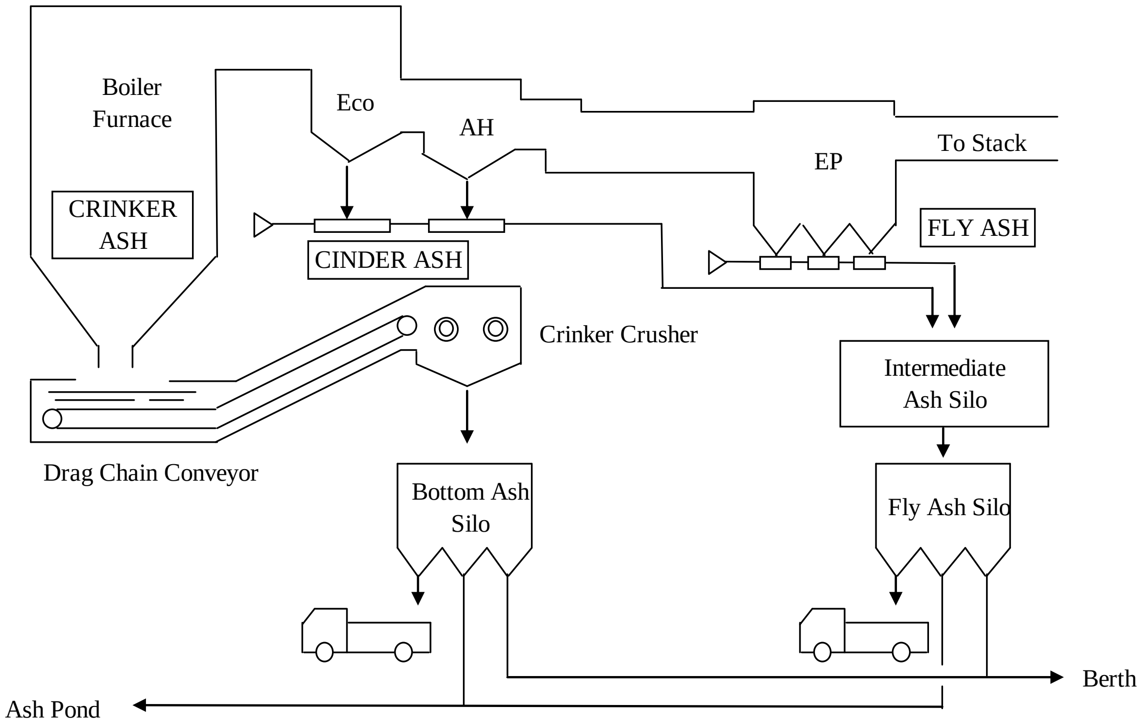


Source: Study Team

Figure 8.3-23 Place of Generation and Ratio of Generation of Coal Ash

The collected coal ash is generally transported and processed through ash handling systems that may be roughly categorized into two systems as follows. Figure 8.3-24 shows an overview of the ash handling system.

- The first system handles clinker that falls to the bottom hopper of the boiler and the pyrite exhausted from the coal pulverizer.
- The second system handles the cinder ash and fly ash that falls to the bottom hopper of the economizer, air heater and electrostatics precipitator.



Source: Study Team

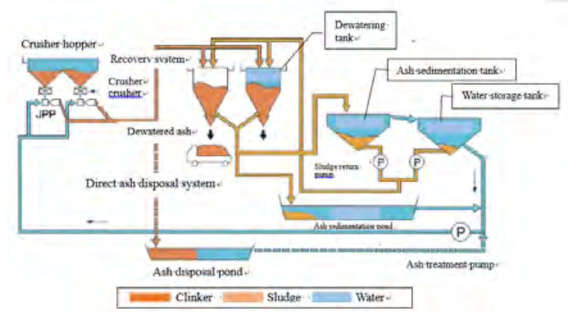
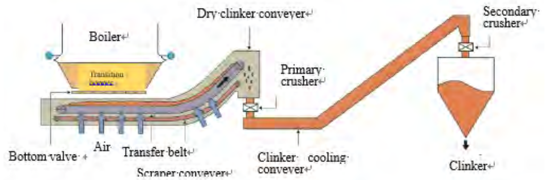
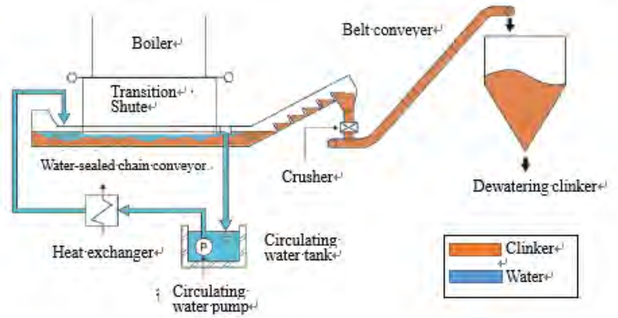
Figure 8.3-24 Ash Handling System

(1) Clinker Ash Handling System

There are three types of clinker ash treatment systems: direct water flow system, water flow system in the recovery tank, dry clinker conveyor system, and water-filled drag chain conveyor system. Table 8.3-16 shows a schematic flow diagram and summary of each system.

As the clinker ash handling system for the Matarbari Units 3/4, we recommend the dry clinker conveyor system which is same specification of Units 1/2. The dry clinker conveyor system has advantage such as no need for aqueous facilities and the ash can be delivered dry with a high possibility.

Table 8.3-16 Comparison of clinker (bottom) ash processing systems

Name of System	Direct water flow method, dewatering tank recovery tank water flow method	Dry clinker conveyor system	Water-sealed drag chain conveyor system
System Flow Diagram			
Outline of System	A number of methods have been adopted to transport clinker stored in the furnace hopper directly to the ash dumping site using seawater, and to circulate the clinker through a dewatering machine that collects clinker in a dewatering tank using fresh water such as industrial water. However, this method has disadvantages compared to other methods, such as the complexity of the water system equipment, which requires water circulation equipment, water quality control equipment, etc., the cost of the equipment is slightly higher, and the installation space is larger.	Recently, the dry clinker conveyor system, which does not use water to transport clinker, has become the mainstream method in consideration of reducing environmental impact. The dry clinker conveyor system does not require water-based facilities such as dewatering equipment, water circulation equipment, and water quality control equipment. In addition, since clinker can be collected in a dry state with low unburned content, it can be used more effectively, and running costs can be reduced, such as power costs for water system equipment and repair costs due to corrosion. Several types of clinker crushers are installed downstream of the dry clinker conveyor, which can crush clinker to the size expected to be discharged from the power generation facility.	The water-sealed drag chain conveyor system is designed to discharge clinker in a continuous manner and to dewater the clinker at the same time on an inclined conveyor. Although it has been used in only a few commercial power generation facilities in Japan, it is more suitable for small-scale power generation facilities than the two systems mentioned above, and is therefore widely used in general industrial facilities.

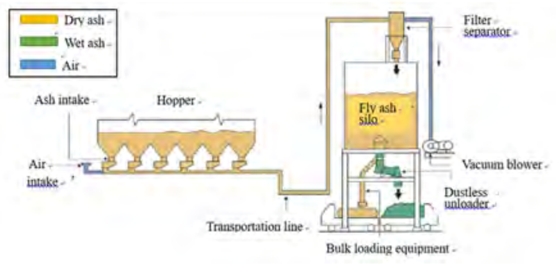
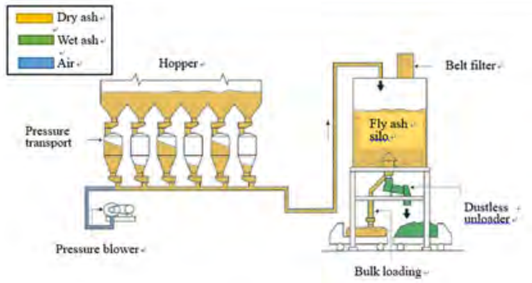
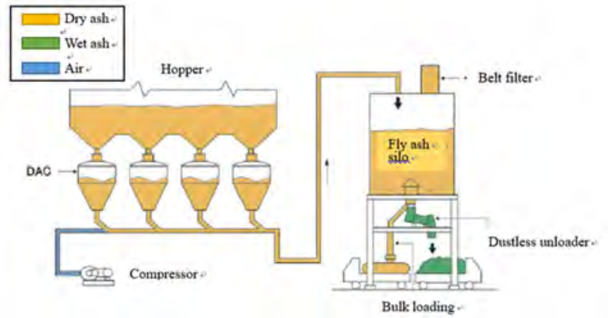
Source: Study Team

(2) Fly Ash Handling System

Fly ash handling systems are based on pneumatic conveying, and can be roughly classified into vacuum conveying and pressure conveying systems. The pressure conveying system is further classified into low-concentration conveying system and high-concentration conveying system. These three types of systems are shown in Table 8.3-17.

As the fly ash handling system for the Matarbari Units 3/4, the study team recommends the combined system of vacuum conveying and pressure conveying which are used in Units 1/2.

Table 8.3-17 Comparison of Fly ash handling system

Name of System	Vacuum transport method	Pressure conveying method (low-concentration conveying)	Pressure conveying method (high-concentration conveying)
System Flow Diagram			
Outline of System	Vacuum transportation is a simple and economical transportation method suitable for short distances and small transportation capacity. It is suitable for systems that collect ash from a number of ash-generating points, such as electrostatic precipitator and flue hopper, and feed it into a single silo.	Pressure conveying is a conveying method that uses a pneumatic compressor to convey a stream of air at or above atmospheric pressure, and is suitable for large-volume, long-distance conveying, and is suitable for systems that distribute materials to multiple silos in distant locations. When the transportation distance is long (more than several hundred meters) and the particle size is relatively large, the boat concentration transportation method, which uses a pressure blower to transport at a relatively low pressure (to 190 kPa), is suitable.	For the transportation of relatively fine granular materials (to 700 kPa) over short distances, high-concentration transportation using a compressor at relatively high pressure (to 700 kPa) is applicable. If the distance from the boiler to the fly ash storage silo is long, a relay silo is often installed on the way, and a combination of vacuum transport and pressure transport is used.

Source: Study Team

(3) Ash Pond
Refer to clause 8.3.21 (9) Ash Pond.

(4) Ash Recycling System
A part of the ash stored in the clinker ash silo and fly ash silo is basically planned to be reused. If the ash cannot be reused, it will be transported to the ash disposal pond. As for the transportation method to each cement company, we recommend the following dry transportation method, which is superior in terms of environment.

(a) For reuse (from each silo to the reuse company)
- Transported by tanker truck to berth and transshipped to a 3,000 DWT class vessel
- Transported by compressed air to the berth and transshipped to a 3,000 DWT class ship

The following table shows the comparison of transportation methods from silo to ash carrier for reuse of fly ash.

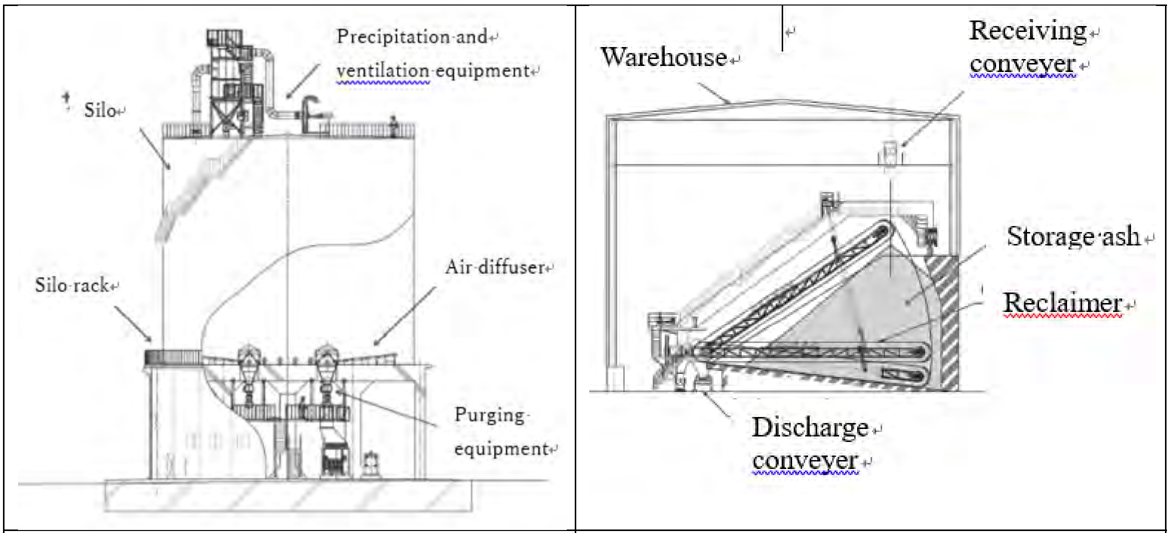
Table 8.3-18 Ash transport method (from silo to silo near the pier)

	Transportation by tanker truck	Transportation by compressed air	Remarks
Ash transport method	Transported by tanker truck from silo to silo at the pier	Compressed air is transported through the pipes from silo to silo.	
Construction cost	base	higher	
O&M cost	Higher (man power fee)	base	
Evaluation		Recommended	

Source: Study Team

In the meantime, temporary unloading berth is planned to use as a shared facility of Matarbari Units 1 through 4.

(5) Ash storage facilities
Facilities for storing fly ash generally use containers called silos, which have a closed structure to prevent dust dispersion. The storage capacity of silos is determined by the purpose of use, and ranges from about 100 m^3 to over 10,000 m^3 per unit. Most of the silos are cylindrical with flat or slightly sloped mortar-shaped bottoms, and fly ash is received from the ceiling and discharged from the outlet at the bottom. Fly ash silos can be made of steel plate or concrete, and either material can be selected based on economic evaluation.
Facilities for storing clinker include a dewatering tank for primary storage and draining of clinker transported by water flow, and a wet ash storage tank for storing humidified clinker in cylindrical containers stacked on the floor.



Structural drawing of dry silo	Structural drawing of wet ash warehouse

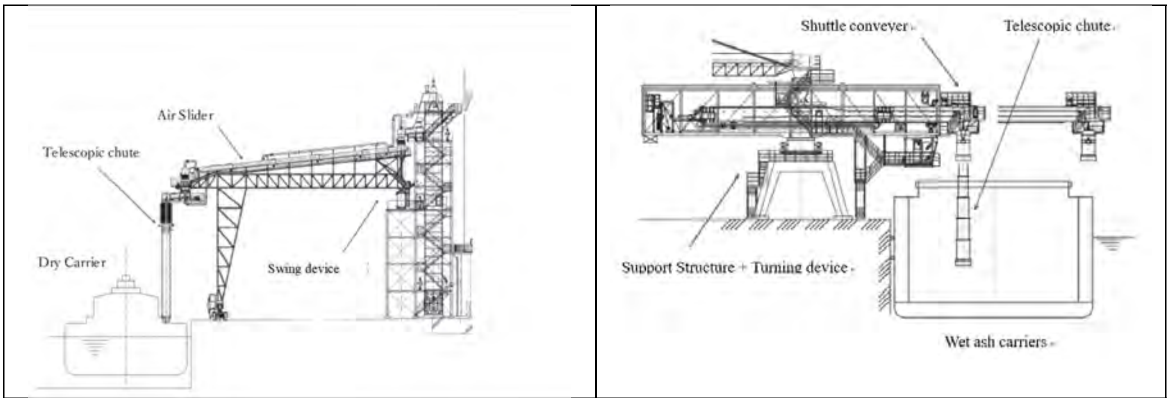
Source: Study Team

Figure 8.3-25   Ash Storage Facilities

(6) Ash ship loading equipment (ship loader)

An ash ship loader is installed on the quay of a power generation facility to transport a large volume of coal ash from the facility to a remote location such as a cement plant where the ash will be effectively used. Coal ash is transported in either dry or wet ash state, and the type of carrier and the type of ship loader vary depending on the state of the ash.

Until now, the mainstream size of carriers for both dry and wet ash was up to 2,000DWT, and even large carriers were limited to 4,000DWT to 5,000DWT. The maximum loading capacity from the ship loader is about 1,000 t/h.



Dry ash ship loader	Wet ash ship loader

Source: Study Team

Figure 8.3-26   Ash Ship Loading Equipment

(7) Amount of ash

The amount of ash from Unit 3/4 operating at 80% load factor for 30 years are shown below.

- Consumption of coal per day (for 2 units as per 100% load at MCR)
  600,000 kW x 860 kcal/kW x 2 ÷ 4,600 kcal/kg ÷ 0.411 (Plant Efficiency) x 1.0385 (MCR/ECR)
  = 566.9 ton/h, 566.9 ton/h x 24hrs = 13,606 ton/day
- Annual consumption of coal = 13,606 ton/day x 365 day x 0.8 = 3,972,952 ton/year
- Ash content of the coal is 6%
- Volume of coal ash per year = 3,972,952 tons/year x 0.06 = 238,377 ton/year (A)
- Unburnt carbon is 0.125%
- Volume of coal ash per year = 3,972,952 tons/year x 0.00125 = 4,966 ton/year (B)

- Annual ash volume : (A)+(B) = 238,377 ton/year + 4,966 ton/year = 243,343 ton/year
- 243,343 ton/year ÷ 1.43 ton/m^3 (compaction with bulldozer and roller) = 170,170 m^3/year

Therefore, the total volume of ash for 30 years operation is calculated as shown below:

- Ash total volume = 243,343 ton/year x 30 year = 7,300,290 ton
- 7,300,290 ton ÷ 1.43 ton/m^3 = 5,105,098 m^3

(8) Utilization of Ash

Various studies have been conducted regarding effective utilization of coal ash produced in large quantities in the boiler, and the following uses have proven practical.

- ➢ Clinker
  - ✓ Road bed material
- ➢ Fly ash
  - ✓ Material for cement
  - ✓ Concrete aggregate
  - ✓ Road pavement
  - ✓ Fertilizer

As described above, there are various ways to use coal ash.

(9) Selling Ash

Some cement company in Bangladesh import fly ash from abroad to use as a raw material of cement, there is a possibility to offtake fly ash which is produced from Matarbari coal-fired power plant.

If some cement company in Bangladesh will buy a part of fly ash, a part of fly ash will be transported by a truck or a vessel.

8.3.14 Fire-fighting system

(1) General

The fire fighting systems of Units 3/4 will be same system of Units 1/2. Outline of the fire fighting systems of Units 3/4 are described in the following each section.

(2) Scope

The fire fighting system to be installed at this power plant are the following:

- Fire water distribution system
- Outdoor hydrant with hose cabinet
- Indoor hydrant system
- Automatic sprinkler system
- Water spray fixed system
- Foam system
- Carbon dioxide fire extinguishing system
- Clean agent fire extinguishing system
- Fire extinguisher
- Fire brigade and fire station equipment

(3) Fire Water Supply and Distribution

(a) Fire Water Tank

The design of fire water supply and distribution system will be based on the use of two separate fire water sources as below;

- Primary source: fire water 100% from service cum fire water storage tank, above ground tank
- Secondary source: fire sea water 100 % from pre-treated plant water storage tank, aboveground tank

(b) Fire Water Pumps

Fire water pumps will each have the capacity to provide 100% of the maximum fire water demand of the power plant and it will consist of the following:

- One (1) 100 % electric motor driven fire water pump
- One (1) 100 % diesel engine driven fire water pump
- Two (2) 100 % electric motor driven jockey pumps

The fire water booster pump will be provided to increase the pressure available from the fire water supplying and it will consist as below:

- Two (2) 100 % electric motor driven fire water booster pumps

Firefighting activities for the main building are to be undertaken in accordance with the acting security norms, standards and regulations for power plants of Bangladesh, and facilities shall be designed on the basis of NFPA standards.

(c) Fire Water Network

The fire water network will be designed in accordance with NFPA 24 and NFPA 850.

The fire water network will be looped around the power plant area with pipe adequately sized to supply fire water to any point in the plant.

Fire water network piping will be provided with a high density polyethylene (HDPE) and will be buried underground with comprising of several loops around plant area.

(4) Outdoor Hydrant System

Outdoor hydrants will be designed in accordance with NFPA 24 and NFPA 850. Along the fire water main, outdoor hydrants will be provided, especially near objects or equipment with an increased fire hazard. Outdoor hydrant spacing in main plant areas will be a maximum of 300 ft (91.4 m). Hydrant spacing in remote areas such as long-term coal storage will be a maximum of 500 ft (152.4 m).

Outdoor hydrants will be of wet barrel, 2-way type with two (2) apparent outlets of two (2) 65 mm hose connections, each outlet connections will be provided with - hose valve, a cap and chain. Red steel hose cabinet will be installed on legs as self-standing type. Fabricated hose cabinet with air vent and drain holes will be provided with lettering of RAL 9003 signal white “FIRE HYDRANT”. Outdoor hydrant hose cabinet will contain the following firefighting equipment:

- Two (2) hose wrenches
- Four (4) 30 m lengths x 65 mm fire hoses with storz couplings (for main plant area) Six (6) 30 m lengths x 65 mm fire hoses with storz couplings (for coal yard shed area)
- Two (2) 65 mm spray-solid stream nozzle

Outdoor hydrant with water/ foam monitors will be provided to protect the oil spill fire at the oil unloading berth area. Outdoor hydrant with water/ foam monitors will be 3-way type comprising with one (1) 100 mm monitor connection and two (2) 65 mm hose connections. The water/ foam monitor will be mounted on hydrant with 65 mm water/foam monitor nozzle. Foam concentrate for foam monitors will be supplied from a foam concentrate drum via pick-up tube. Outdoor hydrant with water/ foam monitor cabinet for oil unloading berth area will contain the following firefighting equipment:

- Two (2) hose wrenches
- Four (4) 30 m lengths x 65 mm fire hoses with storz couplings
- Two (2) 65 mm spray-solid stream water nozzle
- One (1) Foam concentrate drum and pick-up tube

3-way type outdoor hydrant with water monitors will be provided to protect the coal unloading berth area. Outdoor hydrant with water monitors will be comprised of one (1) 100 mm monitor connection and two (2) 65 mm hose connections. The water monitor will be mounted on hydrant with 65 mm water monitor nozzle.

Outdoor hydrant with water monitor cabinet for coal unloading berth area will contain the following firefighting equipment:

(5) Indoor Hydrant System

Indoor hydrant system will be designed in accordance with BNBC Part 4, NFPA 14 and NFPA 850. All indoor hydrants will be sized so that they will provide a minimum flow specified as per BNBC part 4.

(6) Automatic Sprinkler System

Automatic sprinkler system will be designed in accordance with BNBC Part4, NFPA 13 and NFPA 850. Automatic sprinkler system will consist of alarm check valve and sprinkler heads attached to the system distribution water pipe system. Automatic sprinkler system will be applied as following building/area.

- Central control building, workshop building, ware house and administration building
- Firefighting water pump house (Diesel engine area)
- Firefighting sea water pump house
- Cable basement, cable culvert and cable room in power house, central control building, Air compressor AHS and /FGD/ESP control and electrical building & air compressor house for AHS, 400 kV GIS & switchyard relay & control
- Coal handling area;
  Coal conveyor
  Coal transfer tower
  Coal crusher tower

(7) Water Spray Fixed System

Water spray fixed systems will be designed in accordance with API 2030, NFPA 15 and NFPA 850.

(a) Automatic water spray fixed system

Water spray system will be provided with relevant components required for automatic operation normally via electric actuation trim or hydraulic/pneumatic actuation trim. Manual release will also be possible by using the manual switch on deluge valve, local manual release valve and remote control through CCR (Central control room).

This system will consist of deluge valves, isolating gate valves, pressure switches, open type spray nozzles, piping, detection system, manual switch, audible/visible alarms, controls and instrumentation. In fire conditions, when the detection system operates, the system control panel will energize solenoid valve open, causing the deluge valve open and allowing water to enter the system piping. Water will flow through spray nozzles on the system.

(b) Manual water spray fixed system

Water spray system will be provided with relevant components required for manual operation. This system will operate via manual switch on deluge valve, local manual release valve and remote control through CCR. When the handle or button of manual switch is actuated, or when the remote release signal is received from CCR to system control, pressure is released from the priming chamber and the deluge valve will be opened. Water will flow through the system piping and spray nozzles.

(8) Foam System

Foam systems will be designed in accordance with NFPA 11.

Foam concentrate will be pumped from the foam concentrate storage tank by foam concentrate pump to foam proportioner skids by using the hydraulic operated pump. In the event of fire, automatically water will start flowing through the proportioner skids where foam concentrate is induced and mixed with the flowing water in definite proportion.

(a) Fixed foam discharge system

The fixed foam discharge system will be designed in accordance with NFPA 11 and Type Fixed foam discharge system will be automatically activated on fire detection by detection system. The detection system located in each protected area will trigger fire alarm and energize the solenoid valve which will open the relevant deluge valve. Manual switch and manual release valve will also be provided.

(b) Foam monitor

Foam monitors will be provided to protect the small spill fires at oil tank dike area and the coal fires at coal storage shed in accordance with NFPA 11.

(9) Clean Agent Fire Extinguishing System

Clean agent fire extinguishing system will be designed in accordance with NFPA 2001. Clean agent fire extinguishing system will be provided to protect the control rooms, switchgear rooms and battery rooms which are important to the plant operation.

(10) CO_2 Fire Inerting System

Total flooding CO_2 system will be designed in accordance with NFPA 12.

Low pressure CO_2 fire inerting system will be applied to coal bunker.

CO_2 fire inerting system will consist of CO_2 storage, vaporizer, refrigeration unit, CO_2 injection nozzle, selection valve, audible/visual alarm, safety signs, and piping.

(11) Fire Brigade and Fire Station Equipment

The power plant fire brigade will be equipped with two (2) fire trucks with foam/water tanks and one (1) ambulance car including standard firefighting and rescue equipment. Fire brigade and fire station will be equipped with following equipment:

1) Portable gas indicator
2) Heavy duty hand lamp
3) Breathing apparatus with cabinet
4) Dry powders transferring and refilling rig
5) Pneumatic vice for extinguishers locking
6) CO_2 extinguishers filling and powder pressurization rig
7) Electric screwing-unscrewing
8) Hydraulic inspection unit
9) First aid kit
10) Paramedic standard equipment
11) Hose repair equipment
12) Firefighting suits
13) Firefighting blankets
14) Multipurpose nozzle

8.3.15 Service and Instrument Air System

(1) Function

The compressed air system is a common system which supplies dry, oil free instrument air at the required pressure and capacity for all essential services such as pneumatic valves, transmitters, instruments and valve operators. Also the system supplies service air to all essential and non-essential service air users.

(2) Major Equipment

The compressed air system is composed of the followings:

- Six (6) Air Compressor Packages (6 x 25 %)
- Four (4) Air Receivers (4 x 100 %)
- Four (4) Air Dryer Packages including Pre Filters, Air Dryers and After Filters (4 x 50 %)
- Two (2) Service Air after Filters (2 x 100 %)
- Instrument Air Distribution System
- Service Air Distribution System

(3) System Description

Each air compressor package is self-contained within an acoustical cabinet for sound attenuation and equipped with an air intake filter/silencer, an automatic regulation system, a lube oil system, a water cooled oil cooler, a water cooled intercooler, a water cooled after-cooler with condensate separator and automatic drains, a discharge check valve, and a machine mounted control panel. Discharge air from air compressor packages is piped to four (4) air receivers and instrument air and service air will be distributed to their users via four (4) instrument air dryer packages (pre filters, air dryers and after filters) and two (2) service air filters, respectively. The receivers are equipped with a safety relief valve set at 12 bar (g) designed to prevent overpressure of the receiver. The instrument and essential service air which is needed for plant operation is distributed from the instrument air ring main header and essential service air header respectively.

All compressors have same capacity. Normally, only four (4) air compressors are required to supply the compressed air normal continuous demand for the power station instrument air and service air system. The fifth air compressor operates to meet the maximum continuous demand; the sixth air compressor will be on standby.

The total airflow for the instrument air system passes through the air dryer packages. Two dryer packages are in service during normal and maximum operation with the remaining dryer packages on standby. In each dryer package, two (2) parallel desiccant air dryers dry all of the instrument air to a maximum pressure dew point of -40 °C (ISO 8573-1 humidity class 2). Automatic control is provided to switch the airflow between the dryers as required. Each dryer package is capable of handling 50 % of the power station instrument air demand at maximum continuous flow rate.

Separate compressed air distribution systems are provided for the instrument air and service air system.

The instrument air distribution system is arranged in the form of a ring main around the turbine hall and spurs at strategic points to common area of plant. Each side of the ring mains is sized for the full load so that in case of leakage, closing relevant isolating valves ensure safe supply. It is possible to isolate any part of the distribution ring main system without causing interruption of the compressed air supply to other parts of the system.

The service air distribution system is split into two subsystems, essential and non-essential users. For the non-essential users, the service air distribution system is arranged in the form of a ring main around the turbine hall and spurs at strategic points to common area of plant. Each side of the ring mains is sized for the full load so that in case of leakage, closing relevant isolating valves ensure safe supply. It is possible to isolate any part of the distribution ring main system without causing interruption of the compressed air supply to other parts of the system. For the essential users, a separate service air supply is provided. The non-essential supplies are subject to shut down on low pressure within the compressed air distribution system to protect the instrument air and essential service air supplies. A pneumatic shut-off valve is provided in the supply line to the non-essential users, which shall automatically close when the air system pressure falls below a 7 bar (g).

(4) Technical Description of Major Equipment

(a) General

The equipment and material shall conform to high standards of engineering, design, workmanship and construction and shall be capable of operating efficiently and satisfactorily without excessive wear or maintenance under the service conditions.

All components shall be selected from designs, proven in service with at least 5 years satisfactory operating experience. The equipment shall be heavy duty type and be designed for a minimum anticipated plant life of 30 years.

In order to reduce the Site work to a minimum, prefabricated and/or skid mounted equipment shall be supplied wherever possible.

Particular attention shall be paid to keep noise and vibration levels at a minimum and to reduce it to the inevitable values. This is particularly valid for the compressors itself, but also for suction, discharge and distribution piping as well as all valves or fittings. Low noise level equipment shall be selected.

In any case the noise shall be less than 85 dBA at 1 m distance from the noise source.

The continuous large users shall be equipped with a trip valve. It shall stop the airflow if the air pressure drops below a certain value. Should this not be acceptable, other measures such as separate piping shall be provided.

Certain reliable measures against pressure drops are required for single large users.

However, upon failures, e.g. hose rupture, pressure drops shall be avoided. This shall be achieved by flow restriction devices on each user terminal.

All temporary and hose connections shall be limited to the pipes with a quick shut-off coupling.

(b) Suction Air Filter

The filter shall retain all particles possibly harmful for the compressor, the valves or other equipment in the system. In any case the filter shall be capable of dealing with the dust concentration of the site area.

The inlet filter to the compressor shall be designed for the maximum flow at the worst conditions. Each compressor shall have its own suction filter. The filter shall be adequate for operation in a dust-laden atmosphere and to be designed for service intervals not shorter than 4,000 operating hours or six months.

The open cross section of the air suction duct shall be covered by a stainless steel mesh. In the compressor room a single, dry type filter shall be installed for each compressor train.

The maximum allowable pressure drop shall be 30 mbar. The minimum particle size to be retained shall be 3 micron. Each filter shall be equipped with a differential pressure indicator that shall give an alarm in case the maximum allowable pressure drop is exceeded.

The filtering element shall be made of fabric cloth. Regeneration shall be possible by back - purging with compressed air.

The construction shall favor noise absorbing design.

All surfaces inside the filter shall be corrosion resistant.

(c) Silencers

Downstream of the suction filter a silencer shall be installed. It shall absorb noise emitted through the cross section of the duct as well as noise emitted via the surfaces of the pipes. Appropriate connections with the duct are necessary.

The minimum damping effect shall be 10 dB, both axial and perpendicular to the axis. A combined construction with the filter is not acceptable. All surfaces inside the silencers shall be corrosion resistant.

(d) Air Compressor

The air compressors shall compress air from atmospheric pressure to compressed air system pressure.

The compressors shall be a water cooled, oil free, rotary screw type including after cooler.

The compressor shall be driven by a suitably rated electric motor. The drive coupling to the compressor shall be a flexible direct coupling. V-belts coupling will not be acceptable.

Each of the compressors shall be connected to a separate 0.4 kV switchgear section. Each of these switchgear sections shall be fed by a separate transformer. Always two switchgear sections shall be interconnected by a bus coupler equipped with automatic transfer device.

Lubricating oil pumps shall be of positive pressure, fed by suitably rated motors. 2 x 100% electric motor driven lubricating pumps shall be provided for each air compressor.

Oil filters shall be easily replaceable and the lubricating system shall be protected from overpressure by means of a relief valve. A dip stick or sight glass shall indicate crankcase oil level.

Each item requiring water cooling shall be connected to the cooling water system and include isolating valves at the inlet and outlet of each exchanger sub-circuit.

As the compressor may be shut down for long periods of time, all air passages must be corrosion resistant against condensing moisture from the air.

(e) After Coolers

One (1) after cooler shall be provided for each compressor. The after coolers shall be designed for worst conditions of inlet air and cooling water.

The maximum allowable air temperature downstream of the after cooler shall be 10°C above the cooling water supply temperature.

The cooler shall be of shell and tube type with easily removable tube bundle for chemical cleaning.

Water velocity through water tubes shall be limited to 1.9 m/s during maximum conditions.

The cooling water connections shall consist of flexible pipe links.

All parts in contact with air shall be of corrosion resistant material. The tubes shall be of copper - nickel alloy, the shell and the tube plates of galvanized carbon steel or better material. Surface areas shall allow a minimum-fouling factor as recommended by the Tubular Exchanger Manufacturer's Association (TEMA).

The cooling water pipe shall be fitted with a common in line strainer and an electrically operated On/Off flow control valve. The instrument system shall ensure that the water flow is stopped when the compressor is not in running. A visible water flow indicator shall be included in each of the sub-circuits to heat exchangers.

(f) Water Separator

The water separator (collection - drums) shall protect all downstream equipment from water droplets or water mist.

The after cooler separators shall be fitted with condensate local indication, high level alarms and shutdown switches.

One drum is required after every cooler.

At least the collection drum behind the after cooler shall be equipped with a stainless steel wire mesh. Its minimum droplet removal efficiency shall be 99.9 %.

The accumulated water shall be drained off by an automatic condensate trap. The condensate traps shall be equipped with hand - operated bypass valves. All connections shall be flexible links.

In order to prevent noise vibration conduction along the suction and discharge piping, flexible pipe links shall be installed on the compressor nozzles. Also cooling water connections shall be by flexible links.

The compressor with all components including intermediate and after coolers shall be mounted on a common base plate or skid, equipped with springs and dampers for absorbing all vibrations.

(g) Air Receivers

The air receivers shall store an ample amount of air storage capacity based on the plant air peak consumption, reduce the frequency of compressor starts and stops, and reduce pressure pulsations.

The construction shall be a vertical welded cylindrical vessel.

The design pressure shall be 13 bar.

A 600 mm manhole shall be provided.

The vessels shall be of galvanized carbon steel and located outside the building under a sunshade.

Between vessel bottom head and drain valve a sight glass shall be provided to detect condensate. Draining must be possible when the vessel is pressurized.

Automatic drains shall be provided in the service air receivers.

(h) Air Dryer

The dryer shall be capable of maintaining the dew point of -20°C for the instrument air system during maximum instrument air consumption and maximum air/cooling water temperature. The required dew point shall be regarded as the dew point at the pressure prevailing at the dryer discharge.

Air dryer shall be twin tower desiccant type with electric heater. For larger volume externally heated zero purge loss twin tower dryers shall be preferred.

Purge volume control valves shall be needle type lock shielded and a purge flow meter shall be included.

Dryer controls shall be electro-pneumatically operated.

Total cycle time shall be a minimum of 8 hours and shall include suitable cooling and pressure adjustment periods.

Facilities shall be included to effect a gradual depressurization and re-pressurization of the towers to avoid mechanical breakdown of the desiccant beds.

At changeover both absorber beds must be at equal pressures and temperatures. Silencers shall be fitted on blow down lines.

Regeneration air flow and process air flow directions through the desiccant beds shall be in opposite directions.

Desiccant material shall be activated alumina type for reasons of physical strength against changes in temperature and pressure.

Thermostatic devices must be included to limit temperature rises caused during regeneration.

Visual indication is to be provided on the drier to indicate change over failure or purge valve failure. The failure alarm circuit is to be interlocked with the electric heater controls.

Potential free contacts are to be provided to repeat the failure alarm to the common control panel.

Where the inlet air temperature to the air drier exceeds 50°C the drier shall incorporate a refrigerated type pre-cooler in order to optimize the dryer package sizing. In such case the pre-cooler shall be packed onto a common base frame with desiccant dryer.

Each tower shall include a pressure/temperature safety relief valve and pressure indicator. A dew point alarm and indication equipment are to be provided. Visual indication of dew point shall be given by means of color change indicators.

Each drier shall incorporate duty and standby pre-filters fitted with the drier to provide protection from water droplets and oil.

Pre-filters shall be oil removing type in all cases to allow for emergency running conditions with other air compressors. They shall be capable of removing oil down to 0.5 ppm (relative to 20°C). Pre-filters shall be fitted with differential pressure service indicators and automatic drain trap with bypass.

Isolating valves shall be installed either side of each pre-filter for maintenance.

Each drier shall incorporate duty and standby after filters, fitted with the dryer to protect the network downstream from dust particles. They shall have a minimum efficiency of 99.99 % at 1 micron.

The pressure drop at full flow conditions and across the complete dryer/filter package shall not exceed 0.5 bar when clean and 0.65 bar when in service.

PLC control panel with necessary panel coolers/ventilation shall be provided for each dryer unit. Fully automatic sequence shall be provided for the dryer including the regeneration process.

An on-line Dew Point Meter (Dew Point Analyzer) shall be provided.

(i) After Filters

Normally, the air should not contain any scale, debris, droplets or other foreign matter when reaching the after filters. However, for protection of the distribution piping in case of failure or malfunction of upstream equipment, after filters shall be provided.

The design flow shall be identical with the compressor capacity. The filtration efficiency shall be 99.99 % with all particles down to 1 micron.

The filter shall be provided with differential pressure service indicator, which shall also give, an alarm if the maximum allowable pressure drop (30 mbar) is exceeded.

The service intervals shall not be less than 1,000 operating hours.

The after filters shall be of the duplex type with depth filtration elements. The filtering elements shall be of a corrosion free felt or mat, which can be regenerated to a certain extent.

(j) Pipe work and Valves

All interconnecting pipework as well as the piping to all users in the power plant shall be provided. This includes pipe supports, pipe racks and steelwork for piping in trenches and protection sheets for street crossings, etc.

The distribution pipework consists of two ring headers in the steam turbine halls and two sets of branch lines to all other users, one system for instrument and the other for service air.

For continuous service air user, fixed connections are required. The air system shall be piped to the equipment nozzle. Isolating and non-return valves shall be provided close to the equipment, either directly on the provided equipment nozzle or 1 m apart from the equipment.

The pipe sizing shall ensure low noise, moderate velocities, small pressure drop, virtually no pressure pulsation and a large storage volume.

For the compressor suction and discharge piping only long radius elbows shall be provided.

The total pressure drop to any consumer shall not exceed 0.3 bar measured between air receiver and the consumer during its peak consumption and also during normal consumption of all other users.

The velocities in the compressor suction piping shall not exceed 4.0 m/s upstream of the silencer and 6.0 m/s between silencer and compressor. In the distribution piping the velocities shall not exceed 6.0 m/s for normal operating conditions and 8.0 m/s for peak consumption.

Minimum pipe size for headers shall be DN 50.

On each terminal point whether from branch line, header or equipment an isolating valve shall be provided. Each branch line shall be connected to the header with a ball valve.

The branch pipes shall be distributed in such a way that all individual lines terminate near the users and shall be provided with isolating valves at the beginning and at the end.

A ball valve shall be installed at each instrument take-off connection and shall be located as close to the main line as possible. These connections shall be taken off the top of the mains.

Except for throttling services, all valves shall be ball valves. Their free cross section shall be identical with the connected pipes. Valve casing materials shall be made from spherical graphite cast iron or welded carbon steel construction. Internals shall be resistant against the media handled. The offered materials and valve design shall be subjected to the approval of the Engineer.

Pipe materials shall be galvanized, carbon steel (St. 35 or similar). Only the short (less than 2 m) connecting piping between the sub-headers for instrument air and the instruments shall be made of seamless copper pipes 6 x 1 mm, according to DIN 1754 or equivalent. Fittings shall be made of copper or brass compression type according to DIN 2353 or equivalent.

Seamless pipes shall be used for the entire system.

The pipe connections shall be carried out as screwed ones up to DN 50. For pipe sizes DN 80 and upwards on control and isolating valves, equipment, etc. and where technically advisable, flange connections shall be used. Site welding of hot dip galvanized pipes shall not be permitted.

All bolts must be galvanized.

The number of connections from ring main and headers shall be at least 15 % larger than necessary at design stage. They shall serve for future air consumers. Each of these connections shall be equipped with a ball valve.

Immediately upstream of every consumer connection, i.e. next to the valve, a tapping for pressure measurement shall be provided.

A sampling connection is necessary behind every equipment in the compressed air system.

The air distribution system shall be designed as a ring main system.

(k) Pressure Dampers

For consumers with a short time peak consumption of more than 1 % of one compressor's capacity, a local pressure collapse (i.e. a pressure drop of more than 1.0 bar) must be prevented by pressure dampers.

The dampers are small, welded air storage vessels installed next to the consumer, sized for the needs of that consumer.

The inner surface shall be painted or galvanized. If reasonable and possible, dampers shall be avoided by generous pipe sizing.

Appropriate calculations and measuring tapping shall be provided for the specified cases, remote users and where particularly requested by the Engineer.

Measurements during commissioning will finally decide if, where and which pressure dampers shall be provided.

(l) Air Compressor

In order to supply compressed air to all locations in the buildings, (the boiler, or other plant facilities) local air stations shall be provided.

Identical air hoses 15 m long of DN 20 shall be provided at no more than 20 meter intervals around the plant. The connection to the distribution piping shall be by quick shut off couplings.

Sufficient number of flexible hose reels shall be provided and stored inside cabinets at various sections of the plant.

The number and distribution of the air stations shall allow to reach any point inside the buildings as well as all equipment in other plant areas, with a 15 m long hose connected to a local air station.

(m) Corrosion Protection

The outside surfaces of all equipment, pipes and valves shall be painted except if produced of corrosion free material like copper or stainless steel.

The piping system including the suction piping shall be made of galvanized pipes. The valves shall be of corrosion resistant material.

The inner equipment surfaces possibly in contact with humid air, shall be galvanized or made from corrosion resistant or corrosion free material.

The air receiver shall be painted inside as well as outside.

For the galvanized materials a corrosion allowance of 1.0 mm and for painted materials, 2.0 mm shall be provided.

(5) Design Data and Criteria

The following table presents the functional requirements for determination of the air consumption required for Instrument air and service air:

Table 8.3-19 Design considerations for compressed air system (x, y, z are service factors)

Description	Normal	Max	Peak
Continuous demand	100% of total continuous demand (2 Boiler / STG)	100% of total continuous demand (1 Boiler / STG)	100% of total continuous demand (2 Boiler / STG)
Intermittent demand (Multi units)	x % of total intermittent demand for STG & Boiler	x % of total intermittent demand for STG & Boiler	x % of total intermittent demand for STG & Boiler

Intermittent demand (Others)	y % of total intermittent demand for BOP	y % of total intermittent demand for BOP	y % of total intermittent demand for BOP
Air consumption for Boiler/STG Start-up	N/A	100% of total air consumption for start of 1 Boiler / STG	N/A
Cleaning (only for service air)	N/A	N/A	z % of total service air consumption for cleaning

Source: Study Team

Regarding the size of the air receivers following 3 cases need to be at least taken into the design considerations:

Case 1: 3 min. required to supply IA plus SA during peak air consumption
Case 2: ample amount of compressed air during air compressor switch-over (~10 sec)
Case 3: ample amount of compressed air during for safe emergency shut-down (~60 sec)

(6) Process Control

Instrument and service air compressors are locally controlled and automatically or manually operated. Automatic operation foresees the sequential start and stop of the compressors.

Air dryers are locally controlled and automatically operated.

Service and instrument air systems main parameters and alarms are transmitted to the central control room.

8.3.16 Chemical Laboratory

(1) General

This section describes all equipment, apparatus and chemicals which shall be provided for the chemical laboratory Units 3/4 Project. The laboratory will be designed as an advanced analytical chemical laboratory and will be located in the water treatment building.

All equipment, glassware, instruments, apparatus and chemical will be supplied and deemed necessary for a state of the art laboratory for maintaining the various requisite quality standards (Reference for example: latest edition of ”Standard Methods for the Examination of Water and Waste water APHA/AWWA/WEF).

The equipment supplied shall be of the latest and most modern design and fit for the purpose envisaged.

The main purpose of the chemical laboratory are for the basic testing and analysis of all of the various types of water / effluents for the Plant such as water for the water / steam cycle (condensate, feed-water), demineralized water, river water, brine, clear water, cooling water, waste water, etc., as well as the major tests and analyses of fuels, lubricants, transformer oils, etc.

Furthermore, equipment for extended and advanced water/waste water and oil/waste oil, etc. analysis will be provided, such as:

- Bacteriological analysis (e.g. total heterotrophic bacteria)
- Environmental analysis
- Heavy metal determinations
- Organic micro pollutants
- Poly Aromatic Hydrocarbons (PAH)
- Air emission (CO, NOx, SOx, PM10)

The individual items are as follows:

- Chemical laboratory furniture
- Chemical laboratory equipment
- Chemicals for laboratory use
- Safety devices
- Personnel protective equipment / Clothing (PPE)

(2) Chemical Laboratory and Furniture

The laboratory shall consist of the following rooms:

- General laboratory

- Instrument laboratory
- Metal lab for atom-absorbing spectrometer (room)
- Determination of priority organic micro-pollutants in water by laboratory gas chromatography (room)
- Fuel oil lab (room)
- Metallurgical lab for X-ray fluorescence (room)
- Bacteriological laboratory (room)
- Balance room
- Storage room for glass / plastic ware, chemical reagents, gas/ gas systems, etc.
- Four (4) office rooms - staff
- Library and conference room
- Dining room with necessary items like refrigerator, microwave oven, hot plate, kettle, etc.
- Toilets - male & female
- Locker room & shower facility - male & female
- Administration & calculation room supplied with the following equipment
  - Computer with accessories (e.g. printer, scanner, CD RW, etc.)
  - Photocopier (color capable)
  - Camera (digital)
  - Calculators (scientific)
  - Initial and minimal rudimentary office supplies

Provision shall be made such that the air temperature of the laboratory rooms is kept within + 0.5 K to the adjusted temperature at all times.

All laboratory furniture including the following shall be provided:

- Wall-working tables for 4 chemists/laboratory assistants (20 meters total running length), with acid proof surface tiles, integrated wash basins, supply of electrical power, gas, warm/cold water, demineralized water, and compressed air at each workplace
- Intermediate-working tables/cupboards
- Analytical-balance tables
- Fume-cupboard (Hood) with exhaust fan
- Demineralized water tank for laboratory purposes, 100 liter capacity with CO2-trap, made from polypropylene, with connection to the demineralized water plant. Connection point shall be after the mixed bed exchanger and before the demineralized water storage tank, if necessary with pressurizing pump. The demineralized water supply of each workplace shall be served from the laboratory demineralized water tank. Required piping shall be made of polypropylene

For production of silica-free water for silica test, arrangements have to be made for recirculation of demineralized water through cartridges, consisting of resins.

- Chemicals-cabinets, lockable
- Poison - chemicals cabinet, lockable
- Signs for safety instructions, endangered areas and cabinet contents
- Collecting tanks for organic and aqueous liquid and solid chemical wastes
- Water, gas, air fittings and accessories
- Table - drainage system including pipe-work and installation, connection to neutralization tank and drainage
- Forced ventilation
- Compressed air supply from instrument supply system for wall working tables
- One (1) 80 liter capacity Safe, for valuables, platinum crucibles and dangerous poisons
- Safety devices including two emergency showers and two eye showers; 10 personnel safety equipment sets, two first aid sets, etc.
- Also any other necessary furniture the supply of which the Contractor foresees for the chemical laboratory
- All office furniture which are necessary for a four man office including the Chief Chemist
- Laboratory air conditioning, heating radiators and heat exchangers

- All above mentioned particulars shall be stated by the Contractor with full dimensioned drawings for all furniture required in the chemical laboratory
- Foundation drawing where necessary
- Circuit diagrams where necessary

(3) Chemical Laboratory Equipment

The following instruments, apparatus, technical particulars, glassware and chemical agents which are required for the analysis specified below as per the standard methods for the Examination of Water and Waste water" of APHA/AWWA/WEF) shall be provided by the Contractor for two (2) years with all necessary calibration facilities and catalogues for the instruments. In addition any other equipment, glassware or instruments the supply of which the Contractor foresees for the chemical laboratory shall be provided.

All laboratory chemicals required for the analyzing methods and the corresponding calibration procedures; sufficient for two years of laboratory use shall be provided.

Table 8.3-20 Equipment for Routine Water Analysis

No.	Equipment Name	Purpose
1	Microprocessor pH Meter	To measure pH in water samples
2	pH Meter (Potable)	To measure pH of samples at site
3	Microprocessor - Conductivity Meter	To measure conductivity in water samples
4	Microprocessor - Conductivity & Salinity Meter	To measure low level conductivity at site and for salinity measurement
5	Dissolved Oxygen Meter	To measure dissolved oxygen at site
6	Turbidity Meter	To measure turbidity of different samples
7	Pocket Colorimeter	For chlorine analysis in water samples
8	Refractometer (handheld)	For concentration determinations of chemical tanks
9	Analytical Balance	For routine laboratory analytical purpose
10	Precision Balance	Routine Laboratory use
11	Top loader Balance	Routine Laboratory use
12	Gas Monitor (Portable), Methane	For Gas leak check in the Station
13	Gas Monitor (Potable), Hydrogen	For monitoring Hydrogen gas in plant
14	Gas Monitor (Potable), Hydrogen sulfide	For monitoring H_2S gas in plant
15	Ex - Meter N (Explosively Meter)	For checking explosive gases in the Station
16	Universal Heating & Drying Oven	For general laboratory use
17	Multiple Water Bath	For TDS, etc. determination in routine samples
18	Open Bath Circulator	For sample cooling and temperature adjustments
19	Density *I* Specific Gravity Meter	To determine density/ specific gravity of samples
20	Lovibond Comparator	For routine check
21	Rotary Slide Vane Pump	For vacuum filtration
22	Automatic Scale	For chemical weighing
23	Grinder	For sample preparation
24	Hot Plate 120 mm Diameter	For heating samples
25	Hot Plate 400 x 200 mm	For heating samples
26	Powertrol Universal Heater	For distillation of samples
27	Magnetic Stirrer with Heating Plate	For heating and stirring sample
28	Comparator, Sediment Cone, Settlometer kit, etc.	For routine sewage analysis
29	ASTM Hydrometer - 0.650 - 1.100 (Set)	For density check of liquids
30	ASTM Hydrometer- 0.600 - 2.000 (Set)	For density check of liquids
31	Oxygen Indicator (Potable)	For oxygen check in air
32	Stainless Steel Vacuum Filter	For general filtration

33	Digital burettes	For routine titrimetric analysis at site
34	Dispersers - Auto & Manual (Different volume)	For base/acid/solvent dispensing
35	Portable Mixed bed De-Ionized Water Assembly	For producing de-ionized water
36	Thermometers, General purpose	For laboratory general use
37	Spectrophotometer with UV and Visible range	For colorimetric analysis of routine samples
38	Oil Content Analyzer	For oil content analysis in water
39	Auto Titrator - Potentiometric Titration Apparatus	For quality check of bulk chemicals used in the station
40	Refrigerator	For reagent / sample preservation & for ice
41	Sieve shaker with set of Test Sieves	For the sieve analysis of samples like Limestone
42	Transfer pipettes of varying volume	For sample and reagent pipetting
43	Auto Surette sets - Different volume	For routine titrations
44	Ice cube maker (Ice making machine)	Making ice cubes for the sample preparation and other cooling purpose
45	Desiccators different sizes	For sample / Chemical storage
46	Furnace to the range of 1100 C	For deposit analysis
47	Ultrasonic cleaning bath	For glass ware and equipment cleaning
48	Digital Thermometer - Thermocouple probe type	For temperature measurement at site
49	Golfer cart I Personnel carrier (Electric)	For sample collection and site visits in the plant area
50	Trolley cart - Wheel type	For routine sample collection
51	pH meter with digital recorder function and connected laptop computer	For desalination/degasser acid cleaning and other plant activities at site

Source: Study Team

Table 8.3-21 Equipment for Advanced Chemical Analysis

No.	Equipment Name	Purpose
1	Microprocessor - Ion Meter	For the determination of cations and anions in different type of liquid samples
2	Atomic Absorption / Flame Emission Spectrometer with graphite furnace and Mercury/Hydride system	Used for metals and heavy metals in water and oil samples
3	Total Organic Carbon Analyzer	For the determination of Carbon in water samples
4	Ion Chromatograph	For the determination of ions in water samples
5	Gas Chromatograph with TCD, FID, ECO detectors and Sample extraction system	For analyzing pollutants in drinking water (e.g. voe & halo VOC) and natural gas analysis
6	Water purification system	For the production of extra pure OM water
7	GC - MS with data acquisition system	For the analysis of wide range of elements in low level concentration
8	X-Ray Fluorescence Analyzer	For metallurgical and compound analysis

Source: Study Team

Table 8.3-22 Equipment for Bacteriological & Environmental Analysis

No.	Equipment Name	Purpose
1	Precision Incubator	For bacteriological analysis
2	Cooled Incubator	For BOD analysis

3	Hot Air Sterilizer	For dying up to a temperature of 200C
4	Automatic Laboratory Steam Sterilizer	For sterilization use
5	UV Sterilizer	For glassware *I* apparatus and reagent sterilization
6	Colony Counter	For bacteriological analysis
7	Water Bath	For bacteriological analysis
8	Laboratory Centrifuge	General Purpose
9	Binocular Microscope	For bacteriological analysis
10	Filtration Unit	For bacteriological analysis
11	BOD Track	For BOD determination in effluent samples
12	BOD/COD/TOC/AOX/TN/TSS/ Surfactant/Nitrate Analyzer	For bacteriological sample analysis
13	Sound level meter	For sound measurement
14	Flue gas analyzer with data acquisition system, potable	For stack emission check

Source: Study Team

Table 8.3-23 Equipment for Oil Testing

No.	Equipment Name	Purpose
1	Pesky-Martens Semi-Automatic Flash Point Tester	For the determination of flash point in different oil samples
2	Viscosity Bath	For the determination of viscosity of liquid samples
3	Extraction Apparatus for determination of sediments in oil	For oil extraction to determine sediments
4	Automatic Digital Salt-in-Crude	For checking salt content in crude oils
5	Pour Point Tester	To determine the pour point of fuel oils
6	Laboratory Precision Gas Calorimeter	For the determination of calorific value of fuels
7	Water *I* Oil Bath	General Purpose
8	Particle Size Analyzer - Portable	To count the number of particles of different sizes in oil samples
9	Dissolved Gas Analyzer (DGA) – Potable	To determine the dissolved gases in transformer and such oils
10	Saybolt Furol Viscosimeter	To determine the viscosity of heavy fuel oils
11	Dean and Stark Distillation Apparatus	For the determination of water content in %
12	Tintiometer- ASTM Color	For the determination of color of oil samples
13	Auto Titrator with potentiometric & Karl Fischer Colorimetric Technique	For the determination of acid/base number & water content in oil samples
14	X-Ray Fluorescence Spectrometer- Table top energy dispersive type	For sulfur determination in fuel oils and other elemental analysis

Source: Study Team

8.3.17 Cranes and Lifting Equipment

(1) Major Equipment

The Cranes and Lifting Equipment are listed below table.

Table 8.3-24 Crane and Lifting Equipment

No.	Location/equipment	Type of cranes/hoists	Operated/Controlled
1	Steam turbine building	Double girder overhead crane(s), main & aux. hoist	Electrical; cabin and pendant switch
2	Air compressor building	Single girder overhead crane(s) with main hoist	Electrical; pendant switch

3	Boiler feedwater pumps	Hoists with trolleys	Electrically operated
4	Steam turbine ancillary equipment	Hoists with trolleys	Electrically operated
5	Condensate pumps	Hoists with trolleys	Electrically operated
6	Other installations	Hoists with trolleys	Electrically operated
7	Workshop	Six (6) double girder overhead cranes with main hoist and hoists with trolleys; Load capacity: mechanical and electrical workshops 10,000 kg; overhaul workshop 30,000 kg. Hoists for the other workshops	Electrical; pendant switch
8	Other installations	Hoist	Manual
9	Generator Crane	Overhead cranes with pendant type and capacity as per the requirement	Electrical; pendant switch
10	Fire fighting water pump house	Overhead crane with main hoist	Electrical; pendant switch
11	Water treatment plant pump house	Hoists with trolleys	Electrically operated
12	Storage Building	10,000 kg double girder overhead crane with a clear height to the hook of 7 m minimum	Electrical; pendant switch
13	Outdoor storage	One gantry crane(s), 30,000 kg main hoist and 5,000 kg aux. hoist, with a clear height of min. 7 m to the hook; based on rails over the complete length of the outdoor storage area; rail spacing minimum 15m	Electrical; pendant switch
14	Start-up fuel oil pumping station	Overhead cranes with main hoist	Electrical; pendant switch
15	Desalination Plant (RO)	Double girder overhead cranes with main hoist	Electrical; pendant switch
16	Seawater Screening and Pumping Station	Gantry crane	Electrical; pendant switch
17	Chlorination building	Overhead cranes	Electrical; pendant switch

Source: Study Team

The scope of cranes and lifting equipment shall include but not be limited to:

- Overhead travelling cranes
- Motor hoists with trolley
- Manual hoists
- Runway rails and beams
- Control, monitoring and electrical supply
- Complete detail labelling of all installation
- Consumables such as first fill of lubricants and greases
- Set of special tools and equipment for maintenance, inspection and repair
- All standard equipment and accessories which are normally included in the supply schedule but which are not separately listed.
- Detailed design and calculation
- Compiling and local collection of required data
- Training, inspection and supervision services by the Manufacturer
- Spare parts and wear-and-tear parts
- Complete documentation
- Numbering of all equipment
- Test loads as required
- Testing of all equipment as required by the regulation

(2) Technical Description

(a) General

Crane hook approaches shall be of the minimum possible dimensions to ensure maximum coverage of the plant area.

All lifting equipment shall be clearly marked in English and Bengali with the Safe Working Load (SWL). All motors on each crane shall be supplied through one contactor operated main switch. Each motor shall be protected by a protective device of approved manufacture. The protective devices shall be arranged so that in the event of a fault developing on any motor, the main Contactor will open, isolating all motors and applying the electro-mechanical brakes.

Controlled lowering with safety of any load up to and including the test load in the event of extended current supply failure shall be possible, and a brake release lever is to be provided, the initial operation of which shall operate a switch making all crane circuits dead.

Hoisting motors shall also be fitted with a centrifugal type brake capable of restraining under all conditions of load, including test loads, the lowering speed which shall not be greater than twice the normal full load lifting speed. Auto brakes shall be provided on both traversing and travelling motors.

Each automatic brake shall be provided with local manual gear to enable the brake to be released.

A precision speed control shall be provided for all cranes and lifting equipment.

To the greatest possible extent all outdoor cranes, hoists and trolleys shall have adequate protection against exposure to and corrosion from the atmosphere.

(b) Design

The lifting capacity of the main hoist shall be able to handle the heaviest part of the equipment or of the complete equipment if required during maintenance and repair works.

All structural parts of the crane shall be designed to sustain the maximum loads as requested by the standard with due allowance for eccentricity of loading, without exceeding the unit stress of materials. Live load of 240 kg/m² shall be assumed for the design of walkways and platforms.

Collision forces between bumpers and stops shall be taken as the forces due to such collision with the trolley or gantry travelling at full speed with the power off. Dead load only shall be considered as contributing to the collision forces.

Cranes with a span of more than 8 m and a nominal carrying capacity of more than 50 kN shall be in the form of double girder cranes with the crab running on the top of the girders. Smaller cranes shall be in the form of single girder cranes with the crab running on the lower flange of the girder.

Cranes and hoists with a nominal carrying capacity of 20 kN and less shall be hand operated. All others shall be electrically driven.

(c) Mechanical

All mechanical equipment shall be simple and substantial in design, easily erected and inspected. The mechanical parts of the crane shall be designed to have minimum safety factor of five (5) when supporting the rated capacity load, based on the ultimate strength of the material used. Unit stresses shall not exceed 90% of the material elastic limit for the loads due to the break down torque of the hoist motors.

1) Crane Runway Rails

Travelling crane runway rails shall be provided by the Contractor. Joints between rails on opposite runway girders for the cranes shall be staggered with respect to each other and to the wheel base of the cranes. All rails joints shall be welded. Rail joints shall not be located over the runway girder splices. Provision of rail expansion shall be made at the end stop locations only.

Guiding of rails on the girders should be carried out with rail clamps for distance adjustment. Welded clips are not allowed.

End stops shall be designed and located to limit the maximum crane travel. The end stops shall be capable of stopping the travelling crane fully loaded and travelling at rated speed.

2) Trolley Rails

Electrical double girder overhead cranes shall be provided with walkways, platforms and guard hand rails along the bridge rails and on the crab to facilitate cleaning/maintenance of the crane. An escape walkway shall be provided over the entire length of long travel girder to the nearest escape ladders.

The platform and walkways shall be designed to support any weight to be imposed upon them during crane overhaul.

Ladders, platforms and steps shall be provided to permit access to crane flood lights and for lubrication, inspection and maintenance. Operator platform shall have non-skid galvanized checked plate flooring and shall be provided with pipe handrails and toe-boards.

Details of the method of access together with access ladders, platforms, etc., shall be supplied. Stairs and platform with walkways shall be provided, for operator cabin and crane top access from the floor level.

3) Crane Control Cab

The crane cab for cranes provided with a control cab shall afford the operator unrestricted view of the load and a clear view of the surroundings and full view of all crane activities. It must not limit the cross travel of the crab.

Provisions shall be made on platform to mount manually operated master switches, main line disconnecting switch, hydraulic break foot pedal and all necessary wiring and fittings. All electronic equipment shall be suitably enclosed for the protection of the operator. Control cab shall have a clear head room of at least two (2) meters.

4) Crane Mechanical Components

<u>Bridge drive</u>

The driving mechanism shall be designed as two corner drives and so constructed to provide steady travel, free from vibrations or racking in any part of the structure while travelling under any load and speed. The control of the drive motors shall be designed to provide simultaneous starting and stopping of both motors even with very high temperatures that will exist in those locations.

Automatic spring set, electrically released brakes having breaking capacity in either directions of travel equal to at least 125% of full load torque of the drive motors and capable of holding the crane stationary shall be provided. Automatic brakes shall become effective when the drive controller is set in "off" position or when the main power is disconnected.

Shoe type hydraulically operated brakes, controlled from a foot pedal in the operator’s station and having a breaking capacity in either direction equal to at least 125% of the full load torque of the drive motors, shall be mounted on the drive, motor pinion or extension shafts.

<u>Trolley drive</u>

The trolley drive shall consist of oil bath lubricated gear case motor and shall be designed so that the travel under all conditions will be steady and free from vibration or racking in any part. The trolley shall be driven by means of a motor mounted on the trolley frame and connected to one driving wheel on each side of the trolley through gearing and shafting. The motor shall be designed with inching controls. Couplings shall be provided at each side of the gear reducer and ahead of the drive pinion. An automatic electric brake having a capacity not less than 125 percent of the full load torque of the driving motor shall be provided on the trolley drive.

<u>Transmission gear</u>

All gear including the drum gears and pinions shall be enclosed in oil tight gear boxes and shall be easily removable.

All gearings must be machined cut from solid steel. All spur wheels shall be of cast or welded steel and pinions shall be of solid steel forging integral with the shaft. The hardness range of gears and pinions must be the same. Gear boxes shall be made of cast steel or welded steel plates in two halves and shall be fitted with:

- Inspection covers in the upper half of the casing, to permit inspection of both gear and pinion teeth without removing the upper half casing.
- Lifting lugs.
- Baffle opening to prevent any build-up of pressure inside the casing.
- Oil level indicators.
- Drainage fittings

The gears shall be designed for automatic lubrication. Suitable drip pans made of steel plate 3 mm thick

shall be provided to collect oil and grease which may drop from operating parts. Gear box and drip pans shall be provided with means for cleaning and draining without dismantling the equipment. Dust covers shall be provided where necessary to protect sliding and rotating parts and to prevent mixing of dust with lubricant. All shafts shall be forged of alloy steel accurately finished to size the bearing and gearing connections. Gears are to be pressed on and keyed to shafts.
The gear case and cross-shaft bearings shall be antifriction ball or roller type. The bearing housings shall permit easy removal of the shaft. The bearings shall be provided with pressure lubrication and designed to exclude dirt and prevent leakage of oil or grease. Other bearings shall be of the plain adjustable can-type, lined with bronze or white metal.

<u>Trucks, wheels and axles</u>
The end trucks shall be designed to distribute the load evenly between the wheels. Wheels shall be of the rotating axle type. The trucks shall be heavily reinforced to provide rigid structure. Safety lugs shall be provided to prevent a drop of more than 1 inch in case of the broken axle.
Truck sweeps shall be provided at each end of the trucks. Safety lugs shall be provided to prevent the trucks leaving the rails. Truck bumpers shall be rigidly mounted in such a manner that the attaching bolts are not in share. Runway stops will be provided at the limits of travel. All wheels shall be double flanged, made of solid wrought or rolled steel wheel blanks and accurately turned or ground to true diameter. The tread width shall provide ample clearance between wheel, flanges and rail head. Wheels shall be designed to carry the maximum rated load under normal conditions without undue wear, and shall have roller type bearings with high pressure grease lubrication. The load shall be equally divided between the wheels on each side.

<u>Hoists</u>
The trolley shall be equipped with a main hoist of the required rated capacity. The hoisting mechanism shall include the motor, reduction gearing, drum, rope, hooks and blocks, so designed and arranged that the load may be raised or lowered and carried along the bridge, and shall be provided with limit switches to prevent damage to hoisting tackle or trolley frame through over-raising or over-lowering of the hook block.
An eddy current control brake shall be provided on the hoist to prevent any lowering speed greater than that corresponding to the controller setting. The eddy current load break shall have the capacity to hold the full load, and shall be designed to function under full load without overheating. In addition the hoist shall be equipped with the mechanical load break complying with an association of Iron and Steel Engineers (AISE) specifications rated for 150% of the torque. The hoists shall be provided with overload protecting device.

(d) Electrical Equipment Features

The electrical requirements shall be generally in accordance with BS 466 except where otherwise stated in this Specification.

Each motor circuit shall include three phase contactors fitted with inverse time characteristic overcurrent relays of approved type, together with correctly rated fuses to BS 88. The contactor equipment shall be rated to allow all crane motors to operate simultaneously at rated speed and load and is to be housed in a drip-proof sheet steel enclosure class IP 54 to IEC 144.

Electrical installation of the cranes and lifts shall be dimensioned in accordance with the electrical drive and constructed according to the outside ambient conditions off 50°C and 100% humidity.

(e) Controllers

The controllers shall be of the crank-handle drum type for two direction starting and speed regulation.

Drum controllers shall be rated for intermittent duty in accordance with relevant standards. Interlocking contacts shall prevent the closing of the main circuit-breaker, when any controller is in any "on" position. All controllers shall be protected against accidental contacts, coarse dust and vertical fall of water. There shall be ample room inside the controller for connections, all parts shall be accessible, finger tips and contacts shall be easily renewable. All master control switches, manually operated switches and circuit breakers, starters, contactors and relays shall be clearly and permanently marked. The control panels shall be installed in weatherproof cabinets in an accessible position. Accelerating contactors shall be provided in an accessible current or frequency relays to protect the motors from too rapid acceleration at all speeds and loads.

Contactors and starters shall have an ample capacity for the horsepower and current requirements in conformance with the relevant approved standards. A reverse phase relay shall be provided in the main supply circuit to provide protection against phase reversal.

8.3.18 Workshop and Warehouse

(1) General

The workshops of Units 3/4 are shared for Units 1/2. And the repair equipment in the workshop to be installed in Units 1/2 will be able to handle the repair of equipment in Units 3/4. Therefore, workshops for Units 3/4 will not be installed.

In this section, warehouse of Units 3/4 is described the following each sub-section.

(2) Warehouse Building

The warehouse shall serve as delivery point of packed and unpacked spare parts and consumables. It shall be equipped with racks, cabinets and shelves of sufficient size, suitable for ware of all sizes and weights.

(a) Storage Area for Heavy Parts and Long Parts

For the storage of heavy and long parts steel type pallet racking and racking for long pieces, e.g. pipes, shall be provided. The racking shall be designed for standard UIC 435-2 pallets with a loading capacity of 2,000 kg/m². The area shall be optimized for optimal space utilization.

The supply for this storage area shall be as above specified, including:

- single-line pallet racking,
- double-line pallet racking systems
- minimum 1 long piece racking, double sided, having a length of min. 10 meters,
- complete set of pallets filling up all spaces in the above mentioned racks, type UIC-435-2, four-way type, 800 x 120 mm, design accepted by international pallet pool,
- 1 set of minimum 10 warning indication labels
- 1 complete packing/unpacking system
- 2 vacuum cleaners, heavy-duty industrial type

(b) Storage Area for Spare Parts and Unpacked Parts

In the storage area for spare parts and unpacked parts steel type base plate racking system including vertical holding systems shall be utilized.

The racking system shall have several levels with a vertical distance of approx. 0.5 m. The vertical structures at the end of each system shall be closed by steel panels and shall be colour painted. The equipment shall include:

- Vertical holding system
- 1 packing/unpacking system
- 1 set warning labels
- 1 table, size 850 x 1500 x 750 mm

(c) Storage Area for Electrical/Electronic Parts

The area shall be equipped with steel type racking systems including base plates with a size of 450 x 1000 mm and a bearing capacity of 200 kg. Each sixth base plate shall be equipped with two (2) vertical separating walls, 0.2 m height. Each fourth base plate shall be equipped with four (4) polypropylene-type material boxes 3400 x 215 x 200 mm.

The supplies shall include:

- Single-line racking system as specified above to be located next all walls with steel-type base plates and related equipment.
- Double-line racking system
- 1 set warning labels (as specified above)
- 1 table, size 850 x 1500 x 750 mm, with steel support structure and
- 50 mm thick table plate out of laminated wood.

(d) Store Handling Equipment

The store handling equipment shall be consisting of following:

- 3 ladders, aluminium type for inspection with width 0.4 m and safety hook system suitable to be used with safety racking/support system
- 1 hydraulic pallet trolleys 2,000 kg each
- 1 battery operated stacking trolley
- 1 electric sweeper
- 2 electronic weighing scale up to 100 kg
- 1 electronic weighing scale up 2,000 kg with provision of label printing

(3) Laboratory Building

The laboratory shall be designed as an advanced analytical chemical laboratory, covering analysis of both water and coal. The main purpose shall be the basic routine analysis of water for the water/steam cycle and hard coal for the steam generator as well as analysis of lubricants and transformer oils.

Furthermore, equipment for extended and advanced water / waste water and oil / waste oil, etc. analysis shall be provided to undertake both bacteriological and environmental analysis.

The laboratory shall consist of the following rooms:

- General Laboratory
- Instrument Laboratory, including
- Metal lab for atom-absorbing spectrometer (Room)
- Org. micro-pollutants lab. Gas chromatography (Room)
- Fuel oil lab (Room)
- Coal lab (Room)
- Metallurgical lab for X-ray fluorescence (Room)
- Bacteriological laboratory (Room)
- Balance room
- Storage room
- 4 office rooms – staff
- Toilets – male & female
- Locker room & shower facility

The following furniture shall be provided:

- Wall-working tables for 4 chemists/laboratory assistants
- Intermediate-working tables/cupboards
- Analytical-balance tables
- Fume-cupboard (Hood) with exhaust fan
- Demineralised water tank for laboratory purposes, 100 litre capacity

For production of silica- free water for silica test, arrangements have to be made for recirculation of demineralized water through cartridges, consisting of resins. Further equipment is:

- Chemicals-cabinets, lockable
- Poison-chemicals cabinet, lockable
- Signs for safety instructions, endangered areas and cabinet contents
- Collecting tanks for organic and aqueous liquid and solid chemical wastes
- Water, gas, air fittings and accessories
- Table - drainage system
- Compressed air supply from instrument supply system for wall working tables
- Safety devices including two emergency showers and two eye showers, first aid sets
- All office furniture which are necessary for a four man office
- Laboratory air conditioning, heating radiators and heat exchangers

8.3.19 Generator

The overview requirements of the generator are shown below.

Table 8.3-25 Overview Specification of the Generator

Item	Specification
Number of generators	2 (unit 3 and unit 4)
Type	Three phase field rotating synchronous
Number of poles	2
Number of phases	3
Rated output	600MW
Rated frequency	50Hz
Rated speed	3,000rpm
Rated terminal voltage	Manufacture's standard (18-25kV)
Power factor	As per Grid Code
Short circuit ratio	Not less than 0.5
Cooling method	Water or H_2 gas direct cooling for stator coil H_2 gas direct cooling for rotor coil
Type of excitation system	Static or brushless exciting system

Source: Study Team

The comparison related to the Generator stator cooling method is shown in Table 8.3-26. There is no difference between these methods in the 600MW class.

Table 8.3-26 Generator Stator Cooling method comparison

Cooling method	Capacity	Merit	Demerit	Unit1/2
Water direct cooling	500～2000MVA	Maximum cooling effect	Cooling water system required	x
H2 Gas direct cooling	～900MVA	No auxiliary equipment, easy maintenance, no worries about water leaks	High voltage part is exposed at the cooling gas inlet and outlet at the end of the coil, High pressure blower required.	-

Source: Study Team

Table 8.3-27 is the share ability study of Units 1/2 H_2 Gas Generator which is used for the generator cooling described in Table 8.3-25. As a result, Units 1/2 H_2 Gas Generator can be used for 4 units at the same time as Daily use (Normal condition), but its capacity is not enough as initial filling of 4 units.

Tie piping between Units 1/2 and Units 3/4, and modification of Units 1/2 are necessary, however, there is a possibility of cost reduction.

Table 8.3-27 Share ability study of Units 1/2 H_2 Gas Generator

Unit 1/2		1/2, 3/4	Share ability	
Equipment Specification	H_2 Consumption	Estimated total H_2 consumption	Daily use (Normal)	Initial Filling
24 Nm3/h, 3 sets	30Nm^3/d, 2units Total 60Nm3/d (2.5Nm3/h)	30Nm3/d, 4units Total 120Nm3/d (5Nm3/h)	Yes	No (2Units possible)

Source: Study Team

8.3.20 Electrical Equipment

(1) Conceptual Design of the Unit Electrical System

The Configuration for the power plant consist of two boilers, two steam turbines and two generators as Units 3/4 in addition to the existing Units 1/2. Each generator shall be connected to the Generator Step-Up Transformer (GSUT) by an Isolated Phase Bus duct (IPB) respectively. The voltage of the power output from the generator shall be stepped up to 400kV by GSUT. The output from GSUT shall be transmitted to the grid network via the 400kV switchyard located next to the power plant area.

A generator main circuit breaker located at the GSUT low voltage side shall be introduced.

In addition to the 400kV switchyard circuit breakers, the 400kV circuit breakers for the generator step up transformers and the station auxiliary transformer (SAT) shall be provided the high voltage side of each transformer, and these shall be controlled and monitored from Central Control Room (CCR) by DCS.

The design criteria for configuration, size and rating of components of the unit auxiliary power distribution system are as follows, as in Units 1/2:

(a) A single event (either a planned or forced outage of a piece of equipment) shall not cause the loss of the generating unit, but may lead to reduced output of the unit.
(b) For voltage levels 400V and above, except for the case of single-ended switchgear, it shall be possible for any switchgear power supply to transfer safety either automatically or manually as applicable from one source to the alternate source under normal operating conditions, without having to black-out the switchgear.
(c) Loss of the transformer (other than the generator step-up transformer and excitation transformer) shall not lead to an output of the generating unit. The failure of a unit auxiliary transformer (UAT) may cause the loss of the generating unit until such time as the faulty UAT is isolated and the unit can be restarted from a healthy transformer.
(d) Loss of the switchgear bus bar, normally fed from the UAT shall lead to a power output reduction of generation less than 50% and shall not cause a loss of the generating unit.

Each unit shall be provided one three-winding Unit Auxiliary Transformers (UAT) and branched from the generator main circuit by IPB connection.

One three-winding Station Auxiliary Transformer (SAT) shall also be provided for each unit. This power shall be fed from the 400kV switchyard.

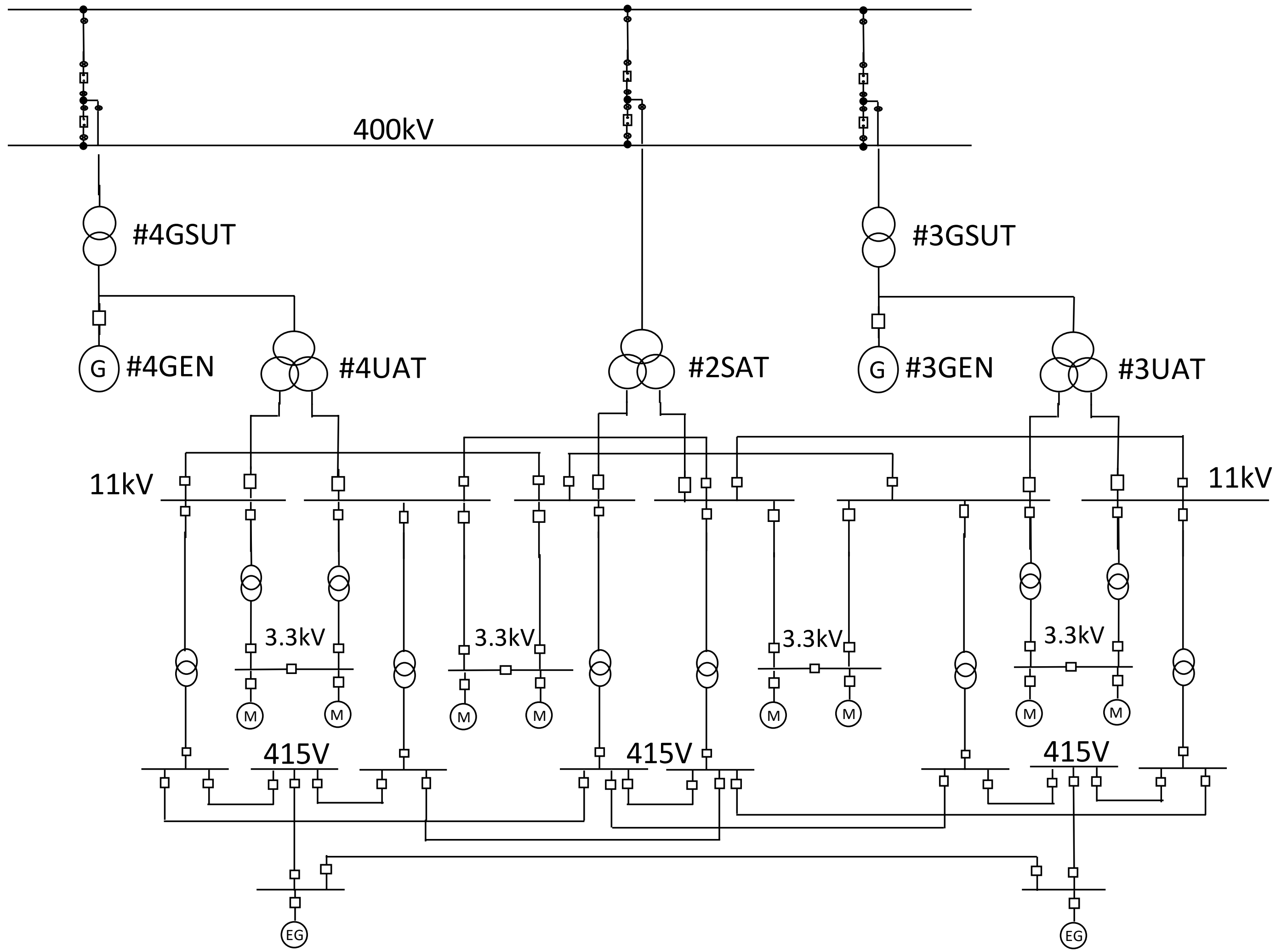
The UAT shall be connected to the two unit 11kV switchgears via a circuit breaker respectively. The SAT shall be connected to the two common 11kV switchgears via a circuit breaker respectively.

Both of the unit 11kV switchgear and the common 11kV switchgear shall be interconnected via a circuit breaker respectively.

During the unit operation, the power source to the unit auxiliary loads shall be fed from the generator output via a unit auxiliary transformer (UAT). During the unit shut down and the unit start up, the power source to the unit auxiliary loads shall be fed from the 400kV switchyard via the station auxiliary transformer (SAT).

Before de-synchronizing the generator, the power source to the unit auxiliary loads shall be transferred from the unit 11kV switchgear to the common 11kV switchgear, and after synchronizing the generator, the power source to the unit auxiliary loads shall be transferred from the common 11kV switchgear to the unit 11kV switchgear.

Figure 8.3-27 shows the key single line diagram for the electrical supply system.



Source: Study Team

Figure 8.3-27 Key Single Line Diagram for Electrical Supply System

(2) Transformer

(a) Generator step-up transformer (GSUT)

The GSUT shall be oil immersed type and shall be fitted with On Load Tap Changer (OLTC) on the high voltage winding, having a range sufficient to allow for the voltage variation at transmission voltage (400kV) and the transformer regulation.

The GSUT shall be provided with Oil Natural Air Forced (ONAF) cooling.

The GSUT shall be rated to match the generator output.

The transformer type shall be recommended by the contractor. In consideration of Units 1/2 configuration, availability and downtime of transformer system, a single-phase transformers is preferable.

(b) Unit Auxiliary Transformer (UAT) and Station Auxiliary Transformer (SAT)

The UAT shall step down the voltage from the generator terminal voltage to 11kV, to provide power supply to the unit auxiliaries.

The SAT shall step down the voltage from the 400kV to 11kV, to provide power supply to the plant auxiliaries during the unit start-up and shut down.

Both the UAT and the SAT shall be oil immersed and shall be fitted with On Load Tap Changer (OLTC) on the high voltage winding with automatic voltage regulator, having a range sufficient to allow for the voltage variation at generator terminal voltage/transmission voltage (400kV) and the transformer regulation.

Both the UAT and the SAT shall be provided with Oil Natural Air Forced / Oil Natural Air Natural (ONAF/ONAN) cooling.

Sizing of the UAT and the SAT shall be based on the total unit load.

The transformer type is three-winding transformer.

(3) Unit Electric Supply

The unit electric supply shall be configured from unit auxiliary transformer and station auxiliary transformer. The unit load for plant operation shall be powered from the unit transformer and the common load for plant operation, such as water handling, waste water handling; coal handling, etc., shall be powered from the station auxiliary transformer.

Moreover, as an electric power source for emergencies, one set of diesel engine driven generators shall be provided for the purpose of safety shut down of the unit.

(a) 11kV Unit and Common Metal Clad Switchgear

Two sets of 11kV unit metal clad switchgears and two sets of common 11kV metal clad switchgears shall be provided for power supply to the unit auxiliary loads and the common auxiliary loads.

Each unit switchgear shall be powered from the unit auxiliary transformer secondary winding respectively and each common switchgear powered from the station auxiliary transformer secondary winding respectively.

The unit switchgear and the common switchgear shall be interconnected via bus-tie circuit breaker respectively for the purpose of a back-up power supply vice versa. The target loads are 1500kW or more.

(b) 3.3kV Unit and Common Metal Clad Switchgear

Two sets of 3.3kV unit metal clad switchgears and two sets of common 3.3kV metal clad switchgears shall be provided for power supply to the unit auxiliary loads and the common auxiliary loads.

Each 3.3kV switchgears shall be powered from 11kV switchgears via the auxiliary transformers. The target loads are 160kW or more and less than 1500kW.

(c) 415V Unit and Common Switchgears

Required 415V unit and common switchgears shall be provided for power supply to the unit auxiliary loads and the common auxiliary loads.

Each switchgear shall be powered from 11kV switchgear via 11kV/415V low voltage transformer respectively. The unit switchgear and the common switchgear shall also be interconnected via bus-tie circuit breaker respectively for the purpose of a back-up power supply vice versa.

(d) Emergency Diesel Generator

In case of a complete blackout of the auxiliary power supply, the emergency diesel generator should start automatically. After the generator voltage is established, the generator power should supply to the essential loads through 415V Essential Bus so that the required controlled shut down procedure of the plant can be carried out without damaging any of the plant equipment. EDG unit shall be installed for each Unit.

(e) Electrical Protection and Metering system

Electrical Protection system should be installed to minimize damage in the event of an electrical fault at 400kV Switchyard, plant power supply system, and electrical equipment. In addition, metering system for operation and recording should be installed.

Existing 400kV Busbar Protection Relay should be modified in consideration of extended BUS bars. The main electrical protection system is composed of relays of GSUT, SAT and UAT. When these relays operate, the related 400kV circuit breakers are opened to prevent an accident to the grid. And, electrical protection relays are installed for plant equipment such as generators, transformers, and motors.

Electrical Metering system for Electrical energy of GSUT bay and SAT bay shall be installed. These Electrical meters shall fulfil the requirement in Electricity Grid Code of Bangladesh. And Electrical Meters are installed to monitor plant operation in coordination with the Distributed Control System (DCS).

(4) Study of the BUS tie of the power supply switchgears to Units 1/2

Studying about installing a switchgear BUS tie between Units 1/2 and Units 3/4 is summarized in the following table.

Table 8.3-28 Studying about the BUS tie to Unit 1/2

BUS tie	Frequency of Use	Unit 1/2 modification	Cost	Conclusion
installing	Mutual Use during Unit3/4 and Unit1/2 maintenance period. More choices, but rare cases	1) Additional Switchgear 2) Control circuit modification 3) Protection circuit modification 4) DCS modification 5) Installation of cable route	Large	Not adopted. There is no frequency of use of only worth the cost.

Source: Study Team

(5) 400kV Switchyard extension

The BUS for Units 1/2 in 400kV switchyard shall be extended, and the equipment for Units 3/4 shall be installed.

(a) Design Concept

As Units 1/2, in order to maintain the reliability of the switchyard, the 400kV bus bar system shall preferably be double bus. The switchyard shall be designed to be able to connect three circuits, consisting of two circuits for Unit 3 and Unit 4, and one circuit for station auxiliary transformer.

The circuit breaker and disconnecting switch shall be the type of gas insulated switchgear (GIS).

This switchyard is owned by CPGCBL. The control and monitoring of this switchyard equipment shall be done from NLDC by remote control.

(b) Quantity of main equipment

The quantity of the main equipment is as follows:

Circuit Breakers (3-phase) : 6 sets
Disconnecting Switches (3-phase) : 15sets

In addition to the above, other equipment including the control equipment shall be installed or modified. The switchyard equipment shall be controlled and monitored from NLDC by remote control through the Substation Control System (SCS) located in the switchyard.

Equipment	Location
Bay Control Unit (BCU)	Control Building at the switchyard
Station Control System (SCS)	Control Building at the switchyard
SCADA	Control Building at the switchyard
Protection relay	Control Building at the switchyard
AC and DC auxiliary power system including battery	Control Building at the switchyard

Source: Study Team

(6) Earthing and Lightning protection

The earthing system will mainly comprise an earthing grid directly buried at a depth of not less than 1.0 m in the ground and a set of raisers connecting all electrical equipment and all metallic frames to the earthing grid forming an equipotential bonding system.

The earthing system will fulfill the following requirements:

- Maintain a low overall resistance of the earth mass to limit the plant potential rise and ensure protective relay operation in the event of an external fault
- Installation of ground connections to all electrical apparatus enclosures and structural steelwork adequate to carry prospective ground faults without excessive heating or fire risk
- Limit potential differences within the power plant site in the event of earth current, originating from within or outside the station. To ensure the safety of personnel and eliminate interference or damage to sensitive electronic circuits
- A potential gradient control system will be installed for all locations where dangerous surface voltage grandients can occur, the step and touch voltage will be less than the permissible values according to standards.
- The overall resistance of the earthing system will be 0.5 Ohm or less.

All buildings and structures will be equipped with a lightning protection system. Lightning protection level according to standards will be considered.

The building lightning protection system is to be executed according to standards and alongside protection of human life to prevent damage not only to buildings, but also to electrical and electronic installations.

All buildings and structures are to be protected against lightning strikes by means of lightning collectors and conductors. The collectors are to be arranged in such a way that, as far as possible, they collect all lightning strokes without these directly striking the parts to be protected.

(7) Cathodic protection

A complete and fully automatic cathodic protection system to cover the entire power plant will be installed. Items in contact with sea water and buried metal structures and tank foundation will be protected by impressed current cathodic protection.

The cathodic protection system will utilize an impressed current system with distributed ground beds, transformer rectifiers, automatic current control based on potential difference measured by reference electrodes.

The scope of supply will include but not be limited to all transformer rectifier equipment, control equipment, distribution panels, anodes, monitoring equipment and wiring.

Sacrificial anodes may be considered for smaller metal structures and steel structures as a part of civil structure.

For seawater platinized titanium electrodes and zinc reference and sensing electrodes should be used. For buried structures appropriate anode materials should be used for the ground beds and reference electrodes as advised by the relevant standards.

8.3.21 Instrumentation and control system

The Units 3/4 shall be designed to be operated from the Central Control Room (CCR). The Distributed Control System (DCS) shall be employed for this purpose.

(1) System configuration of the instrumentation and control system

The design of all the instrumentation and control system shall be provided the maximum security for plant personnel and equipment, while safety and efficiently operating the plant under all conditions with the highest possible standards.

The configuration of the system for control and monitoring of the fully automated operation of the Units 3/4 will be the DCS from the perspective of technology and cost. The DCS equipment will undertake the control and monitoring of the whole power plant, including the common equipment.

Basic configuration of DCS

- The computing and electric power section shall be duplex and the input and output of the DCS will be single

- Power supply to the DCS system shall be duplex with both AC and DC of butted method
- Operation during normal times will be via computer through the use of a mouse while confirming the LCD screen

(2) Units 3/4 control and Monitoring System

The operating and monitoring system of the power plant are configured by DCS, information management system, maintenance and repair system, network system and related equipment.

The DCS is comprised of the LCD operation system, plant interlock system, boiler control system, burner management system, turbine control system, plant auxiliaries interlock and sequence control system, and data acquisition system, etc.

Each independent system shall be integrated with DCS.

(3) DCS Function of Units 3/4

The DCS shall have the following functions:

(a) Unit interlock system
(b) Boiler control system
(c) Burner management system
(d) Turbine control system
(e) Unit auxiliaries interlock and sequence control system
(f) Date acquisition historical storage and retrieval system

(4) Interface to Units 1/2

The interconnection of the DCS between Units 1/2 and Units 3/4 is required, in order to monitor each conditions mutually. In this reason, the DCS of Units 1/2 shall be modified.

(5) CEMS (Continuous Emission Monitoring System)

The continuous emission monitoring system shall be installed to monitor flue gas from the Plant. The required monitoring parameters is mentioned in Chapter 13.

(6) CMMS (Computerized Maintenance Management System)

It is an enterprise asset management system and efficient tool for better operation & maintenance of the power plant. The software should contain all equipment data of Units 1-4.

8.3.22 Land Development and Civil

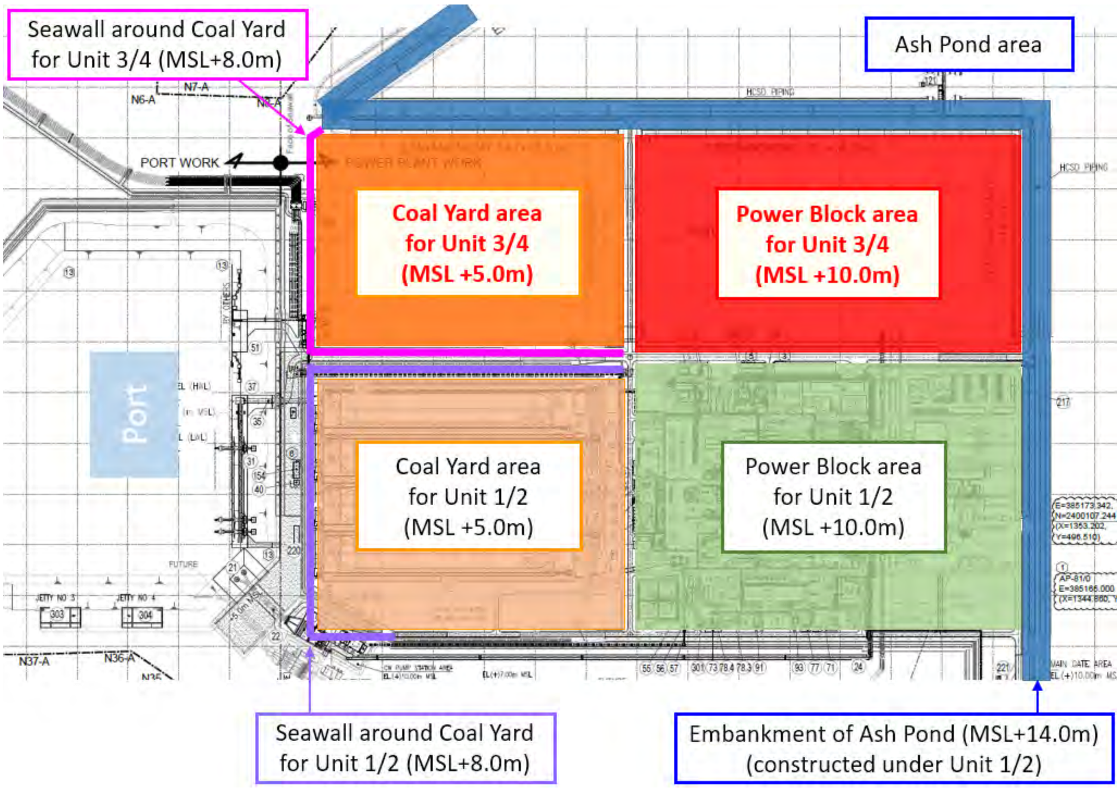
(1) Land Development (Design Ground Level)

The area of this project mainly consists of Power Block area and Coal Yard area. These areas are to be planned as same elevation as Units 1/2 area in order to establish an efficient operation among the whole of Matarbari Power Plant through Unit 1 ~ 4.

The area of Units 1/2 were designed with considering about the previous hurricane in the Bangladesh history, and the elevations were decided in order not to be affected from huge storm surge and wave for a long time operation period.

From the above, for Units 3/4, the elevations of the project area are summarized as below; (see Figure 8.3-28)

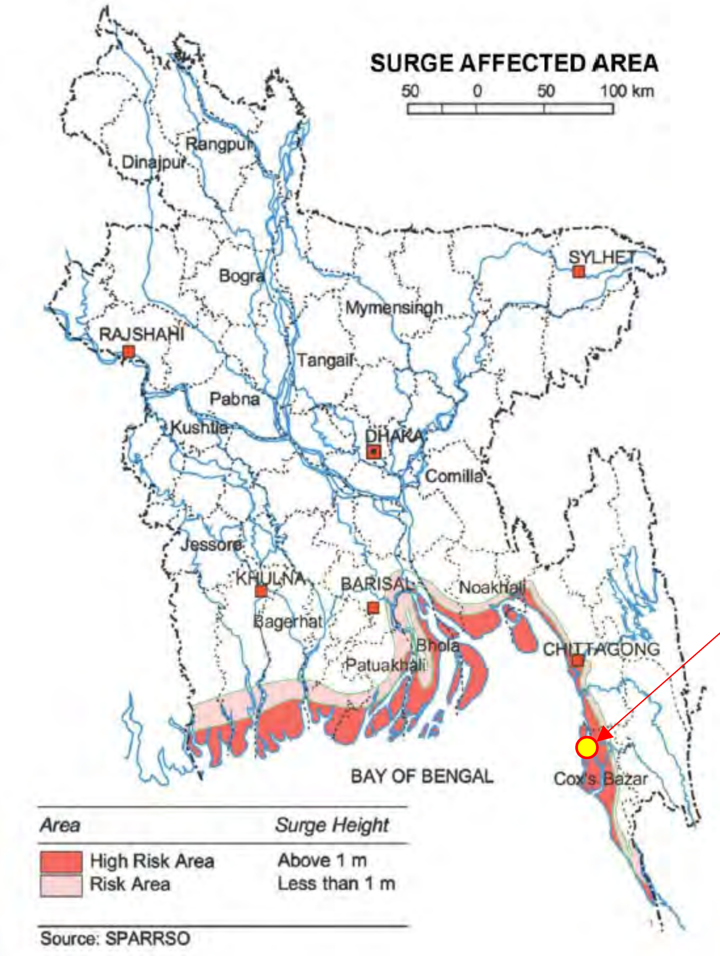
- Power Block area = MSL+10.0m
- Coal Yard area = MSL + 5.0m (but surrounded by seawall which elevation is MSL+8.0m)



Source: Study Team

Figure 8.3-28 Concept image of Elevations of Project area

The above elevations of the project area were designed under Units 1/2 projects to prevent any impact caused by storm surge under Units 1/2 project. According to Bangladesh National Building Code (BNBC, 2015), surge affected areas are designated as shown in Figure 8.3-29. And also, the design surge heights at the sea coasts are defined in BNBC 2015 as shown in Table 8.3-29. The elevations of this project area are higher than these storm surge elevations (50-year probability), so it can be said that the site elevations are stable enough to continue operation even in the event of a disaster for the long-term operation (30 years) of the power plant.



Source: Bangladesh National Building Code 2015

Figure 8.3-29 Surge Affected Area in Bangladesh

Table 8.3-29 Design Surge Heights at the Sea Coasts

Coastal Region	Surge Height at the Sea Coast, h_T (m)	
	T = 50-year$^{(1)}$	T = 100-year$^{(2)}$
Teknaf to Cox's Bazar	4.5	5.8
Chakaria to Anwara, and Maheshkhali-Kutubdia Islands	7.1	8.6
Chittagong to Noakhali	7.9	9.6
Sandwip, Hatiya and all islands in this region	7.9	9.6
Bhola to Barguna	6.2	7.7
Sarankhola to Shyamnagar	5.3	6.4

Notes:
* Values prepared from information obtained from Annex-D3, MCSP.
(1) These values may be used in the absence of site specific data for structures other than essential facilities listed in Table 6.1.1.
(2) These values may be used in the absence of site specific data for essential facilities listed in Table 6.1.1.

Source: Bangladesh National Building Code 2015

(2) Architect Structure

The outline of the main architectural buildings planned to be constructed in this project is shown below, but the foundation type and superstructure is not limited to these.

Table 8.3-30 Outline of Architectural Building Design

No.	Building Name	Foundation	Superstructure
1	Turbine Building	Pile	Steel Structure
2	Center Control Building	Pile	Steel Structure
3	Fuel Oil Pump and Electrical Room	Pile	Steel Structure
4	H2 Generation Plant Building	Pile	RC Structure
5	Electrostatic Precipitator & Coal Ash Electric/Control Room	Pile	RC Structure
6	FGD Electrical Control Building	Pile	RC Structure
7	Desulfurization/Denitration Plant Electrical Room	Pile	RC Structure
8	Water Treatment Plant Control Building	Pile	RC Structure or Steel structure
9	Chemical Laboratory Building	Pile	RC Structure
10	Waste Water Treatment Equipment Electrical/Control Room	Pile	RC Structure or Steel structure
11	Firefighting Water Pump Room and Electrical Room	Pile	RC Structure
12	Firefighting Water Pump Room and Electrical Room	Pile	RC Structure
13	Coal Yard Control Building	Pile	RC Structure
14	Transfer Tower Control Room for Coal Conveyor	Pile	Steel Structure
15	Coal Yard Electrical Room	Pile	RC Structure
16	High Concentration Slurry Disposal (HCSD) Building	Pile	RC Structure
17	Water Intake, Electro Chlorination, Desalination Building	Pile	RC Structure
18	Cooling Water Pump Area Electrical Building	Pile	RC Structure
19	Workshop, Warehouse	Pile	Steel Structure
20	Fire Station	Pile	RC Structure
21	Administration Building	Pile	RC Structure
22	Canteen Building	Pile	RC Structure
23	Garage	Pile	Steel Structure

Source: Study Team

(3) Civil Structure

The main civil structure planned to be constructed in this project are shown below, but the foundation type and foundation structure are not limited to these.

Table 8.3-31 Outline of Civil Structure Design

No.	Structure Name	Foundation	Structure
1	Stack and Foundation	Pile	RC Structure
2	Turbine, Generator and Condenser Foundation	Pile	RC Structure
3	Boiler Foundation and Auxiliary Foundation	Pile	RC Structure
4	Coal Bunker Foundation	Pile	RC Structure
5	Condenser cooling water intake / discharge equipment (intake, intake channel, intake pit, Outfall, Outlet)	Pile	RC Structure
6	Electrostatic Precipitator Foundation	Pile	RC Structure
7	Desulfurization Equipment Foundation	Pile	RC Structure
8	Flue Gas Duct Support Foundation	Pile	RC Structure
9	Limestone Conveyer Foundation	Pile	RC Structure
10	Ash/Limestone Silo and Foundation	Pile	RC Structure or Steel structure
11	HCSD system Foundation	Pile	RC Structure

No.	Structure Name	Foundation	Structure
12	Water Treatment Plant Foundation	Pile	RC Structure
13	Waste Water Treatment Plant Foundation	Pile	RC Structure
14	Chlorination Plant and Piping Foundation	Pile	RC Structure
15	Auxiliary Tank and Foundation	Pile	RC Structure
16	HSD Tank Foundation and Dike	Pile and Direct Foundation (Embankment type)	RC Structure
17	Pipe Rack Foundation and Trench	Pile, Direct Foundation	RC Structure
18	Coal Yard, Coal Yard Shed and Foundation	Reclaimed area (Coal yard), Pile (Shed)	RC Structure (Shed foundation), Steel structure (Shed)
19	Coal Handling Facilities Foundation	Pile	RC Structure
20	Coal Conveyor Foundation, Transfer Tower Foundation and Junction Tower Foundation	Pile	RC Structure
21	Seawall around Coal Yard area	Direct Foundation	RC + Soil Structure
22	Limestone/Ammonia Unloading Jetty	Pile	RC Structure
23	Transformer Foundation	Pile	RC Structure
24	Switch Yard Equipment Foundation	Pile	RC Structure
25	Storm Water Drainage	—	—
26	Service Road	—	—
27	Outdoor Lighting Foundation	—	RC Structure
28	Leveling and Landscaping	—	—
29	Fence and Gate	—	RC Structure

Source: Study Team

(4) Main civil structure and architectural building

The design outline of major civil structure and architectural building are not limited to these.

Basically, the foundation of the structure must safely transmit the load and external force acting on the superstructure to the ground, and be safe in terms of structural strength against subsidence or deformation of the ground.

In Units 1/2, the allowable residual settlement is set to 100 mm, and in order to make the ground behavior after operation in Units 1/2 and Units 3/4 site as uniform as possible, the allowable residue settlement is also set in Units 3/4. It is considered desirable to set the allowable residue settlement to 100 mm.

Since the construction site is a reclaimed land, it is necessary to set an allowable value for subsidence as the most basic condition in designing, and it is necessary to take measures such as ground improvement so that there will be no effect after the operation. The design concept is the same for other structure. However, for small-scale structure with a small load, etc., depending on the ground conditions, there are some that use the direct foundation type instead of the pile foundation.

Corrosion protection should be considered carefully since the project site is located in coastal area. In general, the following countermeasures are applied to Civil & Architect structures as corrosion protection. Detailed structural design should be discussed in the execution stage.

- Type of Cement (Chemical resistant cement)
- Concrete cover thickness
- Corrosion protection paint
- Epoxy coated rebar
- Cathodic Protection system (on steel material of marine structures)
  In the case of Civil & Architect structures, sacrificial anode will be applied to steel parts in marine structures as a corrosion protection system because seawater is one of the big reasons of corrosion.

The following sections provide an overview of the main civil engineering and building structures in this project.

(5) Units 3/4 Turbine Building

The power house is designed in consideration of the arrangement of equipment, piping and cabling, equipment transportation plan, maintenance/operation easiness, and structural method. The elevation of the building will be matched to the environment and landscape. The finishing material of the building will be selected in consideration of durability against the weather conditions, protection of sound emission, maintenance, procurement and economy.

The material of the superstructure is selected in consideration of safety, construction period, procurement and economy. The steel structure is selected because the superstructure of the power plant has a long span, a high floor height, and a heavy equipment weight. The reinforced concrete mat foundation is selected in consideration of the load distribution of the superstructure and equipment, and geological conditions.

For the turbine building, a strong foundation that does not cause harmful subsidence shall be selected in consideration of the load distribution and geological conditions of the superstructure and equipment, and the mat foundation and piles shall be used to support as the strong foundation. The superstructure is planned to be a steel structure.

(6) Stack

The stack will be common to Units 3/4. When designing the stack, the height and diameter of the stack has determined in consideration of the flue gas exhaust volume and topography of Units 1/2 and 3/4, and in consideration of environmental regulations. The height of the stack is as follows.

Stack Height: 275m

Remarks: In Order No. SRO 75 (Amendment by DoE on 16 March, 2020, when constructing a thermal power plant of 500 MW or more within 15 km from Ecologically critical area (ECA), the stack height shall be 275 m. If it exceeds 15km, it is specified as at least 220m. For this project was decided to have a stack height of 275m.

The upper type of the stack outer cylinder is roughly classified into a steel stack and a reinforced concrete stack according to the material. Reinforced concrete stack will be selected in the same way as Unit 1/2 in consideration of foundation ground conditions, earthquake resistance, workability, construction period, economy, etc. The flue inside the stack shall be protected from wind, earthquakes and other external forces.

The foundation type will be planned from the upper type to the mat foundation and the pile foundation according to the concept of the turbine building foundation.

For the stack inner cylinder, the cast lining type is suitable from the viewpoint of availability and material cost. An inner cylinder will be installed in each of Units 3/4. The material used is equivalent to SS400.

The platform will be located inside the outer cylinder for stack maintenance. In addition, the ladder is placed inside the outer cylinder for access to the platform.

The ventilation system for inside of the stack will be a natural ventilation system to keep the proper internal temperature and good condition during maintenance work.

The aviation obstruction lights are the specifications for the installation of high-rise structures (stack) between the project owner and the Bangladesh Air Forces, the Civil Aviation Authority (Bangladesh) are planned to be installed.

As per the requirement of Bangladesh Air Forces, the Civil Aviation Authority (Bangladesh), the aviation obstruction lights are planned to be installed for high rise structure (stack).

Lightning protection equipment shall be installed at the top of the stack.

(7) Cooling Water Facilities

➢ Intake Water Volume

The intake water volume for 2 x 600MW of the power plant is approximated as follows:

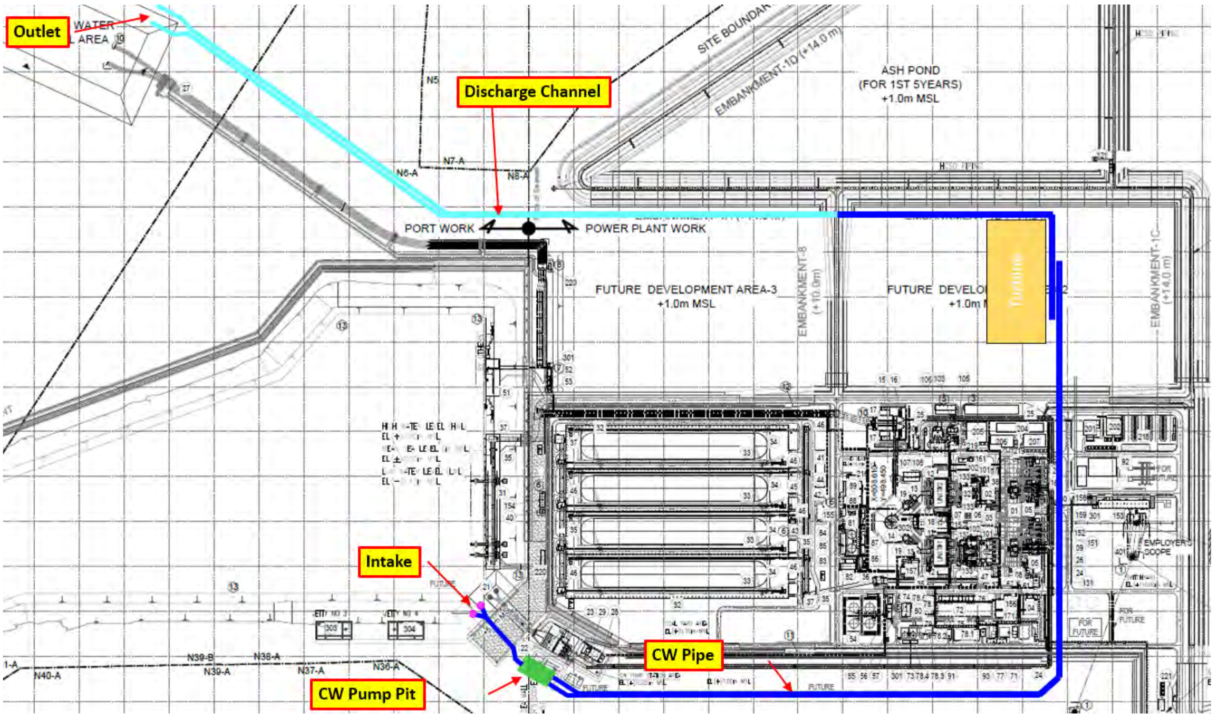
・Intake water temperature: 30 degrees
・Warm water discharge temperature: Increase range = 7 degrees or less
・Calculation (cooling water volume per unit)
$Q = 150(m^3/MW/h) \times \text{Output } (MW/unit)$

$= 150(m^3/MW/h) \times 600(MW/unit)$
$= 90{,}000(m^3/h/unit) = 90{,}000(m^3/h/unit) \div 3{,}600(sec/h)$
$= 25(m^3/sec/unit)$

➢ Main Cooling Water Facilities

The cooling water facilities is mainly composed of the following facilities. The overview of the cooling water facilities is shown in Figure 8.3-30.

- Intake
- Cooling Water Pump Pit
- Cooling Water Pipe
- Discharge Channel
- Outlet



Source: Study Team

Figure 8.3-30 Overview of the cooling water facilities

The outline of the main facilities that composes the cooling water facilities are described as below;

(a) Intake

The intake system has four system as shown in Table 8.3-32.
The intake system shall be selected taking into account the following items:

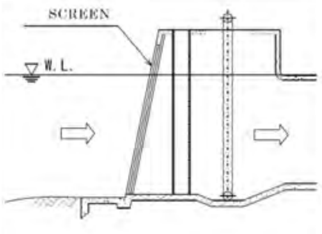
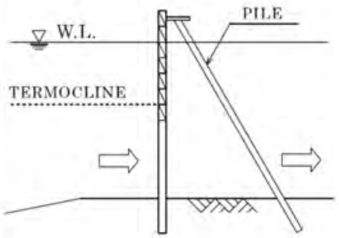
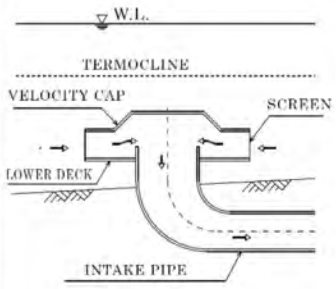
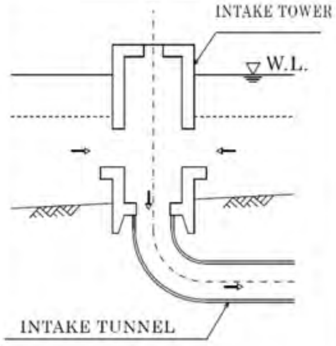
- Effects of warm waste water from discharge outlet
- Effects of flowing wood, PVC, plastics and other foreign matters
- Location of this intake mouth is adopted inside of the project port
- Location of the intake mouth in the southern side of the project port is adopted

In consideration of the above items, it is preferable to adopt the vertical water intake type among deep layer intake system in Units 3/4 as well as the system which is adopted in Units 1/2.

One intake tower is assumed per system (1 unit). It is preferable to secure a between of about 20m for each intake tower. In addition, consideration of the intake tower installation position so that the necessary work area for the installation of the intake towers in Units 3/4 can be sufficiently secured while ensuring the same separation distance as the intake tower of Units 1/2 is necessary.

The intake velocity at the intake mouth shall be about V = 0.2m/sec (at LWL) so as not to disturb the passage of small ships and boats in the sea.

Table 8.3-32 Comparison of Different Intake System Characteristics

Type		Type of Surface Intake System	Type of Deep Layer Intake System		
		Onshore		Offshore	
		Onshore Direct Type	Curtain Wall Type	Pipeline Type	Tunnel Type
Profile					
Description		It is a comparatively simple form. It is the form that it faces shore that the depth of water is comparatively shallow. Generally, it is a structure thing made of the concrete which uses shore, and has equipment such as screen and pump.	It is a selective withdrawal form for the depths water in front of shore. A stake such as H steel and a steel pipe was driven into the central part of the sea in front of shore, and a curtain panel was set up.	It is a selective withdrawal form for the offshore depths water. A pipe way is laid in the bottom of the sea, and it is the structure that load dose intake directly from raising, velocity cap and the lower deck from the horizontal direction in intake point.	It is a selective withdrawal form for the offshore depths water. An undersea tunnel and offshore intake tower are built, and it is the structure that intake is done from the opening set up in intake tower from the horizontal direction.
Characteristics	Flow Rate	Smaller, better effect.	For any size adaptable.	For any size adaptable.	Bigger, better effect.
	Water Depth	Limited due to suitability to shallow area.	Deeper, better effect.	For any depth adaptable.	Deeper, better effect.
	Intake Velocity	About 0.2～0.5m/s	About 0.2m/s	About 0.2m/s	About 0.2m/s
	Wave	It faces it against the small wave.	It faces it against the small wave.	Enough stability can be attained against high wave	Enough stability can be attained against high wave
	Surface Water	The inflow of the surface water isn't avoided.	The inflow of the surface water can be avoided.	The inflow of the surface water can be avoided.	The inflow of the surface water can be avoided.
	Floating Trash	The trash which stagnated in front of on shore flows in easily.	The trash which stagnated in front of on shore flows in easily.	Because the top is spacious, trash doesn't stagnate easily.	Because the top is spacious, trash doesn't stagnate easily.
	Bottom Turbid Water	It is difficult to avoid the inlet of the bottom turbid water.	It is difficult to avoid the inlet of the bottom turbid water.	Inflow can be avoided by securing height from the sea bottom.	Inflow can be avoided by securing height from the sea bottom.

Source: Study Team

(b) Cooling water pump pit

The Cooling water pump pit shall be made of reinforced concrete to ensure convenience of maintenance, reduction of costs and other requirements.

・Cooling Water Pump
・Screen
・Stop Log
・Gantry Crane

Units 3/4 has six sets of cooling water pumps (3 x 50% capacity x 2 units), or four cooling water pumps (2 x 100% capacity x 2 units) will be installed.

The screen removes floating debris, fish and other marine species that have flowed in during seawater intake to prevent them from being sucked into the cooling water pump.

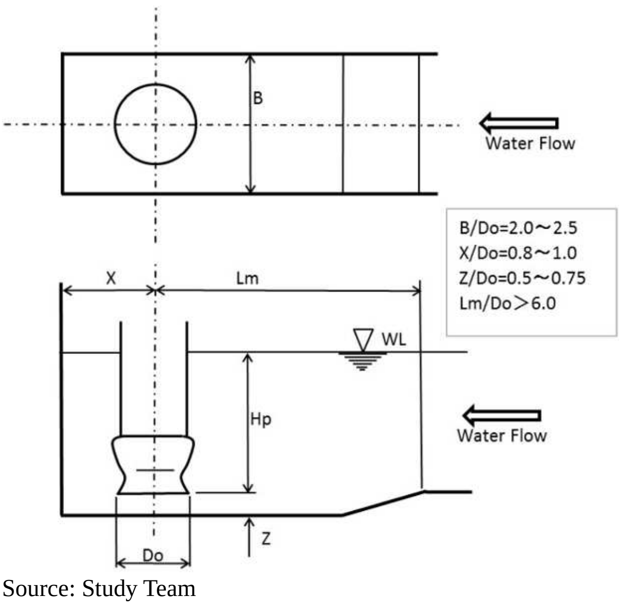
Stop logs shall be provided in front of and behind the screen room in dry conditions during the maintenance of the screen, and a gantry crane will be installed for maintenance of the cooling water pump, screen and other equipment.

The screen pump pit structure must be designed to maintain normal operations during emergency height sea levels (+10.0m M.S.L).

The average velocity of the inside of the pump pit (near the pump) V = 0.3m/sec is adopted.

In the case that the average velocity of the inside of the pump pit far from 8 (eight) x (bell mouth's diameter distance) is over V = 0.5m/sec, model experiments of streamline analysis shall be conducted to confirm the pump capability.

In the pump pit, it is necessary to prevent the generation of vortex due to suction by the cooling water pump. In order to prevent the generation of vortex, it is necessary to consider making the structure near the bell mouth a special shape (Anti Vortex Device). It is preferable to study the shape of AVD by a hydraulic model experiment.



Source: Study Team

Figure 8.3-31 Outline of Form and Dimensions for Pump Pit

(c) Cooling Water Pipe

As the material of the cooling water pipe, Steel pipe, Reinforced Concrete Cylinder Pipe (RCCP), and Glass fiber Reinforced Plastic (GRP) pipe can be considered. Corrosion protection system should be considered carefully since the cooling water pipe handle seawater.

The cooling water pipe shall be direct buried system with a depth of 1.5m or more.

It is preferable to install a concrete slab under the cooling water pipe in places where ground settlement is a concern due to the weight of the cooling water pipe.

Back filing shall be carried out around this pipe with sand of a good quality. In addition, the upper ground surface load must be considered for calculation of the wall thickness of the pipe.

The design upper ground surface load is assumed as follows:

Heavy Equipment Transportation area (ton/m^2)	10.0
Road Area	HS-20 (AASHOTO)
Other Area (ton/m^2)	1.0

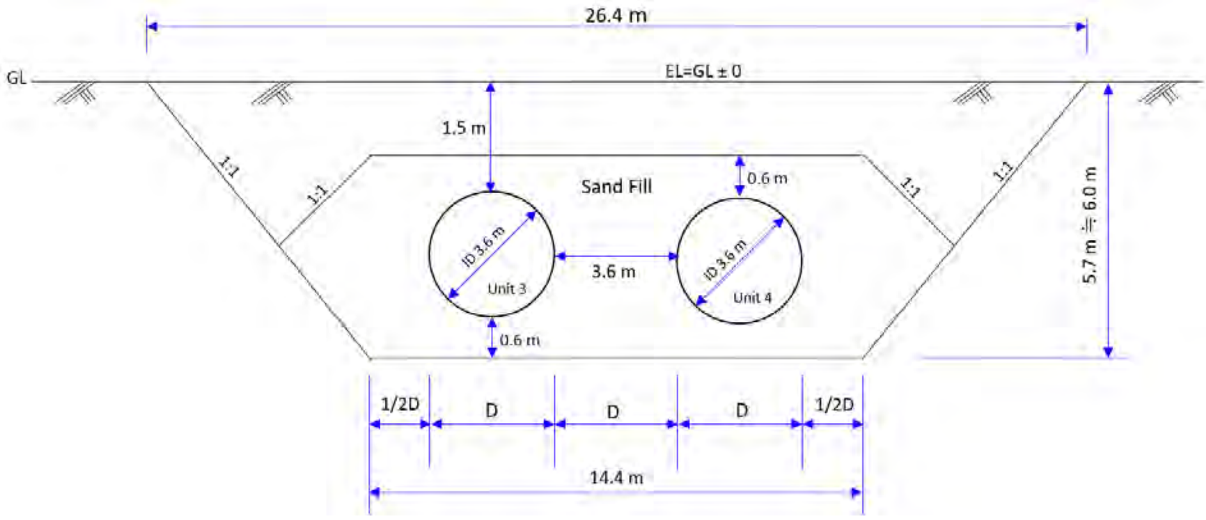
The guideline of the flow velocity in the cooling water pipe in the general part is shown below.

Steel Pipe Size (mm)	Flow Amount (m^3/s/unit)	Average Flow Velocity (m/s)
3,600	25	2.5

In Unit 1/2, the inner diameter of the cooling water pipe is set to 3,400 mm as a result of hydraulic study (calculation of head loss in cooling water). In addition, if the average flow velocity in the cooling water pipe is set to 3.0 m/s or more, there is also the advantage that the adhesion of marine organisms such as shellfish will decrease even though the head loss increase.

Therefore, the inner diameter of the cooling water pipe and the average flow velocity in the pipe are determined after detailed hydraulic studies.

A cross section of a standard underground piping is as shown below:



Source: Study Team

Figure 8.3-32 Section of a Standard Underground Piping

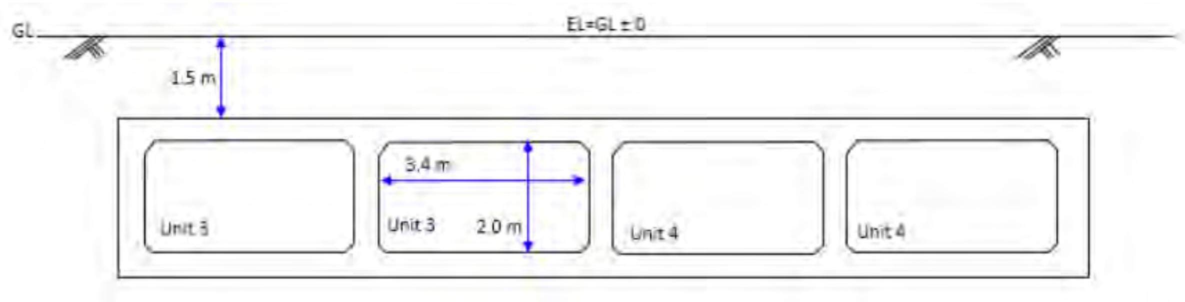
(d) Discharge Channel

For the discharge channel, the coal storage area (MSL +5.0m) will be a reinforced concrete box culvert with pile foundation. Whether the part from the revetment to the outlet will be a box culvert in the same way or a buried pipe like the Units 1/2 project will be decided by detailed design at the implementation stage.

The flow velocity of the discharge tunnel is as follows:

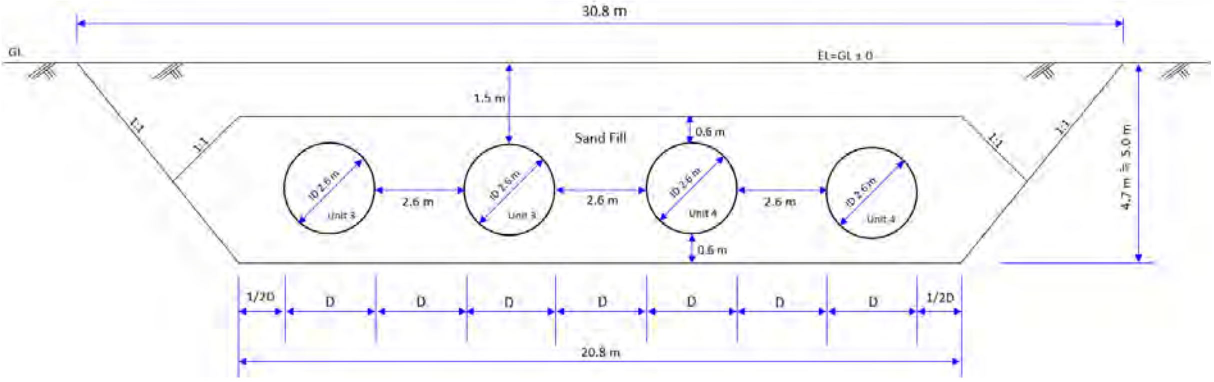
Size (m)	Flow Amount (m^3/s)	Average Flow Velocity (m/s)
2.0(H) x 3.4(B) x 2lines x 2units	50.0 (2 Units)	1.8

In addition, a cross section of a standard underground discharge tunnel is as shown below:



Source: Study Team

Figure 8.3-33 Section of a Standard Underground Discharge Channel (Box culvert)



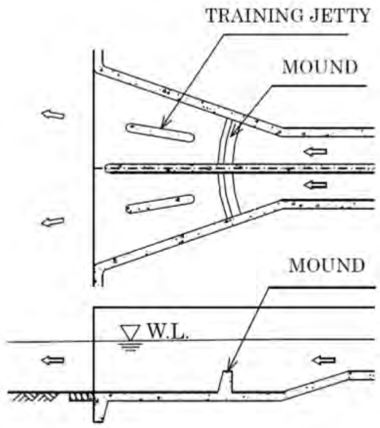
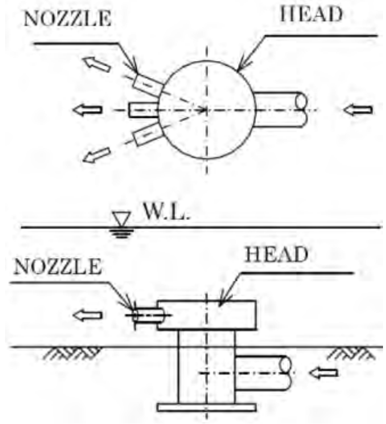
Source: Study Team

Figure 8.3-34 Section of a Standard Underground Discharge Channel (Pipe)

(e) Outlet

As shown in Table 8.3-33, there are two types of water discharge methods: surface water discharge method and underwater discharge method.

Table 8.3-33 Comparison of Different Discharge System Characteristics

<table>
<tr><td colspan="2" rowspan="3">Type</td><td>Type of Surface Discharge System</td><td>Type of Submerged Discharge System</td></tr>
<tr><td>Onshore</td><td>Offshore</td></tr>
<tr><td>Open Channel Type</td><td>Multi Nozzle Type</td></tr>
<tr><td colspan="2">Profile</td><td></td><td></td></tr>
<tr><td colspan="2">Description</td><td>It is the form that it faces shore that the depth of water is comparatively shallow. However due to limited entrainment expected from backside of outlet, the dispersion efficiency is considered comparatively poor.</td><td>Dispersion efficiency is excellent.
Regardless of water depth, varieties of diameter of nozzle, number of nozzle & its directions & angles provide for flexibility of design.
Less restriction for area or water depth & smaller scale of foundation work is required.</td></tr>
<tr><td rowspan="6">Characteristics</td><td>Flow Rate</td><td>For any size adaptable</td><td>For any size adaptable</td></tr>
<tr><td>Water Depth</td><td>Limited due to suitability to shallow area</td><td>Deeper, better effect</td></tr>
<tr><td>Flow Velocity</td><td>Limited in outfall velocity due to restricted water depth</td><td>Reasonable velocity can be attained without jeopardizing loss head</td></tr>
<tr><td>Wave</td><td>It faces it against the small wave</td><td>Enough stability can be attained against high wave</td></tr>
<tr><td>Initial Dispersion</td><td>The dilution effect by initial mixture is seldom expectable. Then, Temperature reduction is lower effective</td><td>The dilution effect by initial mixture is expectable. Then, Temperature reduction is good effective</td></tr>
<tr><td>Dispersion Area</td><td>The effect which makes the diffusion range small can seldom expect</td><td>The effect which makes the diffusion range small can expect most</td></tr>
<tr><td colspan="2">Cost</td><td>Material: Low
Construction: High</td><td>Material: High
Construction: Low</td></tr>
</table>

Source: Study Team

It is planned to set the cooling water in Units 3/4 at offshore from the coastline and adopt the underwater water discharge method. (because the same method is adopted in Units 1/2)

In addition, a hot effluent diffusion analysis must be carried out to confirm the status of seawater temperature due to hot effluent. Details of the hot effluent diffusion analysis in this report are given in Chapter 13.

The discharge flow velocity of the outlet shall be 0.3～1.0m/sec (at LWL) at the end of the discharge outlet in order to not disturb the passage of small ships and boats in the sea.

In order to prevent scouring of the outlet and protect the excavation slope, it is necessary to install 2 ton class armor rocks on the front and back of the outlet. In particular, it is preferable to consider measures such as installing double 2.5 ton class armor rocks in front of the outlet where there is a remarkable concern about scouring.

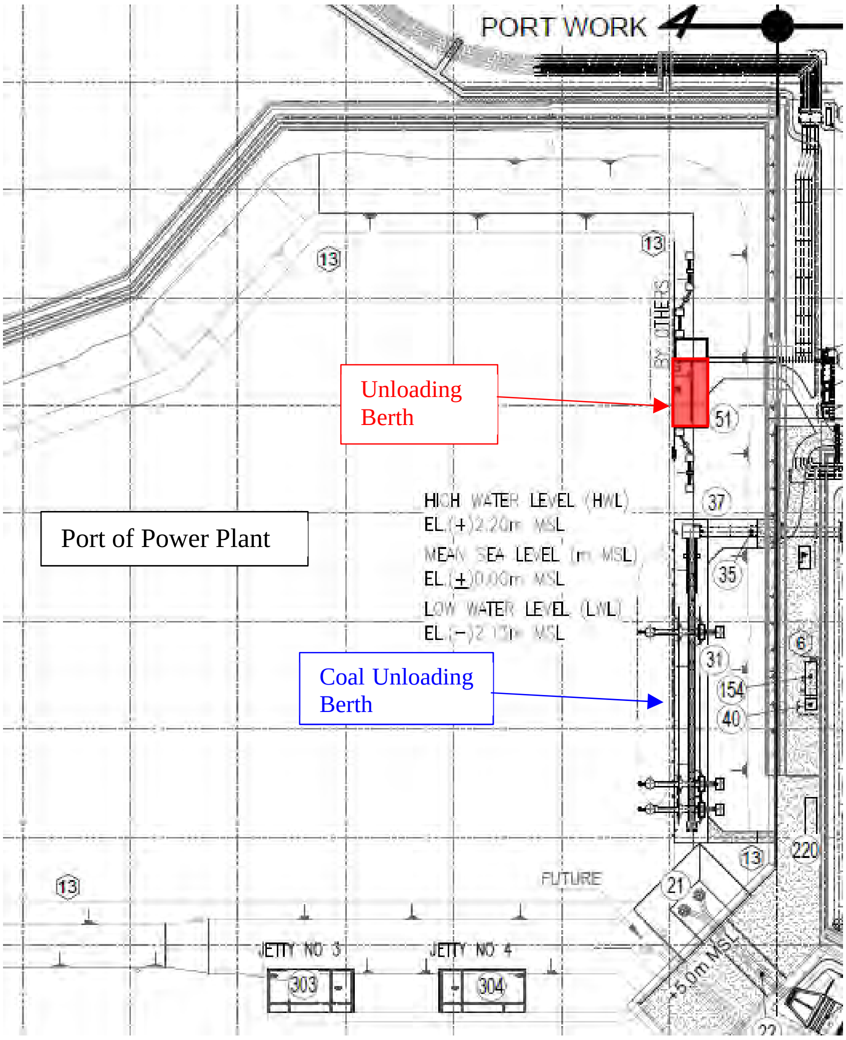
It is necessary that the outlet installation position in Units 3/4 is located in the northeast direction away from the outlet position in Units 1/2 so as to be parallel to the coastline.

At the time of installation work of the water outlet in Units 3/4, Units 1/2 is in operation and the flow from the water outlet is assumed, so the separation distance is considered so that safety can be ensured during construction. The installation position of the outlet will be decided by detailed design at the implementation stage.

(8) Heavy Equipment Unloading Berth

During the construction of the power plant, heavy equipment such as transformers and generators, which weigh up to 500 tons, will be transported to the power plant site. Since heavy equipment are carried by freighters or heavy lift ship of the 4,000 to 10,000 ton class, it is necessary to arrange an unloading berth in the port so that the ships can berth and handle cargo.

Since there is a berth built by Units 1/2, Units 3/4 will utilize this berth. The location of the unloading berth is shown in Figure 8.3-35.

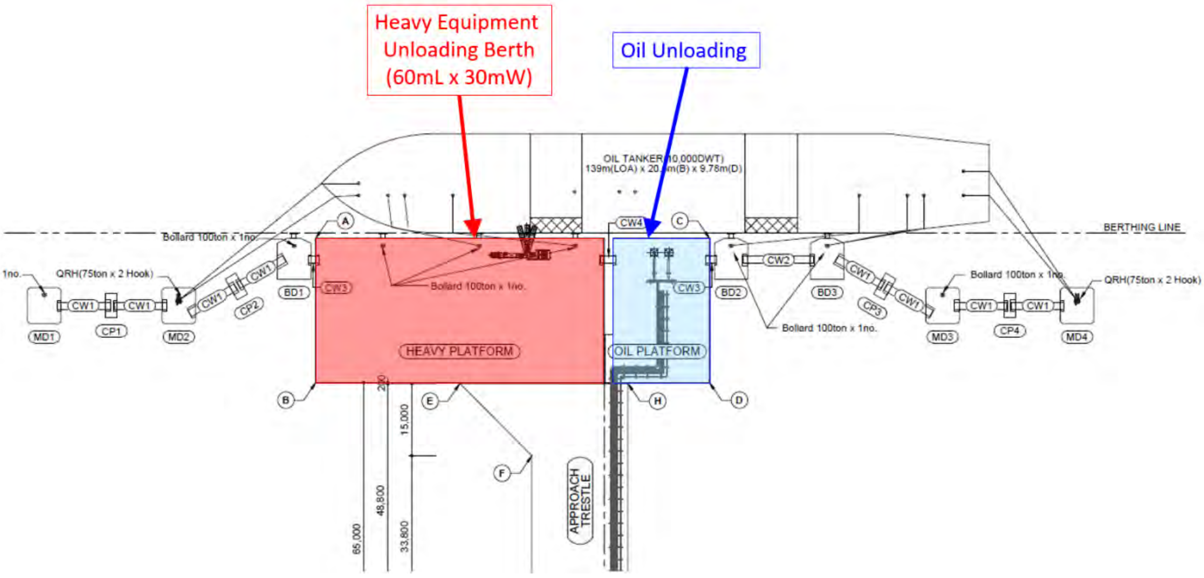


Source: Study Team

Figure 8.3-35 Location of the Heavy Equipment Unloading Berth

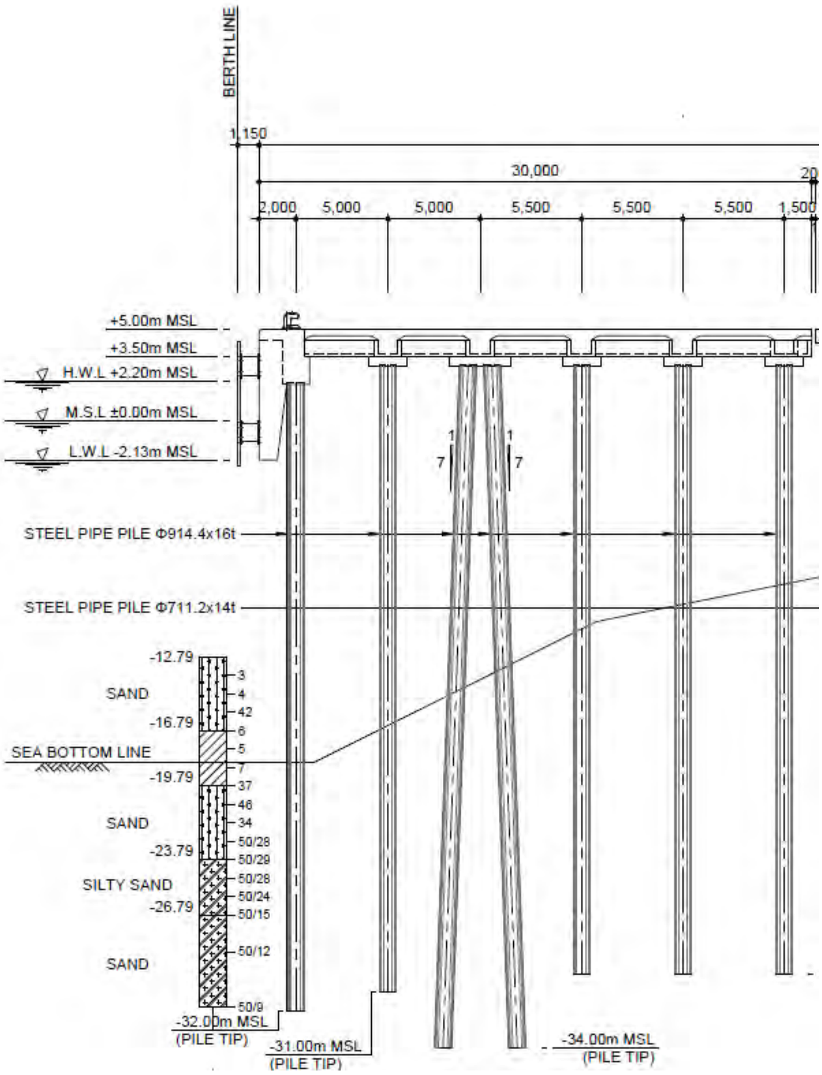
The area of the unloading berth is 1,800 m^2 (60m x 30m), and it can be transported by a 600 ton class crawler crane (196.20 kN/m^2) or a 510 ton class transporter vehicle (48.30 kN/m^2) as a loading load. The structural design was carried out assuming that.

The plan view and standard cross-sectional view of the heavy equipment unloading berth are shown in Figure 8.3-36 and Figure 8.3-37.



Source: Study Team

Figure 8.3-36 Plan view of the Heavy Equipment Unloading Berth



Source: Study Team

Figure 8.3-37 Section view of the Heavy Equipment Unloading Berth

(9) Ash Pond

Ash Pond will be constructed under the Units 1/2 Project as shown below the Figure 8.3-38.

Ash will be disposed at 1st Ash Pond area the first after the commencement of Operation for Units 1/2. This 1st Ash Pond is designed/planned to be satisfied with the required capacity at least 5 years operation for Units 1/2. (Area of this 1st Ash Pond is 429,000m^2 (Ave.))

After full of ash in 1st Ash Pond, ash will be disposed in the remaining Ash Pond area continuously. In this regard, the Partition Wall will be constructed between the 1st Ash Pond and remaining Ash Pond. (The design of Partition Wall had been completed under the Units 1/2 Project, and the volume of the Partition Wall will be 248,000m^3.)

The area of overall Ash Pond is 2,554,000 m^2 (Ave), and the average bottom elevation (surface elevation of the impermeability layer) is MSL +2.0m. And the ash estimated accumulation elevation is MSL+12.5m. (the last 1.5m between MSL+12.5m and MSL+14.0m (the circumferential dyke elevation of ash pond) is a margin for ash pond operation).

Based on the above conditions, overall volume of Ash Pond (V_0) can be calculated from the multiplication of overall area of Ash Pond (A_{all}) and the assumed height of ash stock (H_{ash}). Furthermore, the capacity of Ash Pond (V) can be calculated from a subtraction the volume of Partition Wall (V_e) from the above overall volume of Ash Pond (V_0).

$A_{all} = 2{,}554{,}000 \text{ m}^2$

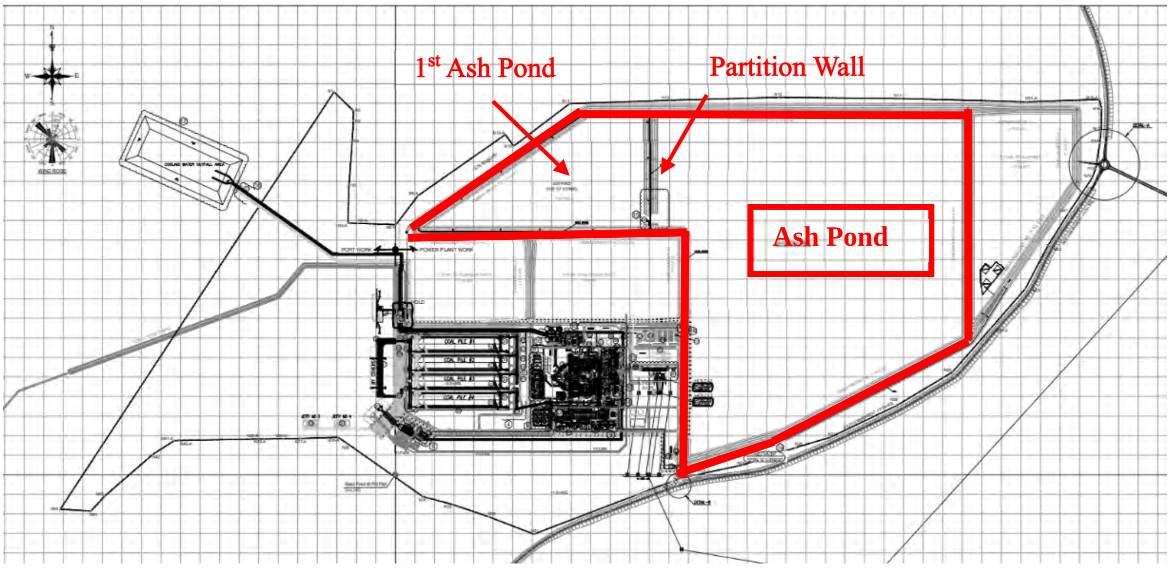
$H_{ash} = 10.5 \text{ m} \quad (\text{MSL}+2.0\text{m} \sim \text{MSL}+12.5\text{m})$

$V_0 = A_{all} \times H_{ash} = 2{,}554{,}000 \text{ m}^2 \times 10.5 \text{ m} = 26{,}817{,}000 \text{ m}^3$

$V_e = 248{,}000 \text{ m}^3$

$V = V_0 - V_e = 26{,}817{,}000 \text{ m}^3 - 248{,}000 \text{ m}^3 = 26{,}569{,}000 \text{ m}^3$

All of the ash generated by both of Units 1/2 and Units 3/4 will be disposed in Ash Pond which the capacity mentioned the above.



Source: Study Team

Figure 8.3-38 Ash Pond Overall Layout

Ash disposal plan of Units 1/2 is considered as follows;

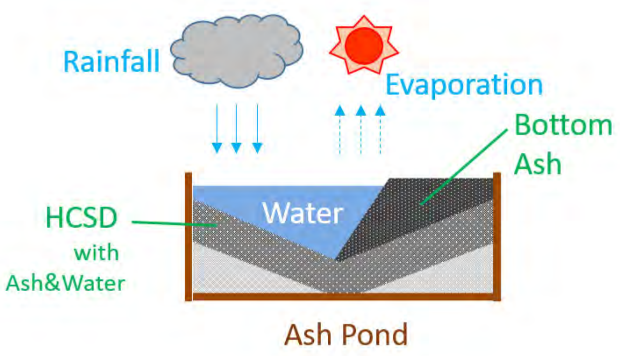
(a) Capacity of 1st Ash Pond

The calculation for capacity of 1st-Ash Pond is as below;

1) Basic Condition

- Area of 1st Ash Pond: 429,000 m^2 (average)
- Elevation of 1st Ash Pond embankment = MSL+14.0m
- Elevation of ash accumulated inside 1st Ash Pond = MSL+12.5m
- Height of accumulated ash inside 1st Ash Pond = 10.5m
  (bottom level: MSL+2.0m ~ top level: MSL+12.5m)
- Volume of 1st Ash Pond V_1: 4,504,500 m^3
- Fly Ash Disposal System: HCSD (High Concentration Slurry Disposal)
- Type of Coal for calculation: Performance Coal (Ash 6%, Water 58.3%)
- Assumed volume of Fly Ash: 13.3 t/h/unit (BMCR with Performance Coal)
- Density of Fly Ash : 1.429 ton/m3
- Water volume for HCSD System: 607 m^3/day/2 unit
- Assumed volume of Bottom Ash: 1.5 t/h/unit (BMCR with Performance Coal)
- Water volume for Bottom Ash: 18 m^3/day/2 unit
- Density of Bottom Ash: 0.75 ton/m^3

2) Calculation for Ash Pond Capacity
- Concept of Calculation Model for Ash Pond Capacity



Source: Study Team
Figure 8.3-39 Calculation Model for Ash Pond Capacity

Fly ash will be transferred to ash pond with slurry condition and be spread widely inside ash pond. On the other hand, bottom ash will be delivered with wet condition by truck and be dumped at the edge of inside ash pond because it cannot be disposed at the center by truck.
In addition to the above volumes of ash, rainfall and evaporation are considered in the ash pond capacity calculation. Regarding metrological data, 5years data were selected from the latest 10years actual rainfall data and the 5years data has maximum difference between the volume of both rainfall and evaporation in order to consider the most severe case in the calculation.
And, although the water for HCSD will be basically used and recycled from water stored inside ash pond, the HCSD water might be supplied from power plant in the case that ash pond water is not enough in dry season.

- Volume of Ash and Water

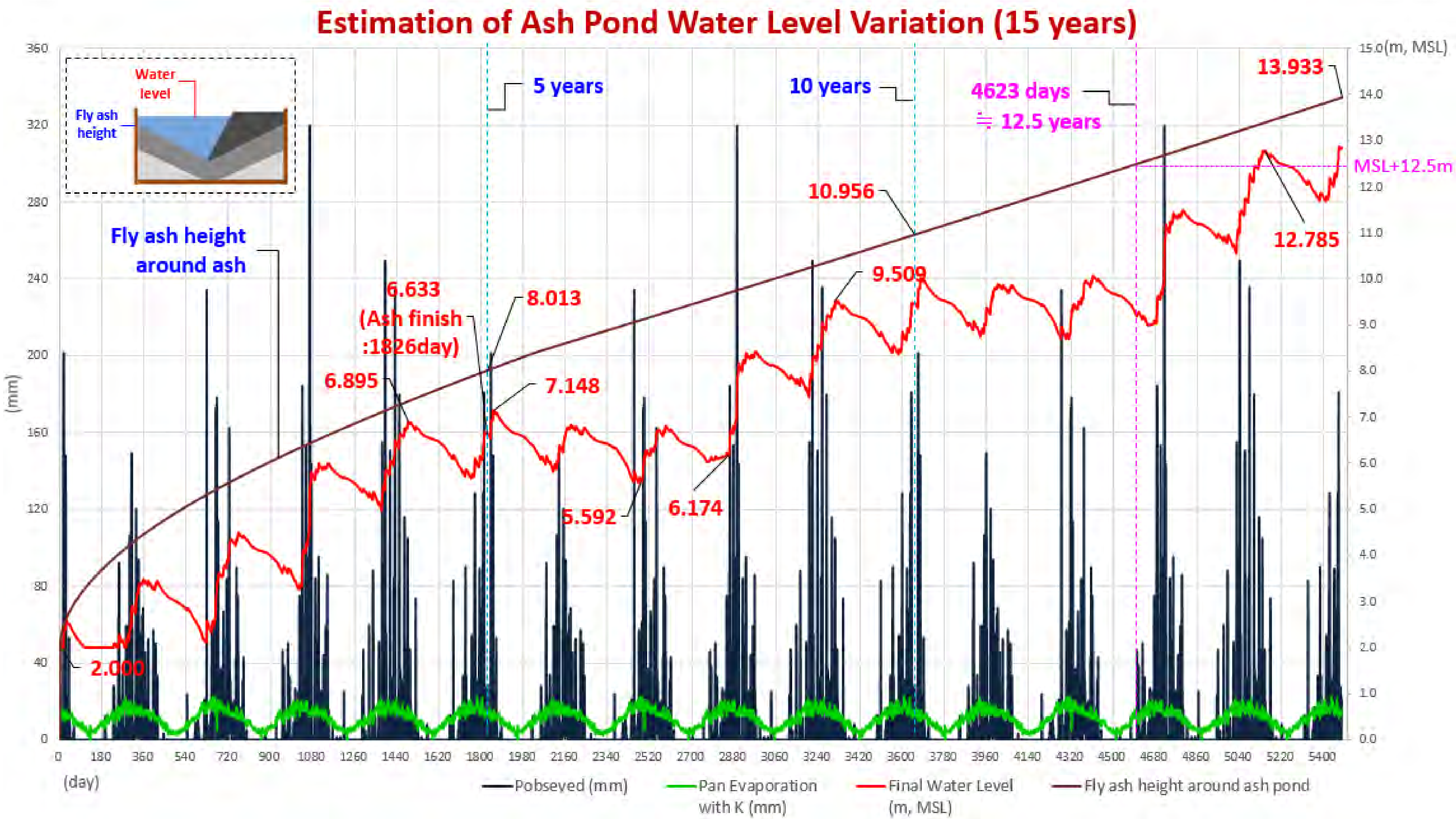
Table 8.3-34 Volume of Ash and Water (HCSD System)

Division	Performance Coal	
	HCSD System	Bottom Ash
Ash (ton)	13.3t/h x 2unit x 24hours x 365days x 5years = 1,165,080 ton	1.5t/h x 2unit x 24hours x 365days x 5years = 131,480 ton
Water (ton)	607 m^3 x 365days x 5years = 1,107,775 ton	18 m^3 x 365days x 5years = 32,850 m^3
Density (ton/m^3)	1.43 ton/m^3	0.75 ton/m^3
Volume (m^3)	1,922,516 m^3	208,157 m^3
Total	2,130,673 m^3	

Source: Study Team

According to the Table 8.3-34, total amount of ash and water of HCSD system can be assumed 2,130,673m^3 against the volume of 1st ash pond (4,504,500 m^3). It means this amount is approximately 47% of the volume of 1st ash pond.

- Water Level with considering Rainfall and Evaporation
  Occupancy rate, which is consist of the elevation of the accumulation ash and the water level inside 1st ash pond, is finally calculated based on the above volume of both ash and water and also the volume of rainfall and evaporation additionally. (storm water remained in ash pond area will be used for greening)
  The result of this calculation shown in Table 8.3-34. The ash will be accumulated up to MSL+8.0m after 5 years passed as the peak of this calculation. Water level will be up to MSL+7.09m. It can be said that the volume of 1st ash pond is much enough for the 5 years operation because the elevation of the embankment (MSL+14.0m) is higher than the level of ash and water. In case that 1st ash pond will be used continuously after 5 years passed, 1st ash pond can be used additional 7.5 years with supposing the maximum ash elevation is MSL+12.5m. In other words, 1st ash pond can be used 12.5 years for the operation of Units 1/2 project.



Source: Study Team

Figure 8.3-40 Result of Calculation for 1st Ash Pond Capacity

(b) Capacity of whole of Ash Pond

The capacity of whole of ash pond is calculated as a volume ratio from the capacity of the 1st ash pond calculated in the previous section. In the case that the volume of ash generated under Units 3/4 are same as the volume of Units 1/2, the capacity of whole of ash pond can be calculated as below;

(Although the assumed volume of ash generated under Units 3/4 will be 170,170 m^3/year in accordance with Chapter 8.3.12 “Ash Handling Facilities” – (3) “Amount of ash” in the condition of 80% operation rate, the above volume of ash (198,010 m^3/year) are to be applied in this calculation because the larger volume is more severe condition for the ash pond capacity calculation.)

According to the previous section, 1st ash pond can be used 12.5 years for the ash generated from Units 1/2 against the volume of 1st ash pond V1 in case of supposing the ash accumulate elevation is MSL+12.5m.

The capacity of whole of ash pond is calculated as a volume ratio from the capacity of the 1st ash pond V1. That is to say, the capacity of whole of ash pond is calculated as follows because the volume of whole of ash pond is V=26,569,000 m^3 calculated in the previous section;

V/ V_1 x 12.5 years = 26,569,000 / 4,504,500 x 12.5 = 73.7 years

This capacity of 73.7 years is for the ash volume generated from Units 1/2 only. Therefore, in case that Units 3/4 will operate concurrently with Units 1/2, the capacity of whole of ash pond will be almost half of 73.7 years. (nearly equal to 36.9 years)

In the above calculation, all of the ash generated by the operation of the power plant will be disposed into Ash Pond. But on the other hand, the first option of the handling of ash will be selling/delivery to cement supplier etc. in Bangladesh for a long time operation of Ash Pond because a fly ash can be used as raw material of cement and a bottom ash can be used as raw material of road construction.

Therefore, although the actual volume of ash disposal volume will be smaller than the above calculation due to ash selling/delivery, it is necessary to monitor the deal of ash selling/delivery with carefully after the commencement of Units 1/2 because the ash disposal volume depends on the volume of ash selling/delivery.

The ash pond which was designed in the scope of Units 1/2 project will be able to receive all of the ash generated from both Units 1/2 and 3/4 project. But on the other hand, there are some remaining soils inside the ash pond which were generated from the construction of Units 1/2 as the actual situation at the time of December 2021. There are some possibilities that the ash pond capacity will have been decreased by the remaining soils if the soil continue remaining during the ash pond operation.

In the next section, it is described about the points to be considered from the viewpoints of a long time operation of Ash Pond, such a remaining soil etc.

(c) Points to be considered for the operation of Ash Pond

1) Remaining Soil in Ash Pond area - generated by construction of Units 1/2 project

As mentioned above, remaining soils accumulated inside the ash pond due to the construction works for Units 1/2 project.

The remaining soils include dredged soils which is not suitable for land development work, and excavated soil generated under the construction of power plant work for Units 1/2. And also, accommodations for construction works for the projects as a countermeasure against Covid-19 will be constructed inside the ash pond area. For the accommodations, temporary land development were constructed and the volume of this temporary land development is included in the remaining soil.

The contractor of Units 1/2 project calculated that the remaining soils will accumulate up to 8,000,000m^3. The 8,000,000m^3 volume of remaining soils is equal to the 22.2 years capacity of ash pond for Units 1/2 operation as below calculation;

Vsoil/ V1 x 12.5 years = 8,000,000 / 4,504,500 x 12.5 = 22.2 years (for Units 1/2 basis)

In other words, if this remaining soil of about 8,000,000m^3 is left as it is, it would reduce 22.2 years capacity in Units 1/2 basis (11.1 years capacity for both Units 1/2 and Units 3/4 basis) from the capacity of the ash pond, even though the original capacity of the ash pond is enough for the operation of both Units 1/2 and Units 3/4.

Supposing the remaining soil are spread evenly in the main ash pond area, the height of the remaining soil will be 3.83m from the calculation of 8,000,000m^3 volume and 2,090,000m^2 area. Therefore, the total height of ash plus the remaining soil (MSL+12.5m + 3.83m) will possibly exceed the height of embankment.

On the other hand, approximately 1.0m settlement will occur on the original ground of Ash Pond because of the huge volume of ash and remaining soil with referring to the actual record of the settlement of the land development for Units 1/2. And also, the ash volume will be smaller the ash volume which was used in the above calculation because the assumed ash volume is based on 100% operation ratio. Therefore, from these reasons, the height of ash will be lower than MSL+12.5m without considering the remaining soil. (And, if the ash can be sold, the ash disposal volume will decrease further more. Then, the remaining soil might not be a cause of problem on the operation of ash pond.)

Although the remaining soil is not suitable for the land development of the power plant project due to the specification of the soil, the remaining soil can be used for temporary ground for construction platform etc. Therefore, the remaining soil can be used for the ground of temporary laydown area for the construction of Units 3/4, and can be possibly used for the construction purpose for the other project around Matarbari area if necessary.

2) Gypsum generated by Limestone FGD system

According to Chapter 8.3.10 “Flue Gus Treatment System” – (2) “Flue Gus Desulfurization System (FGD)”, Limestone FGD system is applied to Units 3/4. Gypsum will be generated as byproduct of Limestone FGD system. The volume of gypsum is assumed 436 ton/day (converted to 189.6 m^3/day by the specific gravity of 2.3) per 2 unit. The annual volume of gypsum will be 69,204 m^3/year.

Gypsum can be used as raw material of cement, and can be used for gypsum board which is a kind of interior/exterior material. Then, the gypsum generated by Limestone FGD system in this project will also be sold to cement suppliers and building material suppliers in Bangladesh. But if it would be difficult to sell/deliver all the volume of gypsum, the remaining volume of gypsum will be disposed into the Ash Pond area.

3) Dredging soil from the maintenance dredging of channel for the project port

Maintenance dredging is necessary after the commencement of power plant operation in order to secure the channel of project port for the delivery of coal etc. The dredged soil generated by the maintenance dredging will be spread into Ash Pond and classified/sediment in the area. In this regard, the handling of the dredged material should be taken into account in the same way as the remaining soil generated during construction as described above.

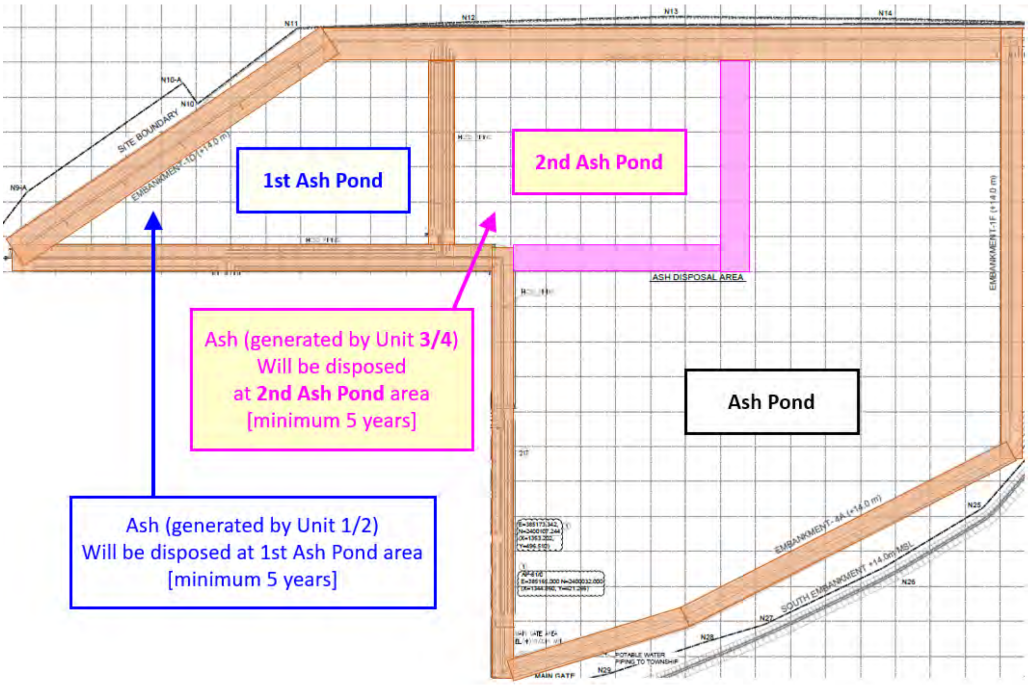
(d) Operation Plan for Ash Pond

Although the capacity of whole of Ash Pond can receive all the ash generated by Unit 1~4 as described in the above (b), two cases of Ash Pond Operation are proposed as follows from the view point of long time ash pond operation because the ash disposal volume will be decreased by the deal of selling/deliver the ash and on the other hand the capacity of ash pond may be compressed by the remaining soil and gypsum etc.

(Case-1) 2nd Ash Pond for the ash of Units 3/4 for first 5 years

For the operation of Units 3/4, a specific area in the main Ash Pond will be prepared to receive the first 5 years of the ash of Units 3/4 as with the 1st Ash Pond for the ash of Units 1/2. The specific area can be called as 2nd Ash Pond. The capacity of 2nd Ash Pond is assumed the same volume of 1st Ash Pond. (see Figure 8.3-41)

Therefore, even though the minimum required capacity of 2nd Ash Pond is 5years of the ash, the volume of 2nd Ash Pond can receive 12.5 years of the ash as described in the above (a).



Source: Study Team

Figure 8.3-41 Case-1 of Operation plant for Ash Pond

It is necessary to consider about the next disposal area with careful monitoring about the deal of selling/delivery of the ash during using 2nd Ash Pond after the commencement of Unit 3/4 operation because the disposal ash volume depends on the deal of selling/delivery.

(e.g. the location of the next disposal area, the necessity width/length of the next disposal area, etc.)

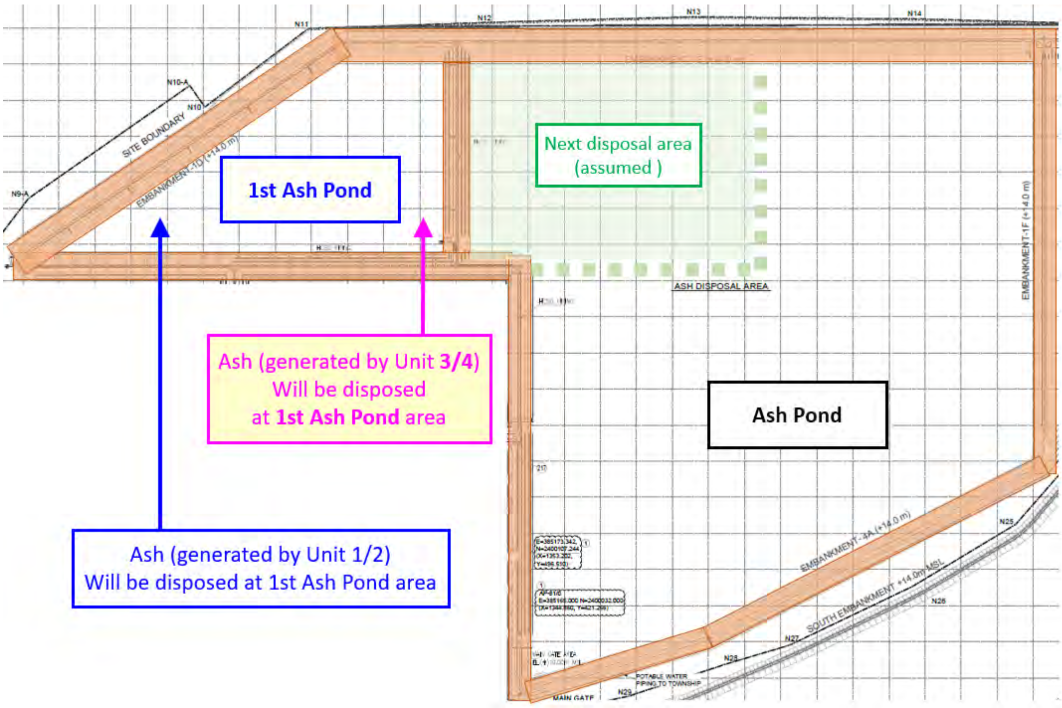
2nd Ash Pond will be made by the soil improvement and soil embankment as with the partition wall of 1st Ash Pond. In this case, the cost of the construction for 2nd Ash Pond is assumed 40 million USD.

But on the other hand, the material of impermeable sheet (High Density Polyethylene sheet) which will be set inside the 2nd Ash Pond is provided by the contract of Units 1/2. In general, the HDPE sheet can be used over 100 years under the some specific conditions (unexposed condition and temperature is lower than 30^{o}C, etc.) Therefore, the material cost of HDPE sheet is not necessary to consider under Units 3/4.

(Case-2) Ash of Unit 3/4 will be disposed at 1st Ash Pond the first

Although the ash of Units 1/2 and Units 3/4 will be disposed at different area separately in the above Case-1, it is supposed that the ash of Units 3/4 will also be disposed at 1st Ash Pond as with the ash of Units 1/2 in the Case-2. (see Figure 8.3-42)

In this Case-2, 1st Ash Pond can be used approximately 6.25 years for the operation of both Units 1/2 and Units 3/4. (based on the above (a), 1st ash pond can be used 12.5 years for Units 1/2, then the capacity will be half for both of Units 1/2 and Units 3/4.)



Source: Study Team

Figure 8.3-42 Case-2 of Operation plant for Ash Pond

It is necessary to consider about the next disposal area with careful monitoring about the deal of selling/delivery of the ash during using 1st Ash Pond after the commencement of both Units 1/2 and Units 3/4 operation because the disposal ash volume depends on the deal of selling/delivery.

(e.g. the location of the next disposal area will be supposed at 2nd Ash Pond area of Case-1, but the necessity width/length of the next disposal area (2nd Ash Pond) should be considered based on the actual record of ash accumulation of 1st Ash Pond)

In addition, in the Case-2, it will be an advantage in terms of initial cost that it is not necessary to establish new embankment for 2nd Ash Pond under the scope of construction of Units 3/4. (but, it depends on the deal of ash selling/delivery. If the ash cannot be sold as expected, the 2nd Ash Pond should be planned and constructed by Variation Order under Unit 3/4 project.)

And also, regarding HDPE sheet which is described in Case-1, the material of HDPE sheet is provided by the contract of Units 1/2. Therefore, the material cost of HDPE sheet can be the item of cost compensation under Units 1/2 contract in case that the 2nd Ash Pond is not necessary under Units 3/4 based on this Case-2.

(10) Service Roads

Roads will be provided for vehicular access around all plants, administration building, etc. Since it is expected that the same vehicles as Units 1/2 will pass through Units 3/4 area, it is considered the road design to have the same design concept as Units 1/2. Road will be made by asphalt pavement or concrete pavement. Road types are classified in six classes as per the Table 8.3-35. Road widths, radius of corners, curves and pavements are designed to be entirely suitable for the sizes of vehicles which are likely to be used during the operation of the power plant. The Vehicles include articulated vehicles and transport vehicles that are used when replacing or renewing the main equipment of a power plant.

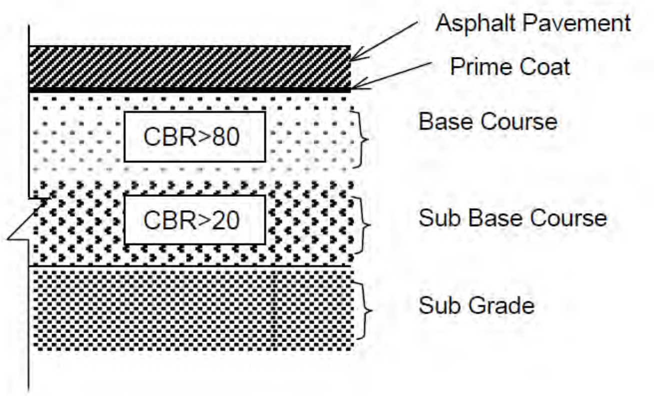
Table 8.3-35 Service Road Classification

Class*	Lane Width(m)	Stopping Lane Width (m)	Shoulder (m)	Sidewalk (m)	Total Width (m)	Remark
A-9	3.0x2	-	-	-	6.0	Ring road around the ash pond
A-11	3.0x2	-	-	-	6.0	South side of ring road including fence space 2.0m
B-9	3.0x2	-	1.5x2	-	9	Standard road width in power block
B-10	3.5x2	-	1.5x2	-	10	Around the Main Building
B-13	3.5x2	2.0x2	-	2.0x1	13	Main Entrance Road (Main gate to Adm. Bui.)
B-13	3.5x2	2.0x2	-	1.0x2	13	Route of transporter for Heavy Equipment

Source: Units 1/2 Design Specification

The cross slope of the road will be 2% and the maximum grade of road will be 5%.
Sidewalks will be surfaced with asphalt wearing course and concrete block lying on a crushed-stone base.

As for the vehicle load, it is necessary to design the durability of the road pavement in accordance with HS-20 and H-10 of AASHHTO (American Association of State Highway and Transportation Officials) as in the case of Units 1/2. The basic configuration of road pavement is assumed as shown in the figure below.



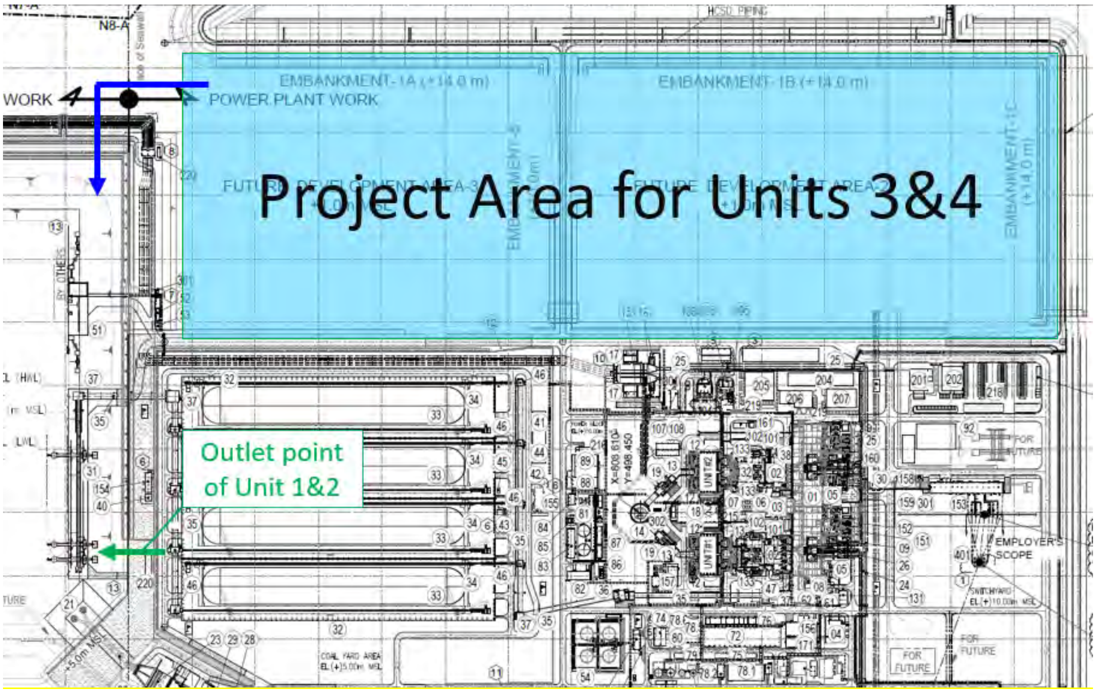
Source: Units 1/2 Design Specification

Figure 8.3-43 Basic Configuration of Road Pavement

(11) Storm Water Drainage Facilities

The storm water drainage system within the premises of the power plant will consist of concrete drain pipe, reinforced concrete manhole, side ditches, catch basin, check pits and so forth.

The storm water drainage system will be installed along the buildings and roads on the premises of the power plant (the storm water will be used for greening as possible as it can be). In addition, it is necessary to install it along the outer circumference of the power plant site so that rainwater inside the power plant site does not flow to outside of the power plant. Since Units 3/4 site is surrounded by Units 1/2 site on the south side and by the ash pond on the north and east side, the outlet of the storm water drainage system at Units 3/4 site is considered to drain to the project port side. The assumed position of the outlet is shown in Figure 8.3-44.



Source: Study Team

Figure 8.3-44　Estimated location of the outlet for Storm water drainage

Check pits are planned in the storm water drainage system to discharge drainage in the plant area smoothly. Check pits will have the capacity sufficient to store an amount of inflow drainage of approximately one minute.

Storm water drainage facilities are required to maintain normal operations during emergency height sea level (MSL +10.0m). At the drain outlet of storm water, two sets of gates are required.

The purpose of the outside gate (valve) is to prevent any seawater from entering the power plant during the emergency height sea level, and the purpose of an inside gate (valve) is to prevent any dirty storm water entering the power plant.

Chapter 9 Construction Method

9.1 Outline

Since Units 3/4 is adjacent to Units 1/2, which is under construction in advance, basically the construction method follows the plan of Units 1/2.

Basically, Units 1/2 supposed to be started operation, so it is recommended to divide the construction area of Units 3/4 and construction-related equipment, facilities and manpower at the boundary and manage security. (Gate control, etc.)

9.2 Civil Works

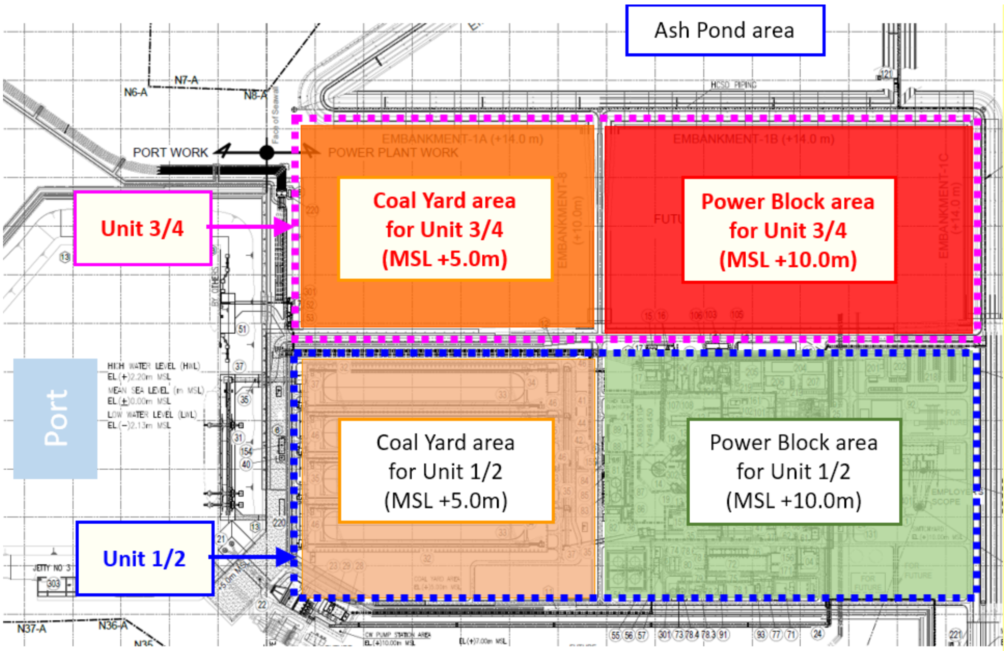
9.2.1 Land Development

(1) Land Development Plan

This project site mainly consists of a power plant area (Power Block area) and a coal storage area (Coal Yard area). Before the start of construction of Units 1/2 project, the original ground level was about MSL+1.0m, but as of 2021, both of Power Block area and Coal Yard area have been reclaimed up to MSL+5.0m and MSL+7.0m in order to be used for temporary material/equipment storage yard for the construction of Units 1/2. Since it is necessary to implement the soil improvement work (consolidation acceleration method described later) at the timing when the land development of this project is started, it is assumed that the land development work will be started from MSL+4.0m in both areas.

In order to realize an efficient operation of the entire power plants of Units 1 to 4, both of Power Block area and Coal Yard area will be planned at the same ground level as the Units 1/2 project site. Therefore, it is necessary to develop the lands up to MSL+10.0m for the Power Block area and to MSL+5.0m for the Coal Yard area. (See Figure 9.2-1)

Approximately 4,200,000 m^3 soil is required for the land development. For this volume of required soil, 3,900,000 m^3 will be prepared under the construction of Units 1/2 project. The remaining 300,000m^3 will be prepared under the scope of Unit 3/4 project (but this volume of remaining soil will be also expected to be generated by the Units 1/2 project and/or port extension works).



Source: Study Team

Figure 9.2-1 Conceptual diagram of site development for this project site

As a result of the soil investigation described in Chapter 5, this project site has similar soil properties to those of the adjacent Units 1/2 site. In addition, since the same ground levels are planned as described above, it is considered that the same land development method as the method implemented in the Units 1/2 project is optimal for the land development method in order to make uniform ground behavior in the future. Therefore, it is preferable to adopt the ground improvement method by Deep Mixing Method (DMM) and the consolidation acceleration method by Prefabricated Vertical Drain & Prefabricated Horizontal Drain (PVD & PHD). These construction methods will be described in the next section.

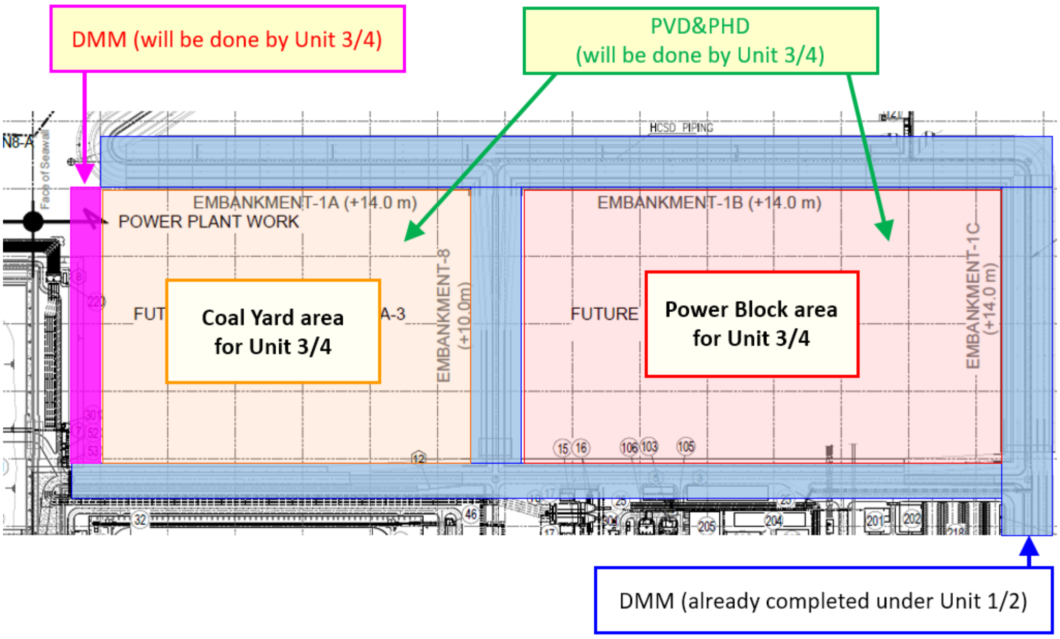
(2) Soil Improvement

The original ground of this project site exists under the elevation of MSL+1.0m, but as a result of the soil investigation, soft clay soil has been confirmed in the layer below the original ground, and the thickness of the layer is about 10m to 20m. When developing of this project site, there is a concern that ground collapse and land settlement will occur in this soft clay layer in the future, so soil improvement is necessary to improve the ground properties of this soft clay soil.

- Deep Mixing Method (DMM)

  When a load is applied on soft ground, ground collapse (such as circular slip on a slope) may occur. When the site is developed/reclaimed on a soft clay layer like this project site, slope failure is likely to occur at the boundary of the developed/reclaimed area. Therefore, it is necessary to improve the boundary line of the site by the DMM.

  On the other hand, the DMM has already been implemented on the north, east and south sides of this project site by Units 1/2 project, therefore the DMM will be implemented only on the west side of Coal Yard area of this project. (See Figure 9.2-2)



Source: Study Team

Figure 9.2-2 DMM location map

DMM is a construction method in which cement slurry is mixed directly into the soft clay soil layer, and has the effect of improving the strength of the ground. (See Figure 9.2-3)

When implementing DMM, the contractor will carry out a soil investigation in the target area, and perform slope stability analysis, and then carry out ground improvement design. Based on the design, the soil sample collected from the target area is mixed with the cement slurry in the laboratory to check the strength, and then the slurry is actually mixed in the target ground to check the actual strength (Trial Mix), then finally DMM construction will be started. A reference photograph of the DMM is shown in Figure 9.2-3.

Construction Equipment

Under Construction

Source: Study Team

Figure 9.2-3 DMM reference photograph

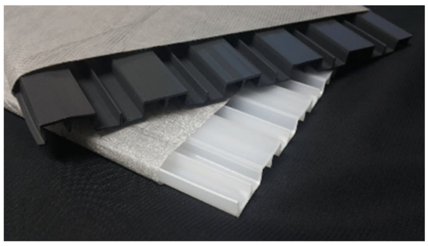
- Consolidation acceleration method by PVD & PHD

The clay soil layer has the property of consolidation when a load is continuously applied. Consolidation is a phenomenon in which the volume becomes smaller due to the drainage of water from the clay soil layer, which causes land settlement. The consolidation acceleration method is a method of dewatering from the clay soil layer, and accelerate consolidation in advance has the effect of reducing the amount of residual settlement that will occur in the future. In PVD & PHD, by arranging a high permeable material in the clay soil layer, the water in the clay soil is drained from there, so the consolidation duration can be shortened. A reference photograph of the PVD & PHD method is shown in Figure 9.2-4.

Construction Equipment

Material (PVD)

Material (PHD)

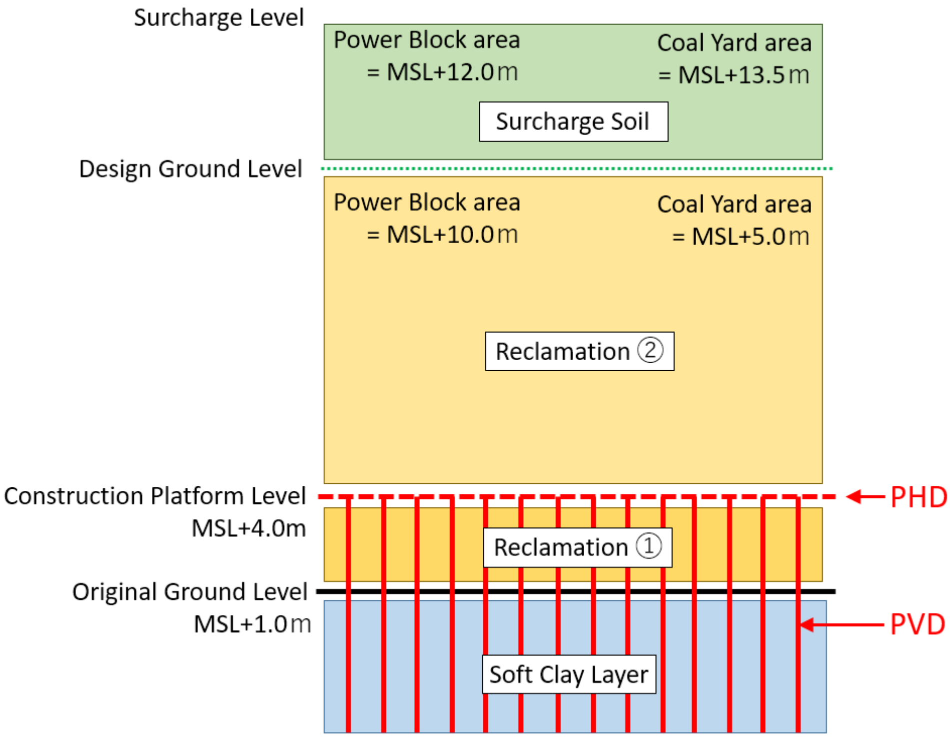


Source: Study Team

Figure 9.2-4 PVD & PHD reference photograph

In this project, it is preferable that the area inside the DMM shown in Figure 9.2-3 be consolidated by PVD & PHD.

In this project, in order to further acceleration of the consolidation, it is preferable to apply a large load to the clay soil layer by stacking more additional soil than the planned site height (surcharge soil), shortening the consolidation duration and reducing the amount of residual settlement. The height of the surcharge soil will be designed in consideration of the load expected in the future in the detailed design phase, but for reference, the height of the surcharge soil in the Units 1/2 project were MSL+12.0m in the Power Block area and MSL+13.5m in the Coal Yard area. Therefore, it is assumed to carry out surcharge soil to the same height in this project site since the ground of the site has similar soil properties to the site of Units 1/2.



Source: Study Team

Figure 9.2-5 Consolidation acceleration method

9.3 Equipment Installation Work

For the process, installation and assembly method for the installation work of the main equipment in the construction of Units 3/4, the standard method for the construction of a power plant of the same scale was referred to. This section outlines the assembly of turbines, capacitors, and boilers, which are the main equipment.

9.3.1 Turbine Assembly

(1) Setting of foundation bolts

The setting levels of foundation bolts were measured by transit and setting positions of them and anchor blocks from the center line of turbine and generator are confirmed. Anchor bolts should be supported with templates and should not be welded to reinforcing steel bars.

(2) Setting of adjusting plates, adjusting pieces and seating plates

Set the adjustment plate and adjustment piece in the first grout, check the correct position with the level gauge and transit, then set the seat plate and adjust the height and tilt within the allowable range. In addition, a grout stopper will be installed for grout.

(3) Turbine on base

Before installing the LP casing on the foundation, make sure that the condenser shell skirt is properly positioned and that the LP exhaust connection is properly connected to the condenser skirt.

(4) Provisional centering

After installing LP lower half casing, HP pedestal and HIP lower half casing, the provisional centering was carried out by adjusting HP pedestal elevation and bearing liner thickness.

(5) Adjusting of clearance

After lower halves of inner casings, nozzle box, blade rings, dummy rings, gland rings, diaphragms and bearings were installed, radial and axial clearances between casing and inner parts were measured, recorded and adjusted where necessary.

After LP rotor and HIP rotor were installed, the radial and axial clearances between stationary parts and moving parts were measured, recorded and adjusted where necessary. The measurements of clearances are carried out by the lead wire method and thickness gauge.

(6) 2nd Centering

2nd centering was carried out by measuring the clearances between the mating coupling faces with dial gauge attached to the coupling flange surface of rotating rotor.

(7) Grouting

After 2nd centering was carried out and the turbine was assembled and is loaded with almost all related weight upon it, grouting was carried out. Material for grouting shall be non-shrink properties. During application of grouting work temperature shall be at 5 °C or above and also grouting surface shall be wet for 7 days after grouting.

9.3.2 Outline of Condenser Assembly

(1) Assembly of shell skirt

The shell skirt consists of four blocks, which are transported from the carry-in entrance to the turbine building and placed under the T/G foundation using overhead cranes and temporary rails, where they are assembled into a single shell skirt by welding.

After assembly, a temporary beam is used to hang the condenser shell at the turbine exhaust port of the T/G foundation for assembly and installation

(2) Assembly of shell

The shell consists of four blocks, carried in through the opening of the turbine building, placed under the CW valve pit, T/G foundation using temporary rails, and assembled into one shell by welding.

(3) Assembly of shell and shell skirt

The shell and shell skirt are connected by welding. Next, the tube plate and the tube support plate are centered (aligned) using the piano wire, and the tube support plate is fixed to the brace by welding.

(4) Tube installation

After assembling the inverted water box into the shell, insert the tube. After the inlet/outlet water box is assembled into the shell, the tube is extended to the tube plate and sealed welded.

(5) Water filling test

After installing the LP heater, extraction steam pipe, and expansion joint on the condenser neck, perform a water filling test on the condenser shell. Make sure there are no leaks from welds, tube connections, and condenser parts.

9.3.3 Outline of Boiler Assembly

(1) Construction schedule

The major events on construction are as follows:

(a) Boiler steel structure: First column lifting
(b) Boiler steel structure: Top girder lifting
(c) Boiler pressure parts
  1) Drum lifting
  2) Welding of pressure parts
  3) Hydrostatic test (Reheater side)
  4) Hydrostatic test (Superheater side)
  5) Air leak test
  6) Boiler initial firing
  7) Chemical cleaning
  8) Blowing out
  9) Safety valve test

(2) Ground Assembly of Boiler pressure Parts

The following parts will be assembled on the ground before being lifted up.

(a) Furnace front wall upper panel + SH* inlet pipe
(b) Furnace front wall baffle panel + Furnace front wall outlet header
(c) SH element tube + SH element tube
(d) RH element tube(upper) + RH element tube(lower)
(e) Economizer hopper block + Economizer inlet header
(f) Furnace front & rear bottom panel

(3) The site ground assembly of boiler pressure parts has the following advantages:

(a) It is possible to ensure better welding condition (working space and welding posture) and to make better welding quality, compared with welding to be carried out in-situ after lifting to the final position.
(b) The number of welding joints to be carried out in the air after lifting can be reduced and the number of lifting work also can be reduced. This is effective to squeeze the manpower of erection team.
(c) Lift up of boiler pressure parts

9.4 Transportation Plan

How to transport materials and equipment including main equipment is important in considering the process of this project. Materials and equipment for machinery/electricity, civil engineering/construction will be procured from overseas and domestic. The outline transportation plan that examined how to transport these materials and equipment to the planned construction site of the power plant is as follows.

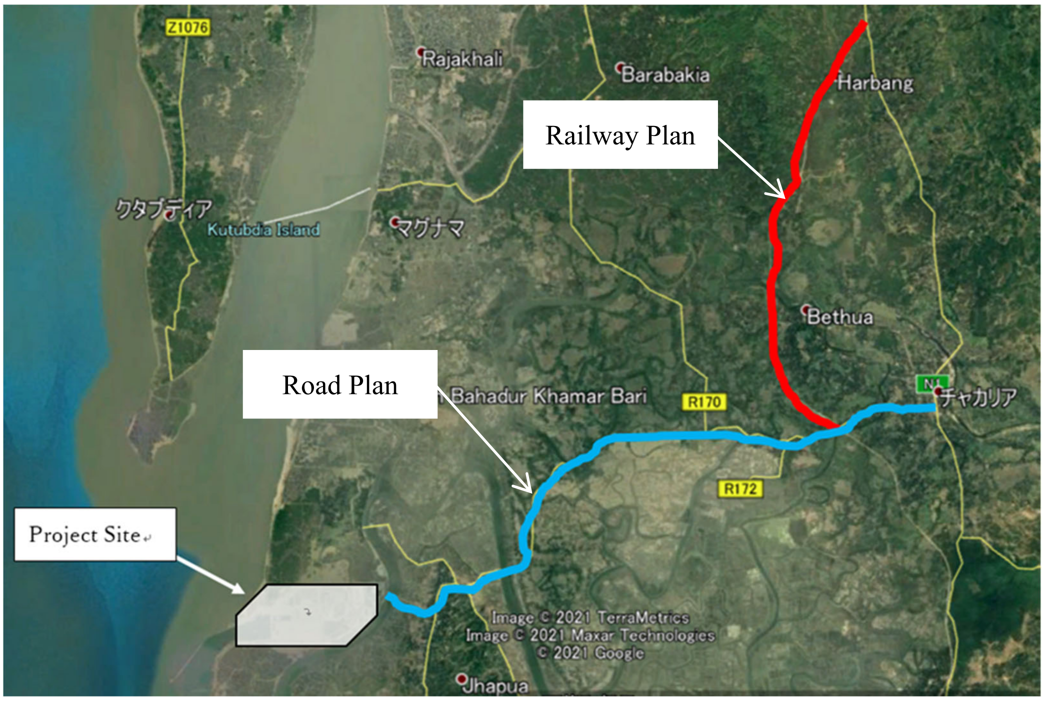
(1) Transportation Means

Currently, the means of transportation that can be considered at this project site are marine transportation and land transportation (including rail transportation).

Among them, regarding land transportation, the development plan around the Matarbari area is underway at the survey stage, but if it is realized according to the construction process of Units 3/4, it will be possible to use both land transportation and sea transportation. The convenience for this project will be greatly enhanced. In the future, if the development plan for land transportation becomes more specific, it will be important to adjust the transportation plan according to the progress of construction under the “Matarbari Port Access Road Plan”. However, at the current survey stage, there are uncertainties in the construction process, land transportation is not consider, and will focus on marine transportation.

➢ Outline of “Matarbari Port Access Road Plan”

The land transportation route as part of the “Matarbari Port Access Road Plan” is shown in Figure 9.4-1.



Source: Study Team

Figure 9.4-1 Land Transport Route Map

The implementation schedule for the "Matarbari Port Access Road Plan" is as follows.

Table 9.4-1 Implementation Schedule

The expected project completion is May 2024.	
•Detailed Design	: Dec. 2018 ~ Nov. 2019 (12 months)
•Procurement of the Contractor:	: Dec. 2019 ~ Nov. 2020 (12 months)
•Construction	: Dec. 2020 ~ May 2024 (42 months)

Source: Preparatory Survey on Matarbari Port Development Project in the People's Republic of Bangladesh

(2) Subject of Transportation equipment

(a) Major Equipment (Transportation plan for heavy and long items)

The transportation weight of the main equipment of the coal-fired power plant (assuming 600MW class) is as follows.

Table 9.4-2 List of Main Equipment

Equipment	Equipment load(t)/length(m)	Transport beam (t)	Dolly(t)	Total load(t)
Generator Stator	290 / 10	10	110	410
HP Integrated Turbine	230 / 10	10	80	320
LP Rotor	100 / 10	0	80	180
HP Heater	100 / 10	0	70	170
LP casing (bottom)	40 / 8	5	25 (Trailer)	70
Deaerator	90 / 16	0	70	160
Main Transformer	350 / 15	0	120	470

Source: Study Team

These heavy and long equipment procured and transported from overseas are imported products. The procedure of customs clearance is done at Chittagong port, and after customs clearance will be transported to the project site by heavy lift ship. In addition, if customs clearance is possible at Matarbari Port, it will be transported directly to Matarbari Port.

The scale of the heavy lift ship is assumed to be 4,000ton to 10,000ton class, and heavy lift such as the generator stator and main transformer will be transferred to the dolly and transported to the project site.

In addition, the temporary road for transportation within the site must have a width of about 15 m with a generator stator, and a bearing capacity of 7 t/m^2 shall be secured.

(b) Transportation plan for civil structure and architectural building related materials and equipment

For civil engineering work, construction materials such as piles, reinforcing bars for foundation work, cement, crushed stone, and cooling water pipes are the main materials. As for piles, it is assumed that large-diameter PHC piles will be used as foundation piles for major equipment, and the manufacturing plant will be sourced from overseas and local. The piles are transported by heavy lift ship or barge ship using the sea. The unloading will be done from the temporary jetty, and the barge will be transferred to the trailer by crane and transported to the pile stockyard in the site. Therefore, it is necessary to consider the process including pile manufacturing and curing, and to formulate a carry-in plan. Reinforcing bars, etc. have almost the same transportation form as PHC piles, so it is necessary to plan in consideration of the number of transportation days.

The main material for construction is the steel frame of the building. Since the steel frame manufacturing factory of the building will be overseas, this steel frame will be transported by the heavy lift ship transportation from the sea, similar to piles.

The main columns and girders of the steel frame of the building are important structural members, and in particular, the top girder of the boiler is huge, so it will be transported separately. Therefore, during marine transportation, it is necessary to be careful not to cause damage due to shear waves caused by other vessels or load collapse due to high waves caused by the weather.

Different sizes of cement quantities such as 50kg bag, 1,000kg bag or bulk type will be transported at site using the sea. Bulk cement will be transported using cement bulk carrier vessel and stored at site in silo. So, it is necessary to plan in consideration of the number of transportation days, location and capacity of cement storage and silo.

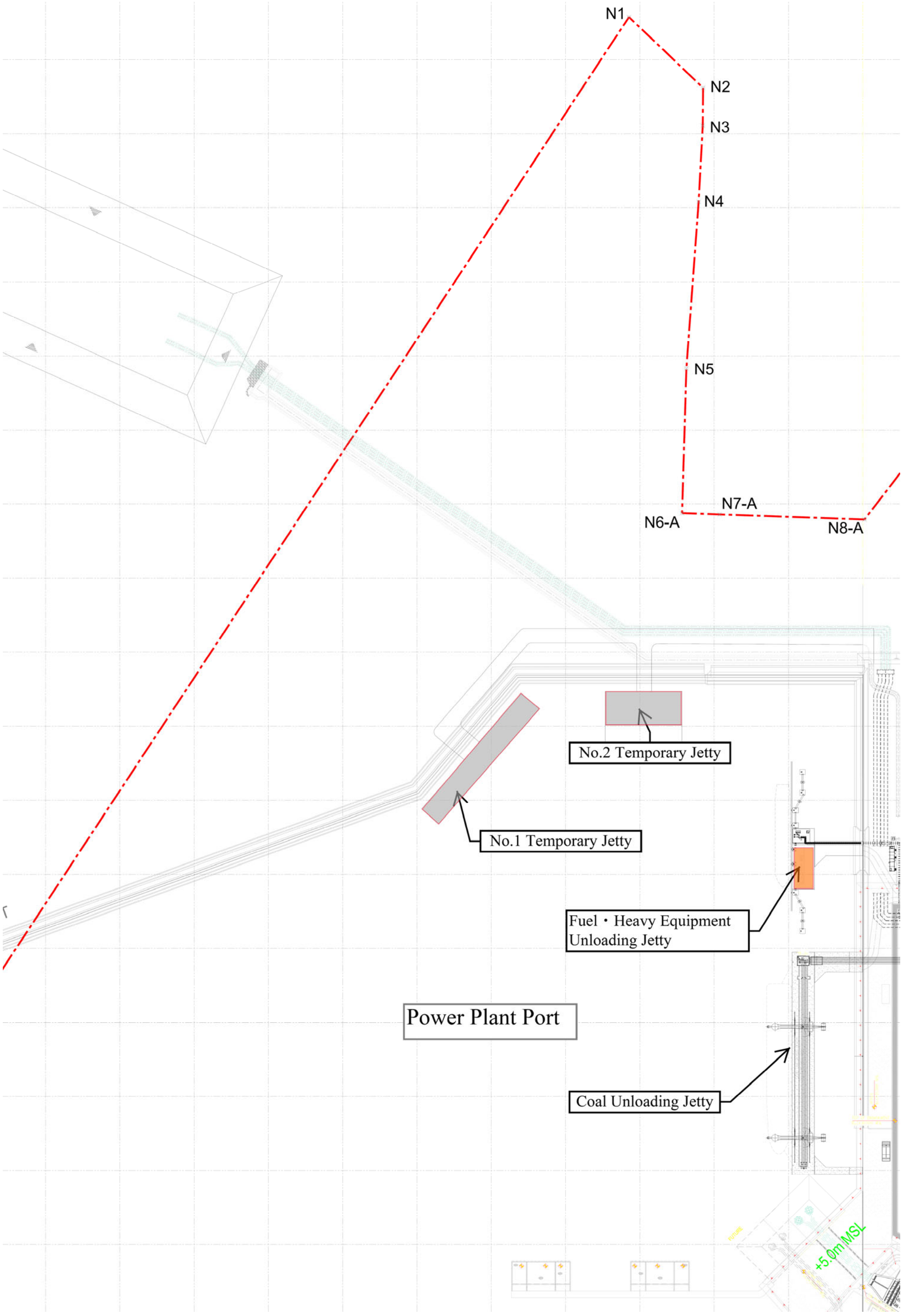
(c) Other materials and equipment

In addition, mechanical materials (pressure parts, piping materials, etc.), electrical materials (cables, panels, etc.), temporary construction materials, etc. can be considered. Large-scale construction machinery will also be transported by sea and must be considered in the transportation plan.

(3) Overview of Unloading Jetty

The current status of the pier in the power plant port is as follows.

The unloading jetty constructed by Units 1/2 is a fuel and heavy equipment unloading jetty, a coal unloading jetty, and four temporary jetty. The location of each unloading jetty is shown in Figure 9.4-2.



Remarks: A heavy lift ship is a ship intended to be used for marine transportation of various heavy equipment such as large plant modules, construction machinery, and large pressure vessels. Heavy lift ships can be broadly classified according to the cargo handling method: lift-on/lift-off (LO/LO) vessels that load heavy lifts onto the ship with a large-capacity crane equipped with their own ship, and lift-on/lift-off (LO/LO) vessels that carry heavy lifts on trolleys, etc. It is roughly divided into roll-on/roll-off (RO/RO) methods in which the cargo is moved horizontally and loaded onto the ship via a ramp way.
Source: Study Team

Figure 9.4-2 Location of Unloading Jetty

(a) Coal Unloading Jetty

It is a common facility for Units 1/2 and Units 3/4, and will be used as a dedicated coal unloading jetty after the completion of Units 1/2. The structure allows 80,000DWT class vessels to berth and handle cargo.

Heavy equipment are being unloaded at the time of construction of Units 1/2, but after the operation, it will be a jetty dedicated to coal unloading, so unloading work for construction of Units 3/4 will not be possible.

(b) Fuel/Heavy equipment Unloading Jetty

The area of a part of the heavy equipment unloading jetty constructed in Units 1/2 is about 1,800m^2 (60m x 30m), and the loading capacity is a 600ton class crawler. The structure is designed assuming transportation by a crane (196.20kN/m^2) or a 510ton class transporter vehicle (48.30kN/m^2). The platform has a structure that can withstand a load of 10 t/m^2, assuming transportation by a transporter vehicle. In addition, the seabed in front of the quay is designed to have a depth of MSL-18.0m so that it can be applied to tugboats towing heavy lift ships.

(c) Temporary Jetty

There are two temporary jetty (No.1 and 2) that were constructed as temporary facilities during the construction of Units 1/2.

Since it is expected that the usage will continue to be severe in the future, it will be necessary to inspect, repair, and reinforce the pier before use.

1) No.1 Temporary Jetty

The platform height is MSL+1.3m, there is a 1:15 inclination toward the land side, and the design load is 2t/m2. Barges can land on this jetty and are mainly used for unloading construction materials.

Units 3/4 is planned to receive ammonia. Ammonia for denitration of Units 3/4 will be transported by sea, so it is planned to be used for receiving ammonia. It is planned to transport it to the ammonia storage tank installed near the boiler by the receiving tank truck at jetty.

2) No.2 Temporary Jetty

The platform height is MSL+3.5m, and the design load is 2t/m2.

Units 3/4 is planned to receive limestone. It is assumed that limestone will be imported by ship (about 2,000DWT, ship arrival once every 6 days), and this temporary jetty will be used. Limestone is unloaded from the ship at the unloading jetty by a ship loader and transported by a conveyor belt from the jetty to the limestone storage.

Arrange limestone receiving equipment and limestone receiving conveyors so as not to impair multipurpose functions.

As Units 3/4, limestone will be received and discharged here, and remodeling, expansion, and reinforcement work will be carried out to make it function as a facility for receiving limestone and as a jetty for unloading heavy equipment.

This jetty can also be used for fly ash and gypsum delivery to local industries by small vessel.

3) Additional Temporary Jetty

Based on the transportation amount, additional temporary jetty is necessary to handle/manage material shipments. The candidate locations are west side of Temporary Jetty No.1 or south side of port. It is preferable to construct this additional temporary jetty with similar design condition to Heavy Equipment Unloading Berth.

The location is this additional temporary jetty should be considered and discussed in the execution stage because there are some possibilities that any other equipment/structures for other project will be planned in the future round the port. Therefore, the project coordination about this location should be held continuously and carefully. In the case that CPA works (port extension project) will not be started until Unit 3/4 project start the commercial operation, Temporary Jetty No.3 & No.4 of Unit 1/2 can be used for the ocean transportation of Unit 3/4.

(4) Transportation amount

The outline of the planned unloading amount of heavy equipment assumed based on the transportation simulation and the transportation results of the same scale power plant in Units 1/2 is as follows.

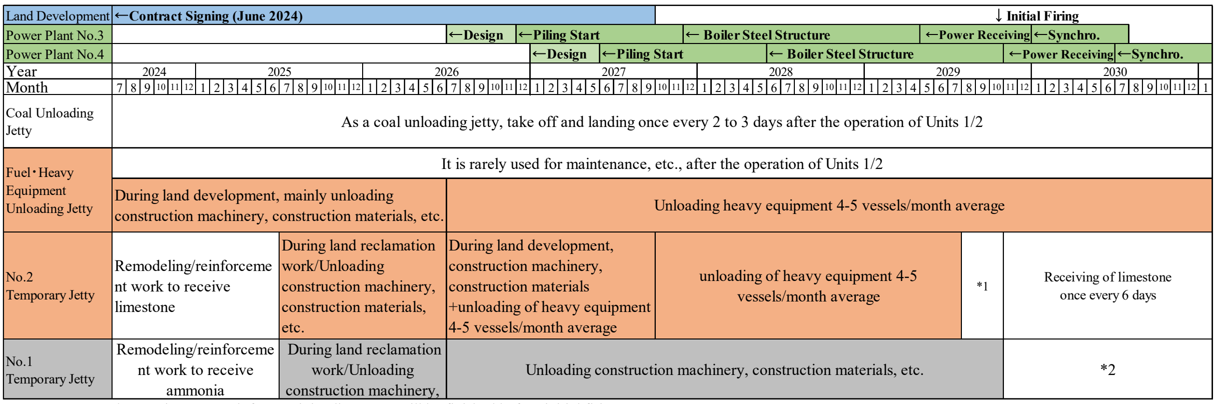
Period: Approximately 2 years from the start of unloading of major equipment
Transport volume per conventional vessel: 4,000 to 5,000 (F/T) on average
Jetty used: Coal Unloading jetty and fuel/heavy equipment unloading jetty

Monthly average number of ships: Approximately 4 to 5 ships / month / each pier
Total number of vessels: Approximately 125

However, this does not include construction materials (concrete, blocks, etc.).
In addition, the situation may change significantly depending on the cargo preparation, cargo shape, and weather.

At the start of construction of Units 3/4, the coal unloading jetty was already dedicated to coal unloading, and it was impossible to unload heavy equipment. If this considerable amount is not borne by other jetty, the transportation volume cannot be processed and ships will be stagnant.

As for No.2 Temporary jetty, it is necessary to remodel the jetty because it is necessary to receive limestone, so it is necessary to plan to improve the function by simultaneously remodeling and reinforcing work for lifting heavy equipment. During the construction period, basic remodeling and reinforcement work will be carried out for about one year from the start of the site development work, and it will be operated as a heavy unloading jetty until 3 months before the initial firing stage. It seems that the stagnation can be avoided by installing the limestone and ammonia receiving equipment before initial firing stage. Figure 9.4-3 shows the usage status of the jetty.



*1: Equipment work for receiving limestone will be finished before initial firing
*2: The frequency of receiving of ammonia depends on the procurement method

Source: Study Team

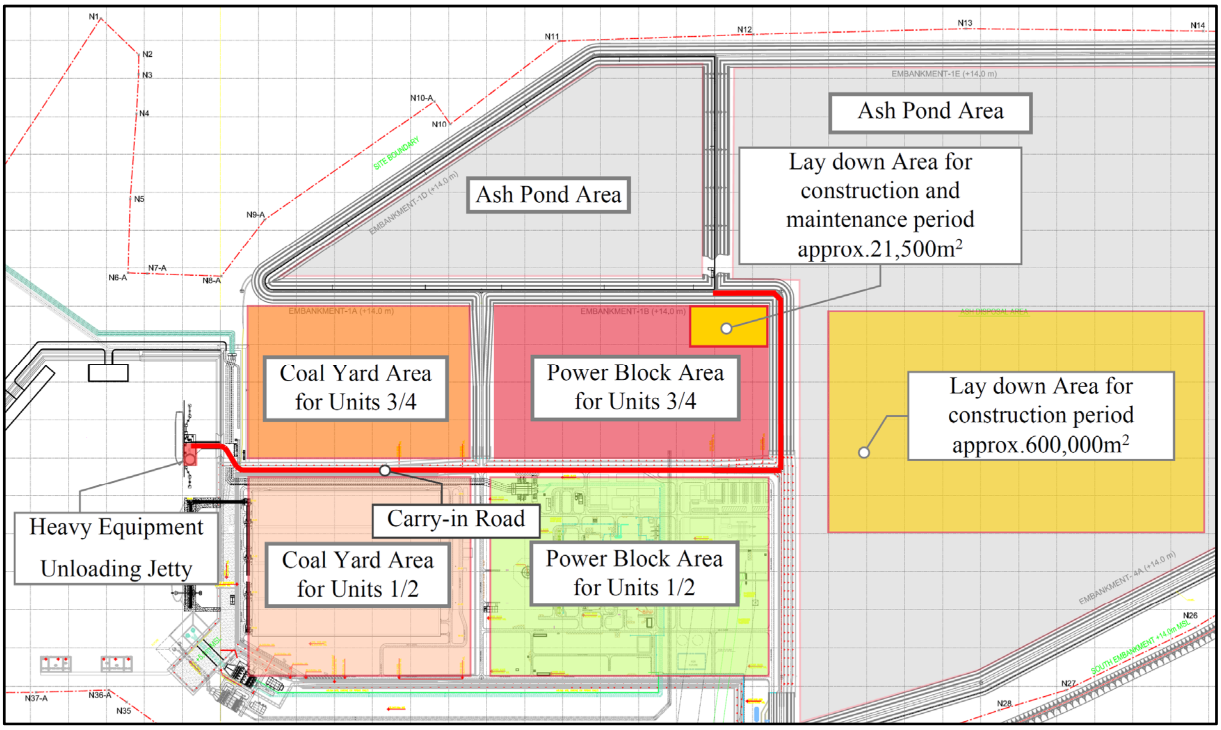
Figure 9.4-3 Usage Status of the Jetty

At the period of construction of Units 3/4, marine transportation of various construction materials and equipment, large ships (coal ship 80,000 DWT) will enter and leave the power plant port, and marine transportation will increase, and construction of an adjacent Coal Transshipment Terminal Project will be carried out. As it begins, there will be further restrictions in the power plant port. Therefore, at the period of construction, it is necessary to simulate the transportation plan of construction materials and equipment in detail, and to carefully consider the transportation plan by large vessels in particular.

(5) Laydown area

In Units 1/2, the laydown area is secured and operated at about 621,500m^2 or more. Therefore, the same scale will be secured for the Units 3/4.

The location of the lay down area is about 21,500m^2 for construction and maintenance period on the north side of the water treatment facility in the power block area, and about 600,000m^2 for construction period on the ash pond across the east side road of the power block area of Units 3/4. The total area is planned to be about 621,500m^2. The location of laydown area is shown in Figure 9.4-4.



Source: Study Team

Figure 9.4-4 Location of Laydown Area and Carry-in Road

Important items such as machinery and electrical equipment will be stored in a temporary warehouse, but others will be stored directly outdoors. Sufficient storage space for materials and equipment is secured to store this large amount of materials and equipment for a long period of time.

In addition, since it rains a lot during the rainy season, if the packed materials and equipment are stored directly on the soil, rust and the like will occur on the equipment, which will cause a problem. Therefore, it is desirable to pave the outdoor equipment storage area by quarrying or laying sleepers so that it does not come into direct contact with the soil.

It is also necessary to systematically transport the materials for the inner cylinder of the stack and the cooling water pipe into the site. Since this material has a large diameter, it requires a considerable area for storage, and there is a risk that the material and equipment for mechanical and electrical work will be carried in at the same time.

As for the carry-in road for large materials and equipment to be unloaded by sea, a straight east-west carry-in road is planned on the south side of Units 3/4 coal storage yard and the power block area.

This large equipment carry-in road intersects the coal receiving conveyor, coal dispensing conveyor (2 lines), intake channel, high-voltage cable, etc. from Units 1/2 on the way, but they should be underground or overhead. It is designed so that it will not interfere with the transportation of large materials and equipment along the carry-in road. The carry-in road is shown in Figure 9.4-4.

Chapter 10 Project Implementation Schedule

10.1 General

In this chapter, the project implementation schedule is discussed based on the assumption that the yen loan for this Project will be signed in April 2022.

10.2 Implementation Plan

In a yen loan project, the following procedures and tasks need to be carried out from the signing of the yen loan until the completion of the project.

10.2.1 Project DPP (Development Project Proposal) Process

Since the project DPP should be approved by GoB for the implementation of the project and project DPP process will be started after the signing of the yen loan, this period is considered in the project implementation schedule.

10.2.2 Consultant Selection

The consultant selection is required for ensuring smooth execution and completion of the project. Normally, the Consultant is selected through an international bidding process conducted by CPGCBL, and the contract period between CPGCBL and the Consultant is until the defect liability period and supplemental.

10.2.3 Phase I (Pre-construction stage)

Phase I is the period from the commencement date of the Consultant's work to the contract signing between CPGCBL and EPC Contractor. Since EPC Contractor is usually selected through international bidding, the preparation for international bidding document, international bidding, technical and financial evaluations of the bid document, contract negotiations, and contract signing between CPGCBL and EPC Contractor are conducted during this period. The various reports to be prepared at each stage should be approved by JICA.

The main tasks to be supported by the Consultant to the CPGCBL in Phase I are as follows.

(1) Site survey, collecting data and review of this preparatory survey report
(2) Conduct sufficient engineering surveys (if required)
(3) Estimate the project cost while taking into consideration of the quantity of work, key engineering solutions, reasonable time frames, and any other factors that impact cost
(4) Preparation of basic design report
(5) Preparation of pre-qualification (PQ) document
(6) Announcement of PQ document
(7) Evaluation of PQ proposal submitted by applicants
(8) Preparation of bidding document
(9) Announcement of bidding document
(10) Technical and financial evaluation of the bid document submitted by the bidders
(11) Contract negotiation with prospective bidder
(12) Contract signing between CPGCBL and EPC Contractor

10.2.4 Phase II (Construction stage)

Phase II is the period from the commencement date of the EPC Contractor's work to the end of the defect liability period, and the main tasks to be supported by Consultant to the CPGCBL in Phase II are as follows.

(1) Check, review and approve design documents, drawing and calculation sheets submitted by EPC Contractor with the consent of CPGCBL
(2) Participation in design meeting

(3) Construction schedule management
(4) Construction supervision
(5) Quality control
(6) Witness of factory tests
(7) Witness of commissioning
(8) Witness of performance test
(9) Preparation of various certificates such as operational acceptance certificate
(10) Correspondence during defect liability period

10.2.5 LTSA (Long Term Service Agreement)

If any failure occurs in the operation of the power plant due to the EPC contractor's fault during defect liability period, the EPC contractor should take action without charge.

After the defect liability period, CPGCBL will decide about LTSA by analyzing the scope and cost of LTSA. If CPGCBL wishes to do LTSA, CPGCBL will enter into a LTSA with the service provider to ensure high availability and reliability of the power plant, efficient operation of the facilities, and optimization of maintenance costs. In addition, CPGCBL will be able to receive comprehensive services to meet its various needs, such as long term management of equipment, planning of periodic inspection, supply and repair of equipment, dispatch of technical advisor, and operation support by the remote monitoring center.

It is customary that LTSA are not included in Yen loan projects. Therefore, LTSA will be negotiated between CPGCBL and the service provider during the project implementation period, and the consultant will support CPGCBL.

As an example, the equipment to be included in the LTSA for coal fired power plant are as follows.

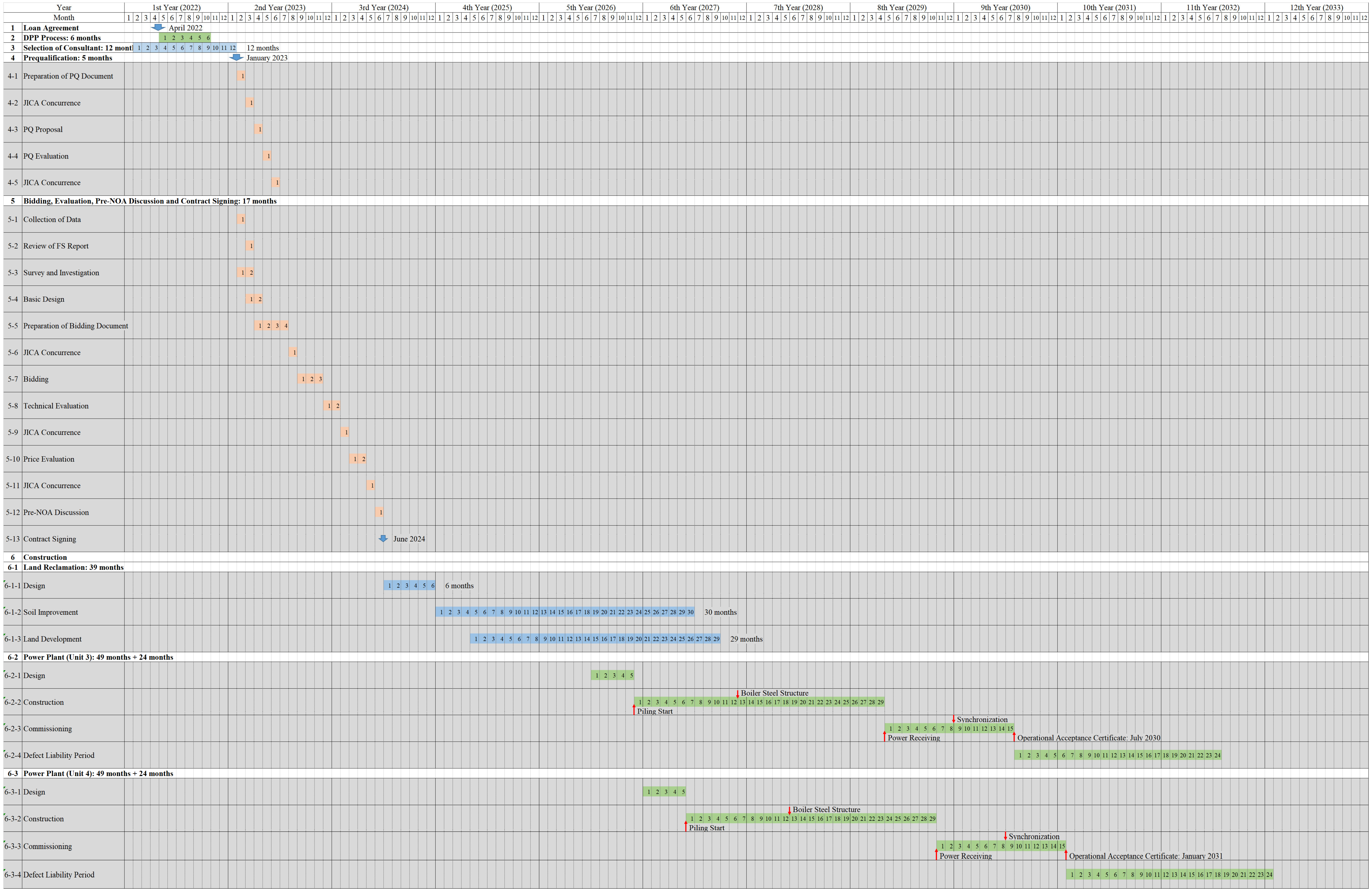
(1) Supply of replacement equipment (boiler tubes, pulverized coal burners, mill rollers, air heater elements, shaft seals for turbines, boiler feed water pumps, etc.)
(2) Dispatch of technical advisor
(3) Defect response
(4) Training
(5) Operation data analysis
(6) Remote monitoring

10.3 Expected Project Implementation Schedule

Figure 10.3-1 shows the expected project implementation schedule in case the procedures and tasks in Sections 10.2.1 through 10.2.4 are implemented. The timing of implementation of the main procedures and tasks is as follows.

The expected project implementation schedule will be finalized during JICA appraisal mission.

(1) Signing of yen loan: April 2022
(2) DPP Process: 6 months (May 2022 - October 2022)
(3) Consultant selection: 12 months (February 2022 - January 2023)
(4) Phase I: 17 months (February 2023 - June 2024)
  Announcement of PQ document: April 2023
  Announcement of bidding document: September 2023
(5) Phase II: 79 months (July 2024 - January 2031)
  Civil engineering: July 2024 -
  Soil improvement (if necessary): January 2025 -
  Site development (from MSL+4.0m): May 2025 -
  Piling for power plant (Unit 3 / Unit 4): December 2026 - / June 2027 -
  Commissioning (Unit 3 / Unit 4): May 2029 - / November 2029 -
  Operational Acceptance Certificate (Unit 3 / Unit 4): July 2030 / January 2031
  End of defect liability period (Unit 3 / Unit 4): July 2032 / January 2033



Source: Study Team

Figure 10.3-1 Expected Project Implementation Schedule

10.4 Study for shorten Project Implementation Schedule

10.4.1 Possibility of direct contract

[Confidential Information]

Chapter 11 Implementation Plan for Consulting Services

11.1 Terms of Reference (TOR)

[Confidential Information]

11.2 Required Description based on "Consultant Employment Guidelines" (April 2012) (Required of JICA)

When employing the consultant, CPGCBL shall follow the selection procedure and contract according to "Chapter 1: Guidelines for the Employment of Consultants under Japanese ODA Loans" in the "Handbook for The Employment of Consultants & Procurement of Goods and Services" issued by JICA in April 2012.

Regarding the selection method of consultants, it is assumed that the method described in Section 3.02 (2) of the above guideline (QCBS: selection based on quality and cost) will be selected.

11.3 Scale of business provided (MM)

11.3.1 Work Scale

[Confidential Information]

11.3.2 Requirement (criteria) for the Consultant

[Confidential Information]

11.4 Cost Breakdown

[Confidential Information]

Chapter 12 Project Implementation and Management System

12.1 Project Implementing Organization

12.1.1 Functions of each organization related to this project and their role in this project

(1) CPGCBL (Coal Power Generation Company Bangladesh Limited)

During the project implementation period, CPGCBL will be the project execution agency (department) of this project, and will play the role of progress management of construction work, disburse management, etc. After the power plant is completed, it will become an operation and maintenance department.

(2) PGCB (Power Grid Company of Bangladesh Limited)

Transmission company. PGCB will play the role of consigning the electric power generated by the power plant constructed in this project.

The electricity generated by the power plant is stepped up voltage by the main transformer, then sent to the switching equipment, and then sent out of the power plant via the transmission line. PGCB will be in charge of maintenance of the equipment after the switching equipment.

(3) BPDB (Bangladesh Power Development Board)

Power off taker. State-owned enterprise. As a single buyer of electricity in the country, it is responsible for purchasing all the electricity sold by the power plant and then wholesale it to distribution companies in each region.

(4) CPA (Chittagong Port Authority)

The construction permitting department of the port in the Chattogram district. After completion the construction of Matarbari Port, its operation and maintenance will be carried out by Chattogram Port Authority.

12.1.2 Execution agency and O&M organization

The execution agency (department) of this project will be CPGCBL, and PIU (Project Implementation Unit) under CPGCBL will be organized during the project implementation period to manage the construction. After the power plant is completed, the maintenance and operation will be executed by the CPGCBL O&M set-up.

12.1.3 Analysis of Financial Status of Implementing and Relevant Organizations

[Confidential Information]

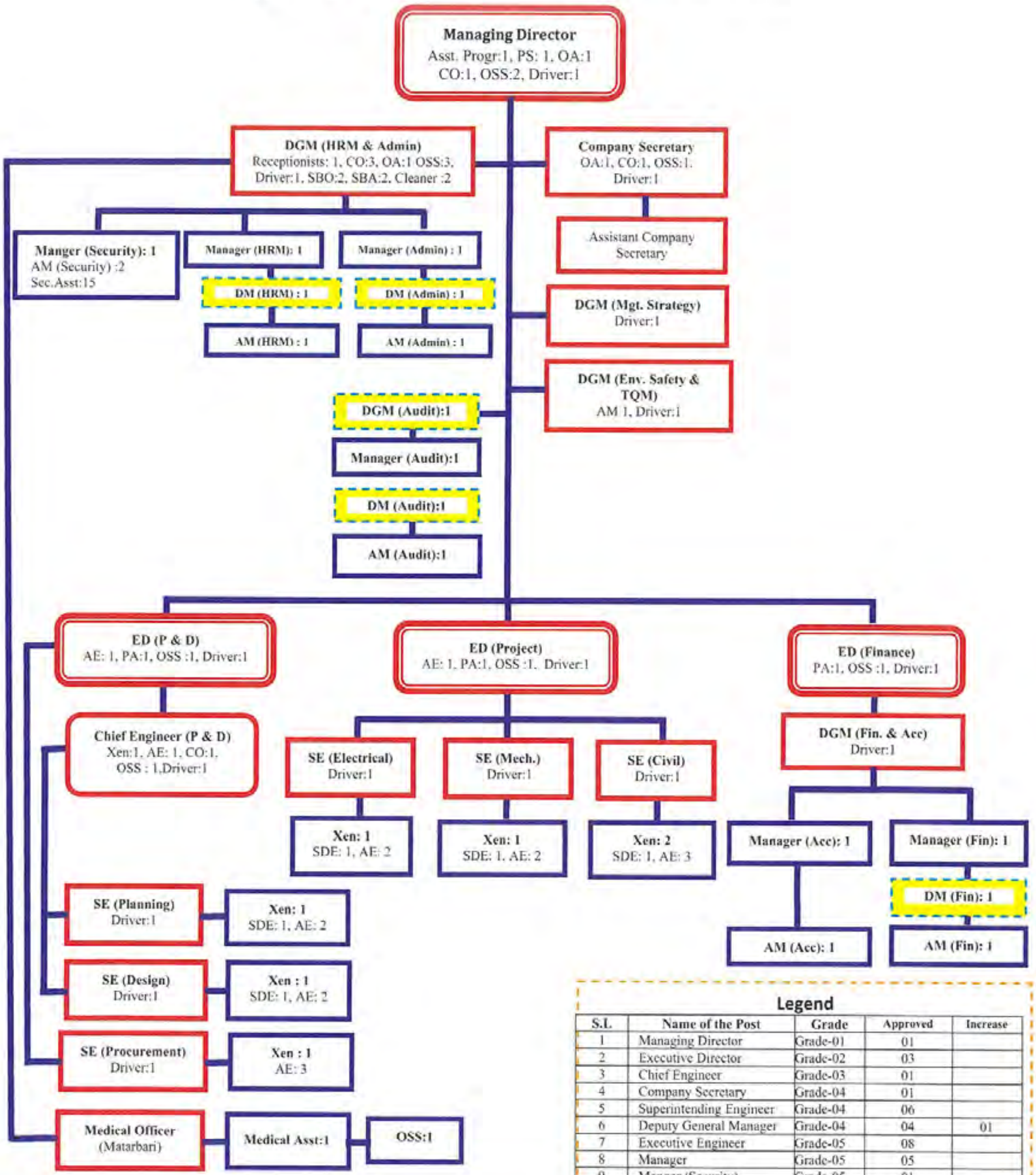
12.1.4 Organizational structure and personnel structure of the execution agency and major Relevant Organizations

(1) CPGCBL

See Figure 12.1-1 for the current headquarters structure of CPGCBL, the execution agency. It is assumed that this system will not change even after the start of Phase 2 Project.

According to CPGCBL's explanation, this structure is a DPP approval matter, and it is not necessary to prepare all personnel immediately.

This structure and the number of personnel are considered to be appropriate considering the current social situation in the country, but in the future, the number of assistant staff, etc. will be reduced or outsourced, so that the cost should aim to be reduced as much as possible.



ED-3	:	P&D-1; Project:-1; Finance-1
SE-6	:	Planing-1; Design:-1; Procurement-1; Elec-1; Mech-1; Civil-1
DGM-5	:	HRM & Admin 1; Mgt & Strategy-1; Env. Safety &TQM-1; Acc & Finance-1; Audt-1
XEN-8	:	Planing-1; Design:-1; Procurement-1; Elec-1; Mech-1; Civil-2; CE-1
Manager-5	:	Admin-1; -HRM-1; -Accounts-1; Finance-1; Audit-1
SDE-5	:	Planing-1; Design:-1; Elec-1; Mech-1; Civil-1;
DM-4	:	Admin-1; -HRM-1; Finance-1; Audit-1
AE-17	:	Planning-2; Desing-2; Procurment-3; Elec-2; Mech-2; Civil-3; CE-1; P&D-1; Project-1
AM-9	:	Admin-1; HRM-1; Account-1; Finance-1; Audit-1; EST-1; ACS-1; AM (Security)-2

Legend

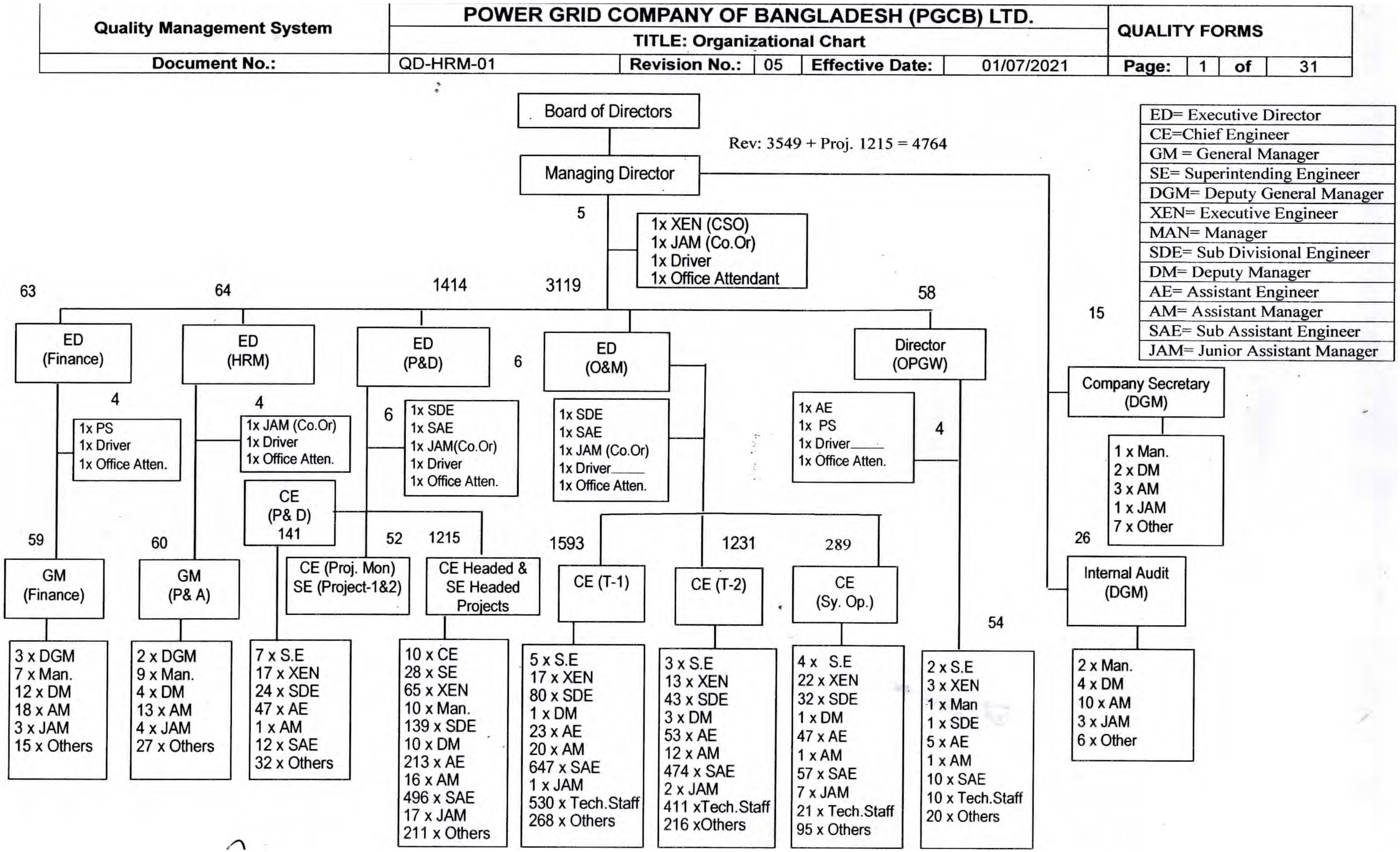
S.L	Name of the Post	Grade	Approved	Increase
1	Managing Director	Grade-01	01	
2	Executive Director	Grade-02	03	
3	Chief Engineer	Grade-03	01	
4	Company Secretary	Grade-04	01	
5	Superintending Engineer	Grade-04	06	
6	Deputy General Manager	Grade-04	04	01
7	Executive Engineer	Grade-05	08	
8	Manager	Grade-05	05	
9	Manger (Security)	Grade-05	01	
10	Sub-Divisional Engineer	Grade-06	05	
11	Deputy Manager	Grade-06	-	04
12	Asst. Manager (Security)	Grade-07	02	
13	Assistant Engineer	Grade-08	17	
14	Assistant Manager	Grade-08	07	
15	Assistant Programmer	Grade-08	01	
16	Personal Secretary	Grade-08	01	
17	Medical officer	Grade-08	01	
18	Medical Assistant	Grade-10	01	
19	Receptionist	Grade-10	01	
20	Personal Assistant	Grade-11	03	
21	Office Assistant	Grade-12	03	
22	Computer Operator	Grade-15	06	
23	Driver	Grade-16	16	
24	Speed Boat Operator	Grade-16	02	
25	Speed Boat Assistant	Grade-19	02	
26	Security Assistant	Grade-19	15	
27	Office Support Staff	Grade-19	11	
28	Cleaner	Grade-20	02	
	Total Strength:		**126**	**05**

Source: CPGCBL

Figure 12.1-1 CPGCBL Headquarters organizational structure and personnel structure

(2) PGCB

See Figure 12.1-2 for the current organizational structure of PGCB.

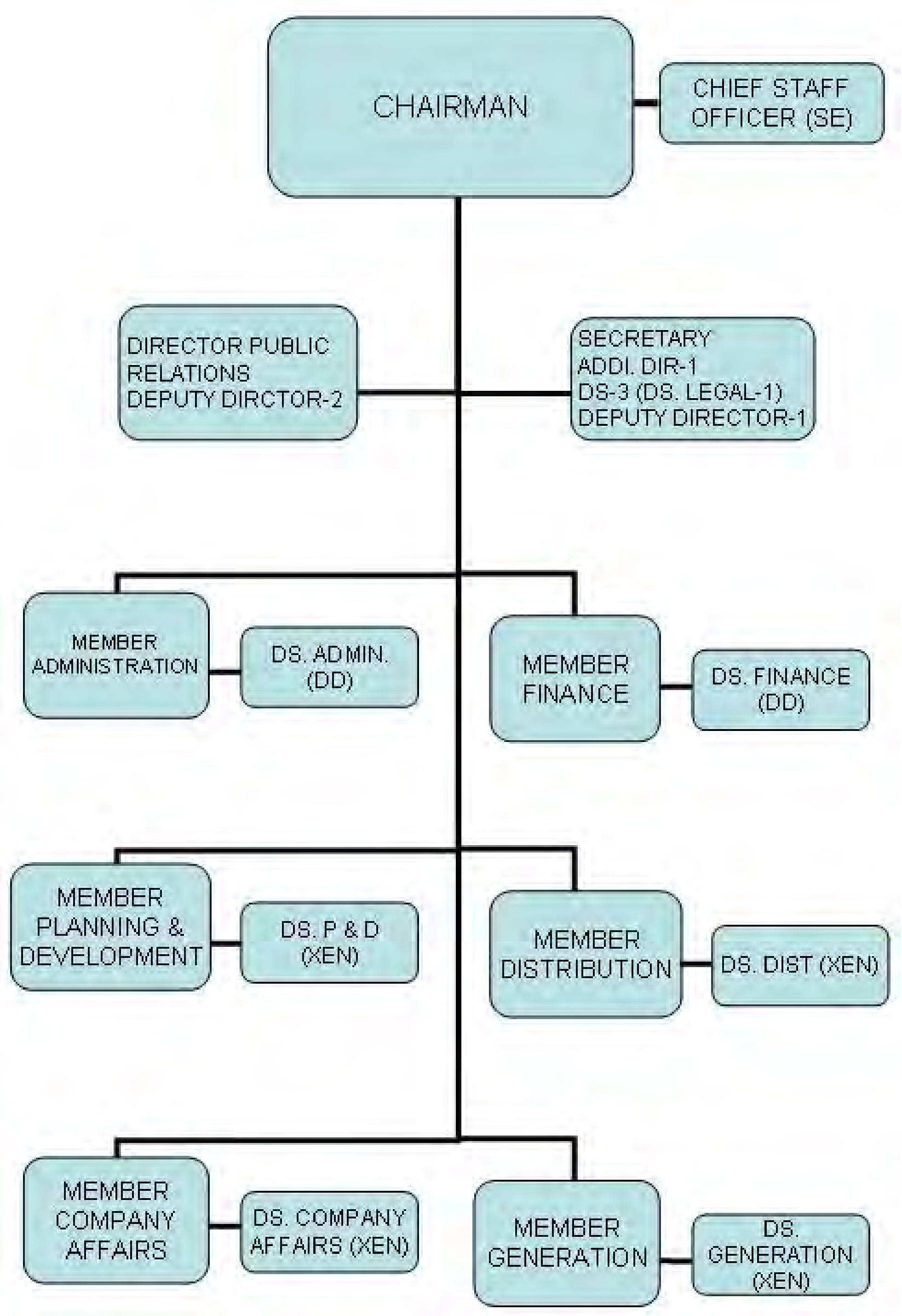


Source: PGCB

Figure 12.1-2 Organizational Structure of PGCB

(3) BPDB

See the figure below for the current organizational structure of BPDB.



Source: BPDB Website

Figure 12.1-3   BPDB organizational structure

12.1.5 Technical level of the implementing organization, experience in similar projects

(1) CPGCBL

CPGCBL does not yet have a completed power generation facility and does not have the means to develop and improve its own technical capabilities. In the future, while learning the equipment through the management of construction work, CPGCBL will proceed with technology transfer from those who have changed jobs from other power generation companies.

The financial capacity of CPGCBL is also unknown because it has not yet earned business income. After starting operation and maintenance after the completion of the power plant, it can be started to acquire know-how on fuel procurement and cost reduction through practice.

(2) PGCB

Twenty-five years have already passed since it was established in 1996, and it is surely that a certain amount of technical and financial capabilities are being accumulated in the company. In the future, it is planned that power generation facilities will be increased to meet the increasing demand for electric power, so the transmission and transformation facilities must be increased accordingly. Under such circumstances, it is important how to create a strong power grid system that is resistant to troubles such as disasters. It becomes a future goal that PGCB necessary to look ahead and make a plan for the expansion of power transmission and transformation equipment, taking into consideration both the growth of the supply side, which is the expansion of power generation facilities, and the growth of demand in each region, so that this can be implemented completely on its own.

There seems to be no major problem with financial capability.

(3) BPDB

Since its establishment in 1972, BPDB has consistently undertaken the business of purchasing electricity generated by power generation companies in bulk and selling it to distribution companies in bulk, further plans to own several power generation facilities as well. However, since it is conceivable to outsource the operation and maintenance of those facilities to other companies, it is considered that the technical capability will not be an issue in that case.

On the other hand, financially, BPDB has sufficient capability by using Government support.

12.1.6 Maintenance costs and sources of income

CPGCBL will bear all maintenance costs after the completion of this project, and the source of income will be covered by sales of electricity generated by No. 1 to 4 power generation units constructed in the Matarbari Phase 1 and Phase 2 projects.

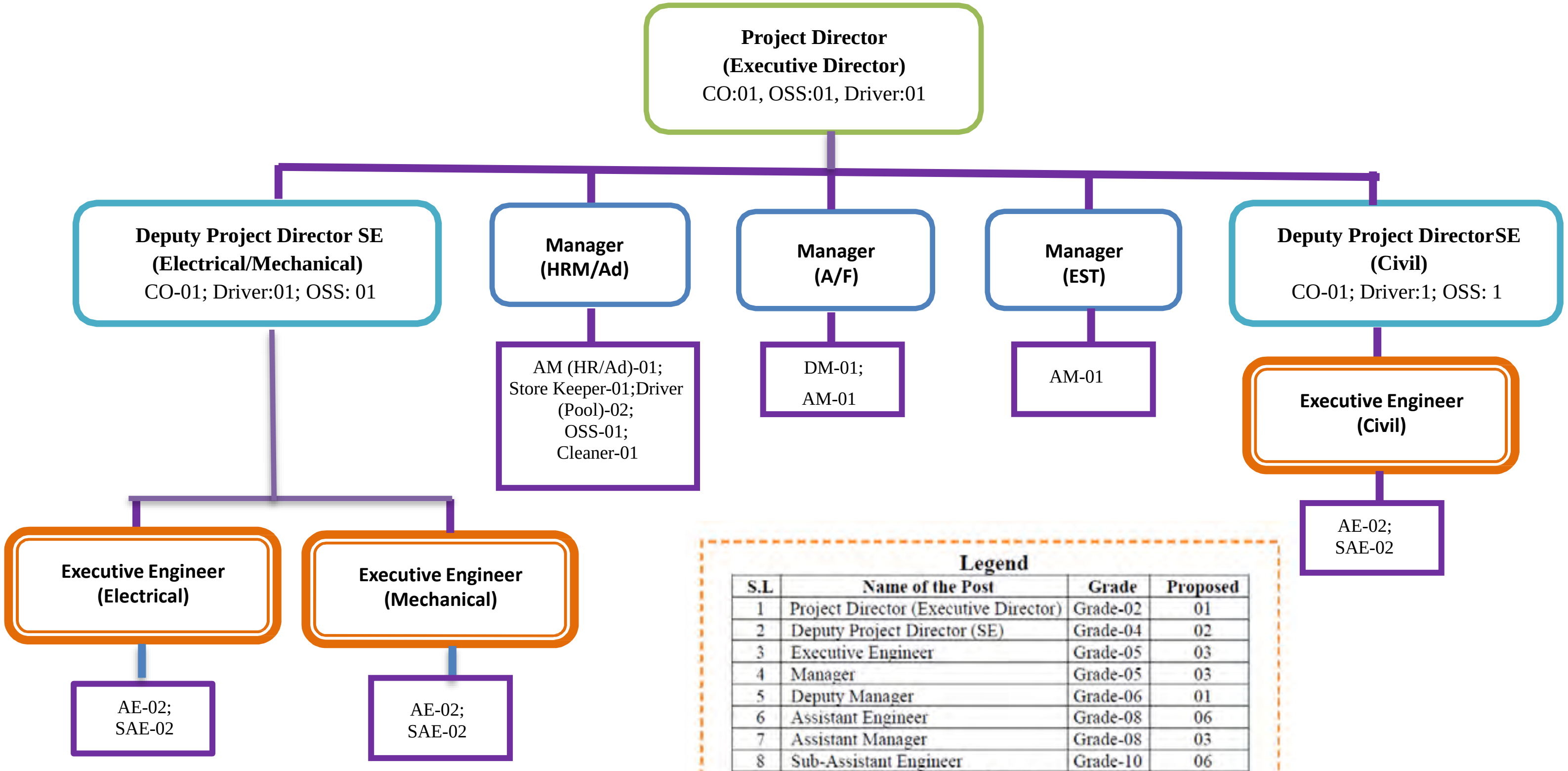
12.2 Project execution agency (department; PIU)

12.2.1 PIU Member structure

Regarding the member structure of PIU that will be organized in CPGCBL when implementing this project, see Figure 12.2-1 for what CPGCBL currently envisions.

CPGCBL considers this PIU to be an organization up to the decision of the main construction contractor, and is considering handing its works over to the implementation department, which will be described later, after the main construction starts. However, actually, it is assumed that PIU members will play a central role in carrying out the project until the start of the commissioning. CPGCBL considers that some members will be doubly assigned by Phase 1 PIU members.

This CPGCBL’s plan can be evaluated as appropriate in general.



Legend

S.L	Name of the Post	Grade	Proposed
1	Project Director (Executive Director)	Grade-02	01
2	Deputy Project Director (SE)	Grade-04	02
3	Executive Engineer	Grade-05	03
4	Manager	Grade-05	03
5	Deputy Manager	Grade-06	01
6	Assistant Engineer	Grade-08	06
7	Assistant Manager	Grade-08	03
8	Sub-Assistant Engineer	Grade-10	06
9	Office Assistant Cum Computer Operator (PD-01; DPD-02)	Grade-12	03
10	Store Keeper	Grade-15	01
11	Driver (PD-01; DPD-02 & Pool-02)	Grade-16	05
12	OSS (PD-01; DPD-02, Manager-01)	Grade-19	04
13	Cleaner	Grade-20	01
		Total Strength	**39**

Source: CPGCBL

Figure 12.2-1 Project Implementation Unit (PIU) of Phase-2 (Units 3/4)

The following is a list of the personnel in the above figure divided into Officer and Staff.

S.L	Name of the Post	Number of Employees	
		Officers*	Staffs**
1	Project Director (Executive Director)	01	
2	Deputy Project Director (SE)	02	
3	Executive Engineer	03	
4	Manager	03	
5	Deputy Manager	01	
6	Assistant Engineer	06	
7	Assistant Manager	03	
8	Sub-Assistant Engineer	06	
9	Office Assistant Cum Computer Operator (PD-01; DPD-02)		03
10	Store Keeper		01
11	Driver (PD-01; DPD-02 & Pool-02)		05
12	OSS (PD-01; DPD-02, Manager-01)		04
13	Cleaner		01
Total (39)		25	14

* Officers includes engineering and non-engineering professions
** Staffs include technicians and non-skilled workers
Source: CPGCBL

12.2.2 Personnel employment plan to achieve the membership of the project executing agency

The recruitment activities for PIU members, which CPGCBL is considering, will be performed initially by giving additional charge to the employees of Corporate Set-Up as well O&M Set-Up (Phase-1). As PIU and O&M Set-Up would need approval of Power Division by inter ministry meeting, the recruitment of employees shall be started after getting concurrence from power division and be finished before commissioning.

12.2.3 TOR, selection method, selection qualification, salary level when hiring people from outside

(1) CPGCBL already established CPGCBL (Employees) Service Rules-2017. In Chapter-III of said Rules, the recruitment and Promotion Policies & Guidelines are settled. CPGCBL (Employee) Service Rules 2017 is shown in Appendix 12.

In the above Rule, TOR and selection qualification is not described in detail. TOR and Selection qualification shall be determined as per Latest CPGCBL (Employees) Service Rules for each post before starting recruitment.

12.2.4 Formulation of training plan for project implementing agency

The training plan for the head office organization is planned to be formulated for the Phase 1 project and submitted to the JICA Bangladesh office.

Know-how regarding the procurement of coal as fuel, limestone, ammonia, etc. which are necessary for continuation of operation, and the sale of gypsum and coal ash, etc. can be acquired by OJT from a consultant whom CPGCBL is considering employment in Phase 1.
Limestone and gypsum are the items that are not handled in Phase 1, but the procurement and sale destinations are considered to be cement companies that are assumed to sell coal ash, so negotiations with the same company will be considered desirable. Therefore, it is considered unnecessary to acquire the know-how from the consultant further.

12.3 Operation / Maintenance Department (Power Plant)

12.3.1 Power plant membership

The operation and maintenance organizations for Phase 1 and Phase 2 of the Matarbari Thermal Power Plant, which CPGCBL considers, are as shown in Figure 12.3-1 and Figure 12.3-2 (Phase 2 is for the increased number of staff).

Comparing Phase 1 and Phase 2, it can be seen that the number of personnel in Phase 2 is slightly suppressed compared to Phase 1.

These systems and the number of personnel are considered to be in a reasonable category considering the current situation in the country, but in the future, the number of assistant staff etc. will be reduced in order to reduce costs as much as possible. It is considered necessary to outsource.

ORGANOGRAM FOR OPERATION & MAINTENANCE (O&M) OF MATARBARI 2x600 M.W ULTRA SUPER CRITICAL COAL FIRED POWER PLANT

Chief Engineer-01

01	Assistant Chief Engineer (X.EN)	1
02	Manager (Accounts & Finance)	1
03	Manager (Admin)	1
04	Deputy Manager Labor Welfare & Admin	1
05	Deputy Manager (State & Transport)	1
06	Deputy Manager (A/F)	1
07	Asst Manager (Labor Welfare, Admin & Transport)	2
08	Personal Assistant	1
09	Front Desk Staff	1
10	Office Asst. Cum-Computer Operator	2
11	SAA (Cashier)	1
12	Driver	2
13	Driver**	16
14	OSS	3
	Total	34

Operation		
01	Superintending Engineer	1
02	Assistant Manager (Accounts/Finance)	1
03	Assistant Manager (Admin)	1
04	Personal Assistant	1
05	Office Asst. Cum-Computer Operator	2
06	SAA (Cashier)	1
07	Driver	1
08	OSS	1
	Total	09

01	Chief Chemist	1
02	Chemist	4
03	Lab-Technician	4
04	Sampler	4
05	OSS	4
	Total	17

Security Unit		
01	Security Officer	1
02	Assistant Security Officer	2
03	Security Assistant	15
04	OSS	1
05	Fire Fighting Operator	4
06	Fire Fighting Helper	4
	Total	27

Audit		
01	Manager	1
02	Deputy Manager	2
03	Assy. Manager	2
	Total	05

Fuel Procurement		
01	Superintending Engineer	1
02	Executive Engineer	2
03	SDE	2
04	Asst. Engineer-Quality Control	2
05	Asst. Manager-Quality Control	2
06	Quality Inspector	2
07	Driver	1
	Total	12

Waste Management (Plant)		
01	Executive Engineer	1
02	SDE	2
03	Assistant Engineer	2
04	Technician	4
	Total	09

Environment, Safety & TQM		
01	Manager	1
02	Deputy Manager	2
03	Asst. Manager	2
	Total	05

ICT Department		
01	System Analyst	1
02	Programmer	1
03	Asst. Programmer	2
	Total	04

Maintenance		
01	Superintending Engineer	1
02	Assistant Manager (Accounts/Finance)	1
03	Assistant Manager (Admin/HR)	1
04	Personal Assistant	1
05	Office Asst. Cum-Com. Operator	2
06	SAA (Cashier)	1
07	Driver	1
08	OSS	1
	Total	09

01	Manager (Store)	1
02	Deputy Manager (Store)	1
03	Asst. Manager (Store)	2
04	Store Keeper	4
05	Helper	4
06	OSS	1
	Total	13

Executive Engineer (Fuel & Ash Management)		
01	Executive Engineer	1
02	Sub-Divisional Engineer	2
03	Asst. Engineer	2
04	Control Room Operator (AE)- Fuel	4
05	Sub-Assistant Engineer (Conv. Belt)	8
06	Reclaimer Operator	4
07	Bull Dozer Operator	4
08	Pay Loader Operator	4
09	Dump Truck Operator	4
10	Excavator Operator	4
11	Work Assistant	4
12	OSS	4
	Total	45

Executive Engineer (Operation Plant)		
01	Executive Engineer	2
02	Sub-Divisional Engineer	4
03	Plant Operator (AE)-Boiler	4
04	Plant Operator (AE)-Turbine & Generator	4
05	Sub-Assistant Engr. (Boiler & Auxiliaries)	4
06	Sub-Assistant Engr. (Turbine & Generator)	4
07	Work Assistant	8
08	OSS	4
	Total	34

Executive Engineer (I &C)		
01	Executive Engineer	1
02	Sub-Divisional Engineer	2
03	Asst. Engineer	4
04	Instrument Mechanics	8
05	Work Assistant	8
06	OSS	1
	Total	24

Executive Engineer (Fuel & Ash Maintenance)		
01	Executive Engineer	1
02	Sub-Divisional Engineer	2
03	Asst. Engineer	2
04	Sub-Asst. Engineer	2
05	Foreman	2
06	Work Assistant	5
07	Fitter	4
08	Welder	1
09	OSS	1
	Total	20

Executive Engineer (Electrical Maintenance)		
01	Executive Engineer	1
02	Sub-Divisional Engineer	3
03	Asst. Engineer	6
04	Sub-Asst. Engineer	6
05	Foreman	6
06	Electrician	12
07	Armature Winder	1
08	Work Assistant	12
09	OSS	1
	Total	48

Executive Engineer (Workshop)		
01	Executive Engineer	1
02	Sub-Divisional Engineer	2
03	Asst. Engineer	2
04	Crane Operator	2
05	Foreman	2
06	Welder	4
07	Work Assistant	4
08	Auto mechanics	2
09	Auto Electrician	2
10	Mechanist	4
11	Fork Lift Operator	2
12	OSS	1
	Total	28

Executive Engineer (Turbine Maintenance)		
01	Executive Engineer	1
02	Sub-Divisional Engineer	2
03	Asst. Engineer	2
04	Sub-Asst. Engineer	2
05	Foreman	2
06	Fitter	6
07	Work Assistant	6
08	Welder	2
09	OSS	1
	Total	24

Executive Engineer (Boiler Maintenance)		
01	Executive Engineer	1
02	Sub-Divisional Engineer	2
03	Asst. Engineer	2
04	Sub-Asst. Engineer	2
05	Foreman	2
06	Fitter	6
07	Work Assistant	6
08	Welder	4
09	OSS	1
	Total	26

Executive Engineer (Civil)		
01	Executive Engineer	1
02	Asst. Engineer	3
03	Electrician	2
04	Foreman	1
05	Mason	2
06	Cook	4
07	Cook Helper	4
08	Work Assistant	4
09	OSS	1
10	Care Taker	2
11	Carpenter	2
12	Plumber	2
13	Pump Operator	4
14	Gardener	3
15	Cleaner/Sweeper	15
	Total	50

TRANSPORTS		
01	Jeep	05
02	Micro Bus	02
03	Mobile Crane	02
04	Trucks	02
05	Double Cabin Pick-up	05
06	Motor Cycle	20
07	Ambulance	02
08	Fire Service Vehicle	02
09	Car	03

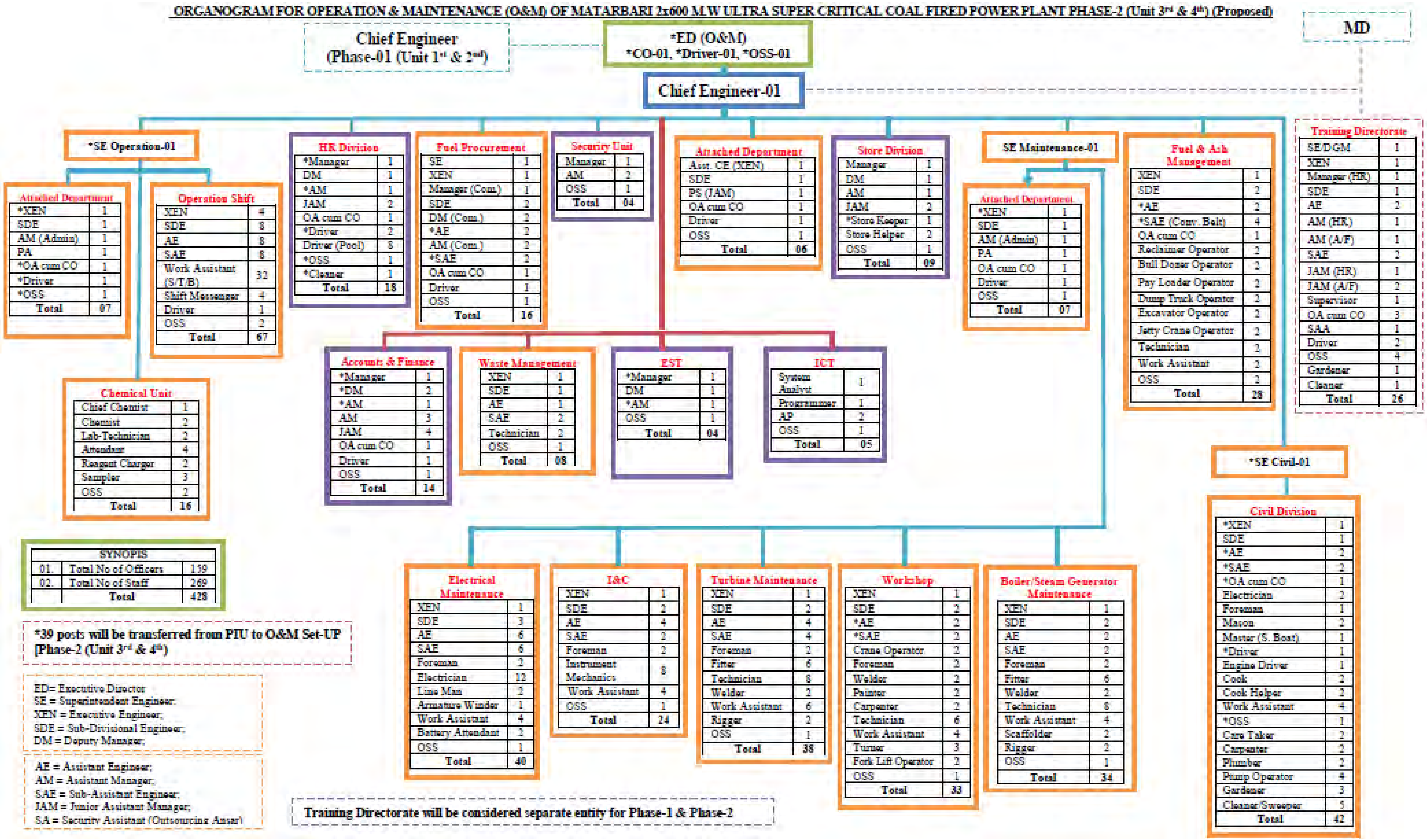
**Driver- For Transportation Pool

SYNOPIS		
01	Total No of Officers	149
02	Total No of Staff	295
	Total	444

Grade	No of Post	Grade	No of Post	Grade	No of Post
Grade-3	01	Grade-9	-	Grade-15	07
Grade-4	03	Grade-10	30	Grade-16	21
Grade-5	22	Grade-11	0	Grade-17	0
Grade-6	32	Grade-12	10	Grade-18	32
Grade-7	02	Grade-13	0	Grade-19	190
Grade-8	59	Grade-14	0	Grade-20	35

Source: CPGCBL

Figure 12.3-1 CPGCBL Matarbari Thermal Power Plant (Phase 1) Organogram



Source: CPGCBL

Figure 12.3-2 CPGCBL Matarbari Thermal Power Plant (Phase 2) Organogram

The following is a list of the personnel in the above figure divided into Officer and Staff. This personnel also includes personnel who will continue to be in charge of operations from PIU.

Table: Number of Employees at the time of project completion

Group Name	The Phase -1 Project (As of July 2024)		The Phase-2 Project (As of July 2031)		Total (Phase-1&2) (As of July 2031)	
	Officers	Staffs	Officers	Staffs	Officers	Staffs
Executive Director (O&M)	0	0	1	3	1	3
Chief Engineer (CE)	1	0	1	0	2	0
Attached Department (CE)	1	26	3	3	4	29
Superintendent Engineer (Operation)	1	0	1	0	2	0
Attached Department SE (Operation)	2	6	3	4	5	10
Operation Shift	22	12	28	39	50	51
Chemical Unit	5	12	3	13	8	25
HR Division	5	0	5	13	10	13
Fuel Procurement	11	1	13	3	24	4
Security Unit	3	24	3	1	6	25
Store Division	4	9	5	4	9	13
Superintendent Engineer (Maintenance)	1	0	1	0	2	0
Attached Department SE (Maintenance)	2	6	3	4	5	10
Fuel & Ash Management	24	41	9	19	33	60
Accounts & Finance Division	2	0	11	3	13	3
Waste Management	5	4	5	3	10	7
Environment, Safety & TQM (EST)	5	0	3	1	8	1
Information & Communication Technology (ICT)	4	0	4	1	8	1
Electrical Maintenance	16	32	16	24	32	56
Instrumentation & Control (I&C)	7	17	9	15	16	32
Turbine Maintenance	7	17	11	27	18	44
Workshop	5	23	7	26	12	49
Boiler/Steam Generator Maintenance	7	19	7	27	14	46
Superintendent Engineer (Civil)	0	0	1	0	1	0
Civil Division	4	46	6	36	10	82
Audit Division	5	0	0	0	5	0
Total	149	295	159	269	308	564

Source: CPGCBL

12.3.2 Personnel employment plan to achieve power plant membership

According to CPGCBL's explanation, the plan for the member composition of the power plant, including PIU, needs to be included in the DPP and approved by Power Division by inter ministry meeting.

After the DPP, which includes the personnel composition plan, is approved and get concurrence of Power Division for employee Set-Up of Phase 2, CPGCBL will prepare a personnel employment plan for the next fiscal year by the end of the previous fiscal year and submit it to the JICA Bangladesh office.

According to the CPGCBL plan, the work of the power plant members will start from the design approval and construction supervision of the EPC contract, so if that is the case, it needs to ensure proper employment of members by the start of the EPC contract.

However, as an exception, it is not necessary to finish employment of members specializing in operation and maintenance by that time. It is enough to employ them until much later stage. If CPGCBL does not plan prior on-the-job training in the other plants, the employment of members specializing in operation and maintenance shall be completed before the start of the commissioning test.

12.3.3 TOR, selection method, selection qualification, salary level when hiring people from outside

It is assumed that it conforms to Clause 12.2.3.

12.3.4 Formulation of training plan for operation / maintenance department (power plant)

(1) CPGCBL will establish the "CPGCBL Training Center" in consultation with consultants and contractors, 1) development of technical training programs for projects for CPGCBL staff, 2) of power plants prepared by contractors during the construction period. It is responsible for maintaining the O & M technical manual and 3) providing appropriate technical training / transferring the above knowledge to CPGCBL staff and outsourced contractors.

(2) In particular, knowledge of design, construction methods and O & M methods shall be appropriately transferred to CPGCBL staff during the project. The key CPGCBL personnel will firstly receive training (TOT) for trainers from consultants and contractors, and then these key personnel will train other CPGCBL personnel.

(3) CPGCBL will implement a comprehensive training plan for operation and maintenance staff with the support of consultants and contractors. CPGCBL has access to appropriate training facilities for plant engineering, operation / maintenance, human resources management (HRM), accounting / finance / audit and environment, safety and TQM (EST) according to the schedule below prior to commissioning. It is expected that approx. 72 personnel will get the training at contractor's or subcontractor's facility.

Item	Person	Training Days	Staying Days	Remarks
Steam Generator	12	60	90	Training Schedule will be shared latter and any course may be combined with any of the batches subject to the approval of the Employer
Steam Turbine and Generator	12	60	90	
Material Handling	12	60	90	
General & Balance of the Power Plant	12	60	90	
Instrumentation and Control (I&C) and Electrical	12	60	90	
Human Resource Management (HRM)	4	20	30	
Accounts/Finance/Audit	4	20	30	
Environment, Safety & TQM (EST)	4	20	30	
Total	72	360	540	

Source: CPGCBL

The cost of the above training is included in the contract amount estimation. The number of people to be trained and the number of days will eventually be negotiated with the contractor, but if the training can be carried out for such a sufficient number of days, it will be a very valuable learning place for CPGCBL operation and maintenance personnel. It is considered that at least 20 days are required for training, so the above number of days is considered to be sufficient.

CPGCBL also plans to provide on-the-job training to on-site engineers during the construction phase. In addition, CPGCBL has stated that it will provide training to its staff in the country. CPGCBL will submit the training plan to JICA after it is formulated. If these opportunities can be realized, it will contribute to the technical mastery of the staff.

The specific content of the training was proposed in Phase 1 FS Final Report 13.3.2. It is considered that a training plan for Phase 1 operation and maintenance personnel is still being formulated according to the contents of the above FS Report. Because, basically, the training content for the operation and maintenance personnel in Phase 2 is considered to be almost the same as that in Phase 1, so a part of it is excerpted and reprinted below.

"13.3.2 Training Method for Power Plant personnel"

(1) Cultivation of O&M staff during the period of construction work

The training of O&M staff during the period of construction work can be established by deploying the candidates of leaders who will become the key men of the operation department and maintenance department of the power plant after starting the operations of the power plant into corresponding division to learn the required specialized technology.

(2) Training in Coal Operation Management and Environmental Management staff

It is necessary to train the personnel in not only plant operations and maintenance but also provide training in the area of coal operations and environmental management after commercial operations. Although there are plans to outsource the management of coal operations and environmental management, personnel who will superintend and deal with the outsourcing companies will be needed. The necessary skills need to be acquired by dispatching a candidate to other coal-fired power plants prior to plant commercial operations.

(3) New employee training

In the future implementation of power plant O&M, new employee training is an important factor to achieve stable operations. The necessary ability of having new employees acquire the necessary technological skills is so that they can handle basic power plant operations. The targets are shown as follows.

- Having a sense of responsibility and understanding the disciplinary rules as a company member
- Understanding the related laws and manuals for power plant operations and maintenance, and carrying out the actual operations according to the laws and manuals
- Understanding the safety rules and safety operations of the power plant

The one year new employee training schedule is proposed in the following table.

"Table 13.3-1 New employee training schedule"

month	1	2	3	4	5	6	7	8	9	10	11	12
Class room training												
Day shift training												
Night shift training												
Comprehensive training												
Operating simulator training												

Source: Bangladesh Chittagong Coal-Fired Power Plant Construction Project Preparation Survey Report

Basically, the staffs who have experience working in overseas plants for a long period of time will serve as instructors. A resident technical instructor from a manufacturer will also be hired if needed.

(4) Adoption of a Recognition System

Measures in which a certain level is set according to the level of acquired technology that is linked to a wage scale is desirable. It is also required to implement measures to avoid the loss of the staff who have acquired the required skills to IPPs whose wage standard is higher by establishing a system where a staff who has acquired the same level of skill as a technical instructor from a manufacturer are given a title like Meister in Germany and an appropriate wage.

"Table 13.3-2 Operator Training Pattern"

<table>
<tr><th>Qualification</th><th>New employee</th><th>Class I</th><th>Class II</th><th>Class III</th><th>Class IV</th><th>Class V</th><th>Class VI</th></tr>
<tr><td>Business experience</td><td>1 year</td><td>1-2 years</td><td>1-2 years</td><td>2-3 years</td><td>2-3 years</td><td>2-3 years</td><td></td></tr>
<tr><td>Skill level</td><td colspan="3">Worker</td><td colspan="2">Engineer
Vice Chief Engineer</td><td>Chief Engineer</td><td>Master</td></tr>
<tr><td>Curriculum</td><td>✓ Induction training (three months)</td><td colspan="4">✓ An examination is taken once during the 1-2 years business</td><td colspan="2">✓ They are responsible for</td></tr>
</table>

	✓ OJT (ten months) ✓ Promotion examination (once every year)	experience mentioned, and if passed, the candidate will be promoted to the 2nd class. ✓ Those with excellent results will be directly promoted to 3rd class ✓ A skill level contest will also be held once a year, and those who obtain excellent results will get a rise in their salary	the junior staff training. ✓ They should arrange to have the trainers receive training.
Penalty	✓ If the examination is failed 3 times in succession, the candidate will be retired from the course.	✓ Staff demonstrating remarkably inferior skills will be demoted.	

Source: Bangladesh Chittagong Coal-Fired Power Plant Construction Project Preparation Survey Report

"13.3.3 Operator Training"

(1) New employee operator training

The schedule of new employees' operator training is described in the previous section. Furthermore, the contents of new employees operator training are shown in the following table.

Table 13.3-3 Contents of new employees operator training

Training	Term	content
Class room training	2 months	✓ Company Policy ✓ Related laws and manuals for operation ✓ Safety education ✓ Basic electrical and mechanical knowledge ✓ Mechanism of the coal-fired power plant
Day shift training	4 months +2 month	✓ Safety training ✓ Feature of coal-fired power plant operation ✓ Work contents of coal-fired power plant ✓ Main system mechanism and layout ✓ Point of drawing and measurement equipment ✓ Point of patrol and manipulation method ✓ Checking point and method of main equipment
Night shift training	3 months	✓ Emergency contact and evacuate system ✓ Method used for tool and measuring instrument ✓ Method of starting and stopping for auxiliary machine ✓ Method of periodical inspection ✓ Emergency operation in case of minor trouble ✓ Security system in power plant
Comprehensive training	1 month	✓ Theme selection of priority issue solving activities ✓ Accident case examination ✓ Basic knowledge of environmental measure
Operating simulator training	2 month	✓ Basic operation training ✓ Emergency operation in case of minor trouble ✓ Priority issue solving activities

Source: Bangladesh Chittagong Coal-Fired Power Plant Construction Project Preparation Survey Report

(2) Turbine operator training

The trainee first joins a duty team; desk training on the following items is mainly performed as the training for a turbine operator. The trainee is made a sub operator in the power plant operation, and is then promoted to operator within a fixed period.

・Circulating water equipment
・Heater
・Deaerator

・Feed water pump

(3) Boiler operator training

While a boiler operator is undergoing training, the trainee joins a duty team similar to that of the turbine operator training and undergoes primarily desk training of the following items. The trainee is made a sub operator in the power plant operation and in particular, undergoes boiler-related valve training, then is promoted to operator within a fixed period.

・Ash handling equipment
・Mill equipment
・Air pre-heater equipment
・Soot blower equipment
・Coal feeder and others

(4) Senior operator

Through five year's work experience as an operator, the operator then conducts the technical generalization of the work of newcomer subordinates as a senior operator, in addition to determining technical matters, judgment, etc. and labor safety as the leader of an operation shift group.

"Table 13.3-4 Operator Training Pattern"

Training candidate	Training items and course	Training period
Sub operator（New employee）	The new employee basic training Basic operator training	1 year
Sub turbine operator	Sub turbine operator training Sub turbine operator work (OJT)	1-2 years
Sub boiler operator	Sub boiler operator training Sub boiler operator work (OJT)	1-2 years
Turbine operator	Turbine simulator application training Turbine operator work (OJT)	2-3 years
Boiler operator	Boiler simulator application training Boiler operator work (OJT)	2-3 years
Senior operator	Accident operation and instruction training Turbine/Boiler operator work (OJT)	2-3 years

Source: Bangladesh Chittagong Coal-Fired Power Plant Construction Project Preparation Survey Report

(5) Accident restoration training

Training to enhance judgment capacity in an emergency and operation skill in the event of an emergency is an essential factor in stable power plant operations not only for new employees but also for senior staff. During these days, a few manual restoration operations took place at the latest power plant due to the automation of the power plant system. Because of that, it is difficult to conduct accident restoration training using an actual system.

Therefore, it is necessary to train with a team using a simulator to make up for emergency operations using the actual system. The following table shows some examples of simulator training and the concept of simulator design is described in the following section.

"Table 13.3-5 Examples of simulator training for accident restoration training"

System	Accident
Boiler System	✓ Tube leak ✓ Pulverized Coal leak ✓ Lowering of vapor pressure ✓ Lowering of vapor temperature
Turbine System	✓ Vibration enhancement ✓ Lowering of oil pressure at bearing part ✓ steam condensate tank leak
Electric System	✓ AVR accident

	✓ Generator stator armature short circuit ✓ Generator rotator short circuit
Control System	✓ Transmitter accident ✓ Controller accident
Other	✓ Earthquake ✓ Lowering of air pressure

Source: Bangladesh Chittagong Coal-Fired Power Plant Construction Project Preparation Survey Report

12.4 Information Management

This clause describes the management of information relevant to the daily operations of the power plant. The structure of this clause is as follows: First, the matter of dispatching information including telecommunication architecture; Second, the feedback of such information to the power company's O&M activities utilizing a database-type IT system; finally the use of the information for public communications, e.g. on environmental matters.

12.4.1 Dispatching information

According to the "Electricity Grid Code 2012," authorized by the Bangladesh Energy Regulatory Commission (BERC), generation power companies shall install a system which provides their power plants' real-time information required by PGCB's National Load Dispatch Center (NLDC) to monitor and control. Such information includes i) bus voltage, ii) frequency, iii) MW, iv) MWh, v) MVAR, vi) Power factor, and vii) the status of circuit breakers. The dedicated communication network for this purpose has been developed by PGCB and the power generation companies. The telecommunication media varies from the power line communications, microwaves, to the optical fiber. The major transmission system is a synchronous digital hierarchy (SDH) system. For SDH, STM-1 (150Mb/s) is adopted for branch sections, while STM-4 (600Mb/s) is composed of the trunk ring network around Dhaka city. To satisfy N-1 criteria, redundancy is required in its design philosophy, usually achieved using two optical fiber routes. The main route is composed of SDH, while the alternative route is composed of PDH, the analogue communication system. In the PGCB network, its telecommunication network for power supply use is physically separated from the network for non-power-supply related data, such as e-mail and the telephones for back-office staff. While they use the public telephone network for the latter purpose, they use their own dedicated telecommunication network for the former purpose.

In the case of CPGCBL, the company is responsible for developing the communication link between its power plant and the PGCB network, while this infrastructure will belong to PGCB once the link is completed. Currently, there are plans to lay the OPGW (optical ground wire) along the 400kV transmission line from the Matarbari Power plant to Anowara 400 kV Substation, leading to NLDC through the also planned Anowara Substation – Megnaghat Substation 400 kV transmission line.

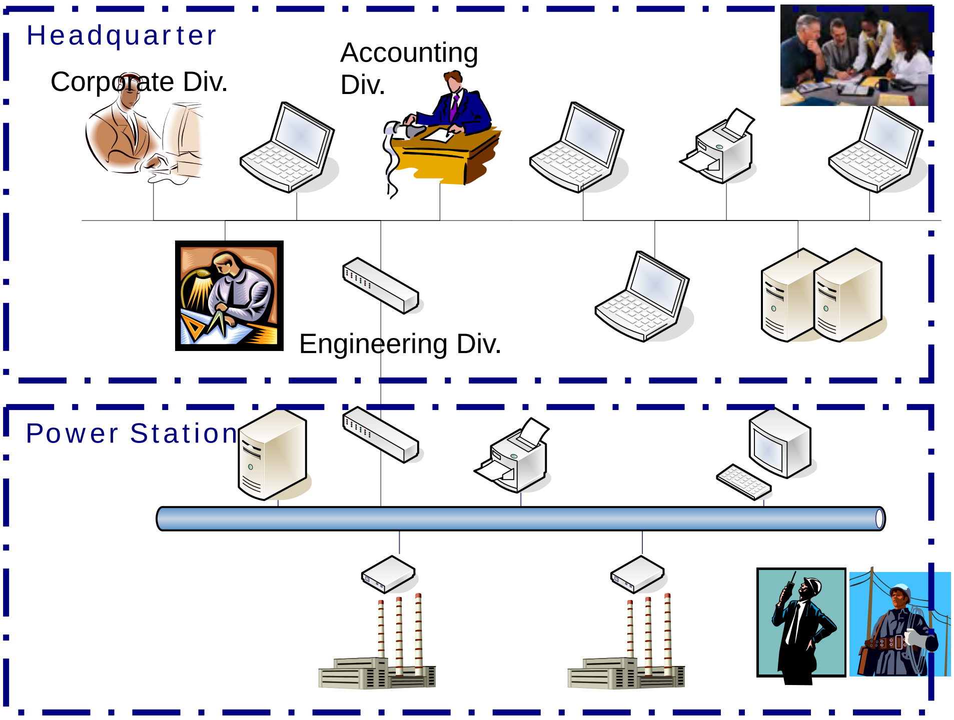
As seen above, the CPGCBL's power plant's dispatching information will be transferred to PGCB's NLDC through the PGCB's SCADA network. On the other hand, the CPGCBL's office will not receive the information because the company's office will not be connected with the SCADA network. Similar to the existing BPDB's subsidiaries, the company's office will only receive limited information like the day-ahead availability of the power plant from NLDC through the public telecommunication network, e.g. fax or email.

12.4.2 Feedback to O&M activities: Introduction of the Performance Management System

Next, maximizing the use of information monitored at the power plant utilizing the database-type IT system and developing the company's own internal network will be described.

Besides the issue of the network, CPGCBL could face a challenge similar to the one that the other BPDB subsidiaries have faced: there has been a tendency for information data like the plant's drawing and facilities' manual to only be available to certain select company staff, usually management because the data is stored as a hard copy or even their electronic copies are stored in the managers' stand-alone personal computer. The key issue here is that such information is not easily accessed by those who really need it, e.g. planning engineers and accounting management staff. Their tasks include the preparation of annual operations and a maintenance plan and/or financial statements.

Figure 12.4-1 shows the image of the system architecture necessary for this purpose. CPGCBL could develop the system by itself or could procure the system with similar function from the market.



Source: Bangladesh Chittagong Coal-Fired Power Plant Construction Project Preparation Survey Report

Figure 12.4-1 The Image of Information Integration in Power Plants

The system would consist of operations data processing computers with functions such as the following:

- ✧ Fuel efficiency management
- ✧ Utilization of generation record to the power production plan
- ✧ Development of reports to be submitted to the government, e.g. monthly generation report.
- ✧ Development of PR material, e.g. IR information such as annual reports.
- ✧ Development of statistical data utilized for the periodical inspection schedule.

Utilizing the system composed of the network and database that would enable the company to develop these outcomes easily and in a timely manner.

Table 12.4-1 Type of Information Data

Item to be monitored 24 hours		**Item to be recorded during installed capacity output level [14:00 1,000 MW]**	
Item	**Sample figure**	**Item**	**Sample figure**
Electricity Generated	16,660 MWh	Output at generator	1,000 MW
Power for station operation consumed	636 MWh	Main steam pressure	246 atg
Availability	69.1%	Main steam temperature	538 ºC
Ratio of power for station operation	3.8%	Reheated steam temperature	567 ºC
Efficiency at power plant	39.6 %	Temperature of supplied water	279 ºC
Fuel consumed	3,354 kNm^3	O_2 at ECO exit	1.4 %
Fuel calorific value	10,740 kcal	Temperature of emission gas	110 ºC
Amount of water supply	2 t	Efficiency at Power Station	40.3%
Gap of water temperature between intake and discharge	3.9 ºC	**Condenser**	
Status of Jelly fish		**Item**	**Sample figure**
Item	**Sample figure**	Seawater temperature at intake	21.1 ℃

Time at peak inflow		Gap of water temperature between intake and discharge	7.0 ºC
Peak amount	t/h	Degree of vacuum	719.7 mmHg
Amount now as of 8 am	t/h	Deviation of vacuum	-1 mmHg
Gas emission			
Item	**Sample figure**	**Item**	**Sample figure**
Concentration of NOx	ppm	Concentration of particulate matter	mg/Nm^3
Concentration of SOx	ppm		

Source: Bangladesh Chittagong Coal-Fired Power Plant Construction Project Preparation Survey Report

For its communication network, because CPGCBL cannot use PGCB’s SCADA network for its own use, the company needs to build its own internal network. Considering the characteristics of the transmitted data, it is preferable to adopt a higher level of network security. For this purpose, it would be appropriate to purchase PGCB’s fiber leasing (dark fiber) service which utilizes PGCB’s OPGW. The use of the commercial VPN service provided by public telecommunication providers would be also the second-best choice.

12.4.3 Public Relationship

While the aforementioned subsection focuses on the use of data for internal usage, this subsection proposes the use of data for external use, i.e. public relationship. Given their large size, power plants tend to attract attention from their local community. Therefore, building mutual trust is essential to maintaining a good relationship. Information disclosure of the plants would be one such approach. The type of information for this objective would include the following:

(1) Gas emissions: Major gases emitted from power plants include particulate matter, NOx, and SOx. Because the Ministry of Environment and Forest (MoEF), the government body responsible for environmental matters, does not require power generation companies to report their emissions regularly, existing power companies rarely disclose their emissions online, such as through their website. Instead, they report their emissions via a paper-based report to the government if requested to do so. The companies should install monitoring posts for the emissions if there is a request from their local community such as from the residents.

(2) Water temperature of condenser (heated water discharge): The change of sea water temperature around the power plant might affect the eco-system there, which could impact the fishing industry. For this purpose, regular monitoring, e.g. water temperature measurement at fixed points would be appropriate to maintain amicable relationships with local fishery groups.

12.5 O&M Cost

[Confidential Information]

Chapter 13 Environmental and Social Consideration

13.1 Environmental and social consideration systems and organizations in Bangladesh

13.1.1 Environmental and social consideration laws, regulations and systems in Bangladesh

(1) Environmental and social consideration policies, laws and regulations, etc.

Table 13.1-1 shows the laws and policies related to environmental and social considerations in Bangladesh. Notable laws and regulations after the preparatory survey on the Units 1/2 Project include the enactment of Bangladesh Biodiversity Act, and Acquisition and Requisition of Immovable Property Act.

Table 13.1-1 The laws and policies related to environmental and social considerations

Category	Name of policies, laws and regulations	Outline
Constitution		
1	The Constitution of the People's Republic of Bangladesh, 1972	Part 2, Article 18A states that efforts should be made to conserve and improve natural resources, biodiversity, wetlands, forests and wildlife for the present and future of people.
Environment policy		
1	The National Environmental Policy, 1992, 2013, 2018	It lists 17 major environmental issues and 12 goals. It shows 271 action plans in 23 sectors. Bangladesh Environment Policy has been changed into 2018 considering the issues such as climate change, limitation of natural resources. Main Key elements of the policy are: ➢ Ensuring sustainable development by reducing human pressure on nature and natural resources. ➢ Each development activity should be part of environmental protection in order to fully meet people's demand for present and future tenure. ➢ Extracting, using and conserving natural resources should be science-based. ➢ The impact and risk to the environment should be considered when extracting and using natural resources. ➢ It is necessary to consider the economic value of natural resources including the ecosystem in the development of the national development plan. ➢ The sustainable use of new and renewable resources must be fostered. ➢ Enhance the long-term agenda of poverty reduction and food security through biodiversity conservation.
2	National Environment Management Plan, 1995	It shows the environmental issues and actions to be taken by each sector for 12 sectors including the water sector. When the workshop has been held to formulate the program, the opinions of NGOs and residents has been incorporated.
Environmental conservation and Environmental impact assessment		
1	The Bangladesh Environmental Conservation Act: ECA), 1995 , amended in 2010	It is the basic law concerning environmental conservation in Bangladesh. It stipulates that factory cannot be established or operated without an Environmental Clearance Certificate (ECC) issued by the Department of Environment (DoE).
2	The Environmental Conservation Rules: ECR), 1997, amended in 2002	Environmental impact assessment and ECC acquisition process, and environmental standards (air, water quality, noise, odor), emission standards (exhaust gas, wastewater, waste) are established.
3	EIA Guidelines for Industries, 1997	It is explained the EIA method defined in ECA195 and ECR.
Pollutant control		
1	Environment Pollution Control Ordinance,	It is established not only preventing pollution of the air,

Category	Name of policies, laws and regulations	Outline
	1977	water, soil, etc., but also preventing to impact of a wide range of environments such as adverse effects on lifestyles and plants.
2	The Environmental Court Act, 2000	In order to ensure the enforcement of ECA and ECR, a court has been established to conduct criminal trials related to environmental pollution.
Natural environment		
1	Bangladesh Biodiversity Act, 2017	It stipulates the conservation of biodiversity, the sustainable use of resources and biota, and the fair and equitable distribution of benefits obtained.
2	The Wildlife (Conservation and Security) Act 1974, 2012	It stipulates the conservation of biodiversity, the sustainable use of resources and biota, and the fair and equitable distribution of benefits obtained.
3	The Vehicle Act (1927) and the Motor Vehicles Ordinance (1983)	Provide rules for exhaust emission, air and noise pollution, and road and traffic safety.
4	Water Supply and Sanitation Act (1996),	Regulates the management and control of water supply and sanitation in urban areas.
5	The Protection and Conservation of Fish Act (1950)	It deals with the protection and conservation of fishes in Government-owned water bodies
6	The Ground Water Management Ordinance (1985)	It describes the management of groundwater resources and licensing of tube wells.
7	The Forest Act (1927)	It describes for the protection of forest reserves, protected forests and village forests.
8	The Private Forests Ordinance Act (1959)	It deals with the conservation of private forests and afforestation of wastelands.
9	The Embankment and Drainage Act (1952)	It describes the protection of embankments and drainage facilities.
10	The Antiquities Act (1968)	It describes the preservation of cultural heritage, historic monuments and protected sites.
11	Bangladesh Labour Law (2006)	It deals with occupational rights and safety of factory workers; provision of comfortable work environment and reasonable working conditions.
Land acquisition and resettlement		
1	The Acquisition and Requisition of Immovable Property Act, 1982, 2017	The Acquisition and Requisition of Immovable Property Ordinance (1982) has been amended as a law. It stipulates procedures for acquiring land and assets associated with the land, and the amount of compensation for land and compensation for damages associated with acquisition have been improved.

Source: Study Team

Table 13.1-2 shows the environment-related international treaties that Bangladesh has ratified.

Table 13.1-2 The environment related international treaties

No	Name of international treaties	Ratified year
1	Convention on Wetland of International Importance Especially as Waterfowl Habitat, 1972	1992
2	United Nations Convention on the Law of the sea, Montego Bay, 1982	2001
3	Rio Declaration, 1992	1992
4	Convention on Biological Diversity, Rio de Janeiro, 1992	1994
5	Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal, 1992	1993
6	(Kyoto protocol 1997) the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal	2001
7	United Nations Framework Convention on Climate Change, 1994	2016
8	MARPOL 73/78 (Annex I/II)、(Annex III)、(Annex IV)、(Annex V)	2003

Source: Study Team

(2) Environmental impact assessment system

(a) Acquisition Process of Site Clearance: (SC) and Environmental Clearance Certificate (ECC)

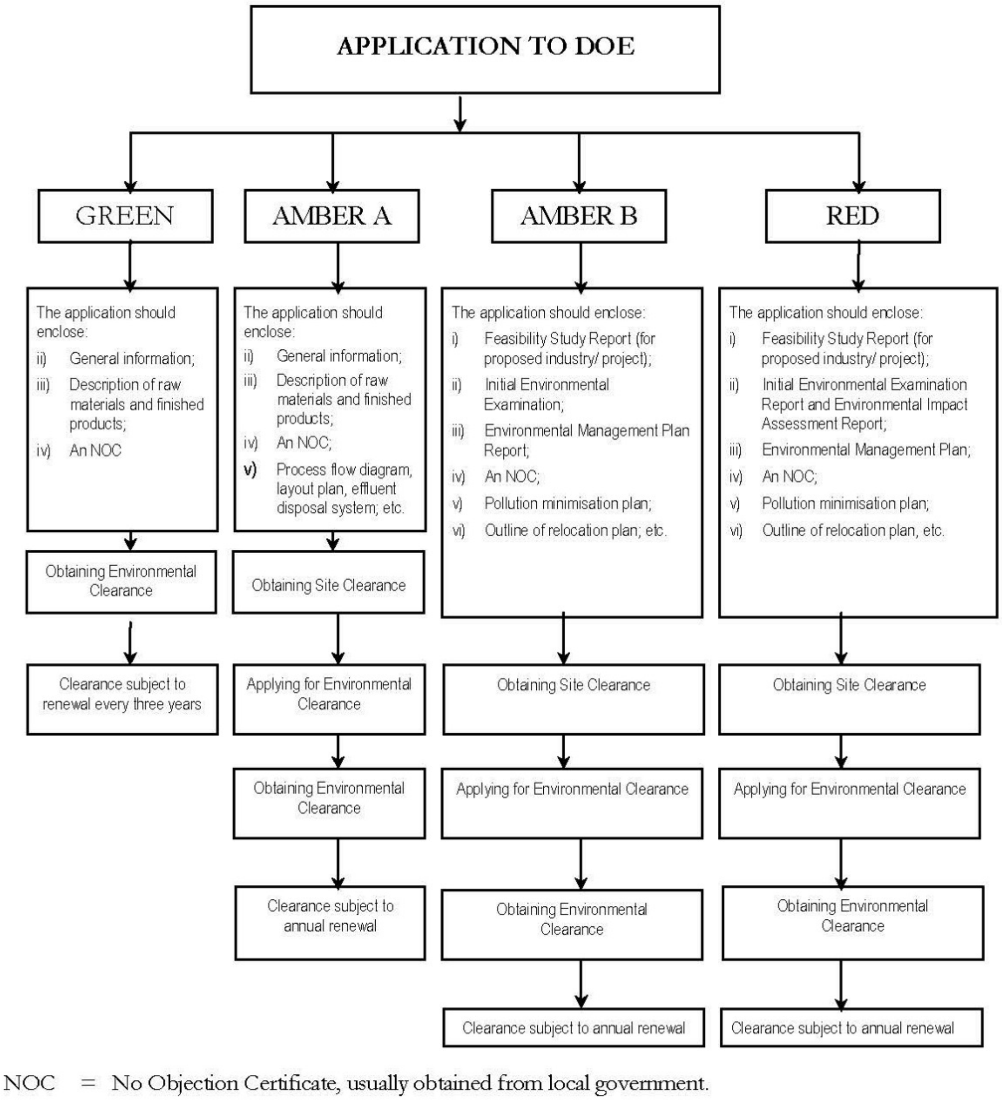
According to the Bangladesh Environmental Conservation Act (ECA), all project proponents should obtain Site Clearance (SC) and an Environmental Clearance Certificate (ECC) issued by the Department of Environment (DoE) of the Ministry of Environment, Forest and Climate Change (MoEFCC).

Under the Environmental Conservation Rules (ECR), which are the operational rules of SC and ECA, the each projects are classified into four categories; Green, Amber A, and Amber B and Red, depending on the magnitude of the expected environmental impact, and the acquisition process of SC and ECC, which differs depending on the magnitude of the environmental impact (Figure 13.1-1).

Of these, the projects classified as Green and Amber A can obtain ECC by submitting the project summary and the document showing that there is no objection to the local government.

The projects classified as Orange A apply for ECC after acquiring SC. As for the projects classified as Orange B, it is necessary to prepare an Initial Environmental Examination (IEE) and Environmental Management Plan (EMP). The projects classified as red, it is necessary to prepare an environmental impact assessment (EIA) in addition to IEE and EMP.

This project is a development of power plant project, it is classified as red, and therefore, it is necessary to prepare IEE and EIA in accordance with ECR Appendix 1. (D), based on the red category item 6.



Source: DOE (1997), EIA Guidelines for Industries

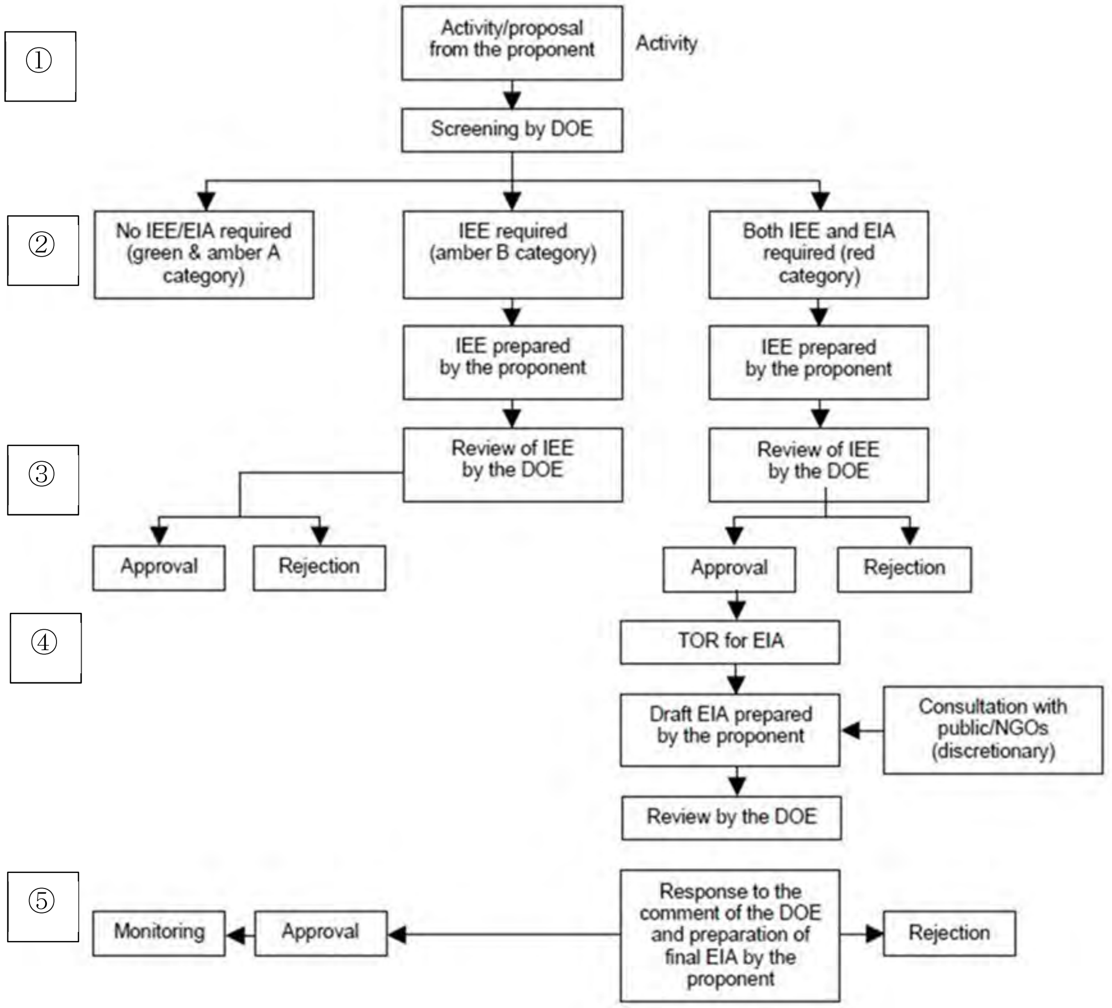
Figure 13.1-1 Acquisition Process of Environmental Clearance Certificate (ECC)

(b) EIA approval procedure

Figure 13.1-2 shows the flow of EIA procedure.

When the project plan is submitted to the DOE by the project proponent (① in the figure), DOE screens and the above-mentioned categories are determined. Along with this, it will be decided which of the three processes that the project plan needs to go through: IEE not required, IEE only required, and IEE and EIA required. (② in the figure). In the red category, it is examined by IEE (③ in the figure), and the TOR of the EIA survey is approved by DOE (④ in the figure).

The project proponent prepares the draft EIA based on the approved TOR, submits it to the DOE, prepares the final EIA based on the comments from the DOE, and obtains the final EIA approval. (⑤ in the figure).



Source: Evaluation of environmental impact assessment procedures and practice in Bangladesh, Impact Assessment and Project Appraisal 22(1), Rafique Ahammed and Nick Harvey, 2004.

Figure 13.1-2 The flow of EIA procedure

According to ECR, the details of the procedure for the red category to which this project applies are as follows.

1) Creation of IEE (Project proponent)
   a) Collection of baseline information on the outline of the project (facility composition and operation flow, project plan, outline of environmental pollution control facility, etc.), the impact of the project, and the environment of the project implementation area.
   b) Identification of important items in the IEE stage
   c) Proposals for mitigation measures, environmental management plans (EMPs), alternative sites and other improvements of plan
   d) EIA Survey Plan (TOR: Terms of Reference)

2) SC application / acquisition
After IEE report is completed, the project proponent must apply for the site clearance (SC) to the Environment Bureau and obtain approval using the prescribed format. The documents required to apply for a location permit are as follows.

a) Project Feasibility Study (FS) Report
b) IEE Report
c) No Objection Certificate (NOC) from the local government
d) Management plan including emergency response plan to control adverse effects on the environment
e) The outline of the resettlement plan, if applicable
f) Other information deemed necessary

Within 60 days after applying for the SC, the permit will be issued to the project proponent along with comments on the EIA survey plan (TOR).

3) Preparation and review of EIA report

The project proponent conducts EIA based on the above TOR and submits the EIA report to the Environment Bureau.

The review of EIA will be conducted by the Environment Bureau within 60 days after the EIA report is submitted by the project proponent.

4) ECC application / acquisition

After obtaining the approval of the EIA report, the project proponent can start construction work, must conduct monitoring and apply for ECC to DOE.

ECC will be issued 30 days after application.

5) ECC update

For the projects classified as red, the project proponent must renew ECC every year after starting service. ECC renewal procedure will be issued by the Environment Bureau within 60 days after the application from the business operator.

(c) Information disclosure

There are no laws or regulations regarding information disclosure related to administrative documents in Bangladesh (Ahmed and Ferdausi, 2016)[1]. In addition, there are no provisions in ECA1995 and ECR regarding the disclosure of EIA reports.

On the other hand, according to the JICA ESC Environmental Guidelines, EIA reports (which may be referred to differently in different systems) must be written in the official language or in a language widely used in the country in which the project is to be implemented. When explaining projects to local residents, written materials must be provided in a language and form understandable to them. EIA reports are required to be made available to the local residents of the country in which the project is to be implemented. The EIA reports are required to be available at all times for perusal by project stakeholders such as local residents and copying must be permitted.

[1] Ahmed, Tanvir and Shakil Ahmed Ferdausi, 2016：Evaluation of the EIA System in Bangladesh. Conference: 36th Annual Conference of the International Association for Impact Assessment

13.1.2 Environmental standards / regulations, etc.

The environmental regulation values of Bangladesh are described in the environmental conservation regulations. The environmental standards of air quality, water quality, noise, nature protection area and environmentally regulated areas related to this project are as follows.

(1) Air quality

Table 13.1-3 shows air quality standards of Bangladesh and the corresponding WHO air quality standards (IFC/WB EHS Guideline 2007).

Table 13.1-3 Air quality standard[2] (ECR, 2005)

No.	Pollutant	Concentration (mg/m^3) ECR	Concentration (mg/m^3) IFC/WB EHS Guidelines 2007	Exposure time
a)	Carbon Mono-oxide	10	-	8 hours
		40	-	1 hour
b)	Lead (Pb)	0.5	-	Annual
c)	Nitrogen Oxide	0.1	0.04	Annual
d)	Suspended Particulate Matter (SPM)	0.2	-	8 hours
e)	Particulate Matter 10 (PM10)	0.05	0.070 (Interim target-1) 0.050 (Interim target-2) 0.030 (Interim target-3) 0.020 (guideline)	Annual
		0.15	0.150 (Interim target-1) 0.100 (Interim target-2) 0.075 (Interim target-3) 0.050 (guideline)	24 hours
f)	Particulate Matter 2.5 (PM2.5)	0.015	0.035 (Interim target-1) 0.025 (Interim target-2) 0.015 (Interim target-3) 0.010 (guideline)	Annual
		0.065	0.075 (Interim target-1) 0.050 (Interim target-2) 0.0375 (Interim target-3) 0.025 (guideline)	24 hours
g)	Ozone	0.235	-	1 hour
		0.157	0.160 (Interim target-1) 0.100 (guideline)0.160	8 hours
h)	Sulfur dioxide	0.08	-	Annual
		0.365	0.125(Interim target-1) 0.050(Interim target-2) 0.020 (guideline)	24 hours

Note:

(1) Regarding IFC/WB EHS Guidelines 2007, “Interim targets” are provided in recognition of the need for a staged approach to achieving the recommended guidelines. As reference, Japanese air quality standards are shown as table below.

Pollutant	Concentration (mg/m^3)	Exposure time	Remarks
SOx	0.114	24 hrs	Interim target-1 equivalent
	0.286	1 hr	---
NO2	0.079-0.118	24 hrs	---
CO	12.5	24 hrs	---
	25	8 hrs	---
Ox(O3)	0.129	1 hr	Intermediate value between Interim target-1 and guideline value
PM10	0.100	24 hrs	Interim target-2 equivalent
	0.200	1 hr	---
PM2.5	0.015	Annual	Interim target-3 equivalent

2 One time per year is not exceed

	0.035	24 hrs	Interim target-3 equivalent

(2) Considering, currently, Bangladesh is developing country, Study Team referred Interim target-1 in this survey.
Source: Bangladesh Gazette July 19 2005, IFC Environmental Health and Safety Guidelines 2007

Table 13.1-4 shows the emission standards for industrial facilities in Bangladesh, and Table 13.1-5 shows the emission standards for industrial boiler in Bangladesh.

Table 13.1-4 Emission standards for industrial facilities (ECR, 1997)

No.	Parameter	Unit	Standard Limit
1	Particulates		
	a) Electric Power Station of 200 Megawatts and above	mg/Nm^3	150
	b) Electric Power Station less than 200 Megawatts	mg/Nm^3	350
2	Chlorine	mg/Nm^3	150
3	Hydrochloric Acid gas & mist	mg/Nm^3	350
4	Total Fluoride (F)	mg/Nm^3	25
5	Sulfuric Acid mist	mg/Nm^3	50
6	Lead particle	mg/Nm^3	10
7	Mercury particle	mg/Nm^3	0.2
8	Sulfur Dioxide		
	a) Sulfuric Acid manufacture (DCDA process)	kg/ton	4
	b) Sulfuric Acid manufacture (SCSA process) Minimum Stack height for Sulfuric Acid emission	kg/ton	10
	Lowest height of stack for dispersion of sulfuric acid a) Coal Fired Electric Power Station		
	i) 500 Megawatts & above	m	275
	ii) 200-500 Megawatts	m	220
	iii) Below 200 Megawatts	m	14 (Q)$^{0.3}$ [3]
	b) Boiler		
	i) For Steam up to 15 tons/hour	m	11
	ii) For steam above 15 tons/hour	m	14 (Q)$^{0.3}$
9	Nitrogen Oxides		
	a) Nitric Acid manufacture	kg/ton	3
	b) Gas Fired Electric Power Station		
	i) 500 Megawatts & above	ppm	50
	ii) 200-500 Megawatts	ppm	40
	iii) Less than 200 Megawatts	ppm	30
	c) Metal Treatment Furnace	ppm	200
10	Soot & Dust Particles		
	a) Air Ventilated Furnace	mg/Nm^3	500
	b) Brick-field	mg/Nm^3	1000
	c) Cooking Furnace	mg/Nm^3	500
	d) Limestone Furnace	mg/Nm^3	250

Table 13.1-5 Emission standards for industrial boiler (ECR, 1997)

No.	Parameter	Standards for presence in a unit of
1	Soot and particulate (fuel based)	
	a) Coal	500
	b) Gas	100
	c) Oil	300
2	Oxides of Nitrogen (fuel based)	
	a) Coal	600
	b) Gas	150
	c) Oil	300

Source: The Environmental Conservation Rules, 1997

[3] Q=SO_2 emission in kg/hour

Coal-fired power plant uses coal (main fuel) and light oil (starting fuel) as fuel.

Since the planned coal-fired power plant has an output of 600 MW, the emission standard for soot and dust will be 150 mg/Nm^3 or less. As for sulfur dioxides in emission, there is no concentration regulation or total emission regulation in Bangladesh

Table 13.1-6 shows a comparison of emission standards between Bangladesh and the IFC/WB EHS Guidelines (Thermal Power Plants; 2008, 2017 draft) regarding coal-fired power plants. The emission standard for nitrogen oxides is 600 or less mg/m^3. New coal-fired power plants must be considered to meet national standards and international guidelines.

Table 13.1-6 Emission standards for coal-fired power plants

Parameters	Standard Limit	IFC/WB EHS Guidelines (Thermal Power Plants; 2008)	IFC/WB EHS Guidelines (Thermal Power Plants; 2017 draft)	
			NDA[4]	DA[5]
SO_2	-[6]	850mg/Nm^3 [7]	200-600mg/Nm^3	200mg/Nm^3
NOx	600 mg/m^3	510mg/Nm^3	500mg/Nm^3	200mg/Nm^3
Particulate Matter (PM)	500mg/m^3	50mg/Nm^3	40mg/Nm^3	25mg/Nm^3
Dry Gas , Excess O_2 Content	-	6%	6%	6%

Note: In case the location of power plant is within 15km from important facility or sanctuary, the stack height is required 275m. In case the location of that is over 15km, the stack height is required at least 220m.
In addition about the calculation results of concentrations of sulfur oxides, nitrogen oxides etc. using atmospheric dispersion model developed by US EPA, the stack height must be set (adjust) to be complied with environmental standards of Bangladesh (Order No. SRO 75 (Amended by DoE on 16 March, 2020)).
Source: The Environmental Conservation Rules 1997, IFC Environmental Health and Safety Guidelines 2008, 2017 draft

(2) Water quality

Table 13.1-7 shows the environmental quality standards for water (surface water) in Bangladesh, and Table 13.1-8 shows the drinking water standards in Bangladesh. Table 13.1-9 shows the wastewater standards in Bangladesh. For drinking water standards and wastewater standards, the corresponding WHO standards, IFC/WB EHS Guidelines are also listed. The IFC/WB EHS Guidelines (Thermal Power Plants; 2008) stipulate the monitoring of necessary heavy metal components according to the characteristics of thermal power plants.

Table 13.1-7 Environmental quality standards for water (surface water)[8] (ECR, 1997)

No.	Best Practice based classification	pH	BOD mg/1	Dissolved Oxygen (DO) mg/l	Total Coliform Bacteria quantity/ml
a)	Potable Water	6.5-8.5	2 or less	6 or above	50 or less
b)	Water used for recreation purpose	6.5-8.5	3 or less	5 or above	200 or less
c)	Potable Water	6.5-8.5	3 or less	6 or above	5000 or less
d)	Water used for pisciculture	6.5-8.5	6 or less	5 or above	5000 or less
e)	Industrial use water including chilling & other processes	6.5-8.5	10 or less	5 or above	
f)	Water used for irrigation	6.5-8.5	10 or less	5 or above	1000 or less

Source: The Environmental Conservation Rules, 1997

4 Non-degraded airshed
5 Degraded airshed; Airshed should be considered as degraded
6 Lowest stack height is stipulated
7 Non-degraded airshed
8 Original note is as follows.
(1) Maximum amount of ammonia presence in water are 1.2 mg/l (as nitrogen molecule) which is used for pisciculture.
(2) For water used in irrigation Electrical Conductivity-2250 micro mho/cm (at 25^{o}C). Sodium less than 26 mg/l, Boron less than 2 mg/l

Table 13.1-8 Drinking water standards

No.	Parameter	Unit	Standard limit	WHO guideline
1	Aluminum	mg/l	0.2	0.2
2	Ammonia (NH_3)	mg/l	0.5	-
3	Arsenic	mg/l	0.05	0.01
4	Barium	mg/l	0.01	0.7
5	Benzene	mg/l	0.01	0.01
6	BOD_5 20 ºC	mg/l	0.2	-
7	Boron	mg/l	1.0	0.5
8	Cadmium	mg/l	0.005	0.003
9	Calcium	mg/l	75	-
10	Chloride	mg/l	150-600	-
11	Chlorinated Alkanes			-
	Carbon tetrachloride	mg/l	0.01	-
	1.1 Dichloroethylene	mg/l	0.001	-
	1.2 Dichloroethylene	mg/l	0.03	-
	Tetrachloroethylene	mg/l	0.03	-
	Trichloroethylene	mg/l	0.09	-
12	Chlorinated phenols			-
	Pentachlorophenol	mg/l	0.03	-
	2.4.6 Trichlorophenol	mg/l	0.03	-
13	Chlorine (residual)	mg/l	0.2	-
14	Chloroform	mg/l	0.09	0.3
15	Chromium (hexavalent)	mg/l	0.05	-
16	Chromium (total)	mg/l	0.05	0.05
17	COD	mg/l	4	-
18	Coliform (fecal)	n/100 ml	0	-
19	Coliform (total)	n/100 ml	0	-
20	Color	Huyghens unit	15	-
21	Copper	mg/l	1	-
22	Cyanide	mg/l	0.1	-
23	Detergents	mg/l	0.2	-
24	DO	mg/l	6	-
25	Fluoride	mg/l	1	1.5
26	Hardness (as $CaCO_3$)	mg/l	200-500	-
27	Iron	mg/l	0.3	-
28	Nitrogen (Total)	mg/l	1	-
29	Lead	mg/l	0.05	0.01
30	Magnesium	mg/l	30-35	-
31	Manganese	mg/l	0.1	0.4
32	Mercury	mg/l	0.001	0.006
33	Nickel	mg/l	0.1	0.07
34	Nitrate	mg/l	10	3
35	Nitrite	mg/l	Less than 1	-
36	Odor		Odorless	-
37	Oil & Grease	mg/l	0.01	-
38	pH		6.5-8.5	-
39	Phenolic compounds	mg/l	0.002	-
40	Phosphate	mg/l	6	-
41	Phosphorus	mg/l	0	-
42	Potassium	mg/l	12	-
43	Radioactive Materials (gross alph a activity)	Bq/l	0.01	-

No.	Parameter	Unit	Standard limit	WHO guideline
44	Radioactive Materials (gross beta activity)	mg/l	0.1	-
45	Selenium	mg/l	0.01	-
46	Silver	mg/l	0.02	-
47	Sodium	mg/l	200	-
48	Suspended particulate matters	mg/l	10	-
49	Sulfide	mg/l	0	-
50	Sulfate	mg/l	400	-
51	Total dissolved solids	mg/l	1000	1000
52	Temperature	ºC	20-30	-
53	Tin	mg/l	2	-
54	Turbidity	JTU	10	-
55	Zinc	mg/l	5	-

Source: The Environmental Conservation Rules 1997, Guidelines for Drinking-water Quality WHO 2008

Table 13.1-9 Wastewater standards[9] (ECR, 1997)

No.	Parameter	Unit	Inland Surface Water	Public Sewer at secondary treatment	Irrigated Land	IFC/WB EHS Guidelines (Thermal Power Plants; 2008)
1	Ammoniacal Nitrogen (N molecule)	mg/l	50	75	75	-
2	Ammonia (free ammonia)	mg/l	5	5	15	-
3	Arsenic (As)	mg/l	0.2	0.05	0.2	0.5
4	BOD_5 20 °C	mg/l	50	250	100	-
5	Boron	mg/l	2	2	2	-
6	Cadmium (Cd)	mg/l	0.05	0.5	0.5	0.1
7	Chloride	mg/l	600	600	600	-
8	Chromium (total Cr)	mg/l	0.5	1.0	1.0	0.5
9	COD	mg/l	200	400	400	-
10	Chromium (hexavalent Cr)	mg/l	0.1	1.0	1.0	-
11	Copper (Cu)	mg/l	0.5	3.0	3.0	0.5
12	Dissolved Oxygen (DO)	mg/l	4.5-8	4.5-8	4.5-8	-
13	Electrical Conductivity	micro mho/cm	1200	1200	1200	-
14	Total Dissolved Solids (TDS)	mg/l	2,100	2,100	2,100	-
15	Fluoride (F)	mg/l	7	15	10	-
16	Sulfide (S)	mg/l	1	2	2	-

[9] Original note is as follows.
(1) These standards shall be applicable to industrial units or projects other than those given under Quality Standards for Classified Industries (Schedule 12).
(2) These quality standards must be ensured at the moment of going into trial production for industrial units and at the moment of going into trial production for industrial units and at the moment of going into operation for other projects.
(3) The value must not exceed the quality standard during spot check at any time ; if required, the quality standards may be more strict to meet the environment terms in certain areas.
(4) Inland Surface Water shall mean drain, pond, tank, water body or water hole, channel, river, spring and estuary.
(5) Public sewer shall mean sewer connected with fully combined processing plant including primary and secondary treatment.
(6) Irrigated land shall mean appropriately irrigated plantation area of specified crops based on quantity and quality of waste water.
(7) Inland Surface Quality Standards (Schedule 13) shall be applicable for any discharge taking place in public sewer or land not defined in Notes 5

No.	Parameter	Unit	Inland Surface Water	Public Sewer at secondary treatment	Irrigated Land	IFC/WB EHS Guidelines (Thermal Power Plants; 2008)
17	Iron (Fe)	mg/l	2	2	2	1
18	Total Kjeldahl Nitrogen (N)	mg/l	100	100	100	-
19	Lead (Pb)	mg/l	0.1	1.0	0.1	0.5
20	Mangaense (Mn)	mg/l	5	5	5	-
21	Mercury (Hg)	mg/l	0.01	0.01	0.01	0.005
22	Nickel (Ni)	mg/l	1.0	2.0	1.0	-
23	Nitrate (N molecule)	mg/l	10.00	Undetermined	10	-
24	Oil & grease	mg/l	10	20	10	10
25	Phenol compounds (C_6H_5OH)	mg/l	1.0	5	1	-
26	Dissolved Phosphorus (P)	mg/l	8	8	10	-
27	Radioactive Materials	As determined by Bangladesh Atomic Energy Commission				-
28	pH		6-9	6-9	6-9	6-9
29	Selenium	mg/l	0.05	0.05	0.05	-
30	Zn (Zn)	mg/l	5.0	10.0	10.0	1
31	Total Dissolved solid	mg/l	2,100	2,100	2,100	-
32	Temperature	ºC	40	40	40-summer	-
			45	45	45-winter	-
33	Total Suspended Solid (TSS)	mg/1	150	500	200	50
34	Cyanide (CN)	mg/1	0.1	2.0	0.2	-

Source: The Environmental Conservation Rules 1997. IFC Environmental Health and Safety Guidelines 2008

(3) Noise / vibration

Noise standards values are specified for each location category. Table 13.1-10 shows the noise standards in Bangladesh. Since there are no standards for vibration in Bangladesh and IFC/WB EHS Guidelines.

Table 13.1-10 Noise standards[10] (ECR, 1997)

No.	Zone Class	Limits in dBA (ECR)		Limits in dBA (IFC/WB EHS Guidelines 2007)	
		Day	Night	Day	Night
a)	Silent Zone	50	40	55	45
b)	Residential Zone	55	45		
c)	Mixed Zone (this area is used combinedly as residential, commercial and industrial purposes)	60	50	70	70
d)	Commercial Zone	70	60		
e)	Industrial Zone	75	70		

Source: The Environmental Conservation Rules, 1997 IFC Environmental Health and Safety Guidelines 2007

(4) Nature protection areas, environmentally regulated areas, etc.

Table 13.1-11 shows the classification of nature protection area and environmentally regulated areas in Bangladesh. Bangladesh has national parks, wildlife sanctuaries, hunting areas, botanical gardens stipulated by the Wildlife Conservation Act, the protected forests stipulated by the Forest Act, and environmental conservation areas stipulated by the Environmental Conservation Act.

[10] Original note is as follows.
(1) The day time is considered from 6 a.m. to 9 p.m. and the night time is from 9 p.m. to 6 p.m.
(2) From 9 at night to 6 morning is considered night time.
(3) Area within 100 meters of hospital or education institution or educational institution or government designated / to be designated / specific institution / establishment are considered Silent Zones. Use of motor vehicle horn or other signals and loudspeaker are forbidden in Silent Zone.

Table 13.1-11 The classification of nature protection area and environmentally regulated areas

Item		Administrative organization	Related law
A	National parks	Forest Bureau	The wildlife Conservation Act
B	Wildlife sanctuaries		
C	Hunting areas		
D	Botanical gardens		
E	Nature protection areas		The Forest Act
F	Environmentally regulated areas	Environment Bureau	The Environmental Conservation Act

Source: Power System Master Plan 2010

The Wildlife Conservation Law stipulates 18 national parks, 20 wildlife sanctuaries, 5 nature reserves such as protection areas, botanical gardens, and environmentally regulated areas. Table 13.1-12 shows the list of nature reserves stipulated by the Wildlife Conservation Law.

Table 13.1-13 shows the environmental conservation areas specified by the Nature Conservation Act. There are 9 conservation areas, with a total area of 8,063.2km^2 excluding the area around Lake Gulshan in Dhaka (A situation Analysis Report on Environment (MDG7) Bangladesh).

In principle, industrial development will be restricted in environmental conservation areas, but IEE will be exceptionally carried out for developments that have a high possibility of development and should be prioritized as the nation, and whether or not they can be implemented, and its Judgment will be made by the Environment Bureau.

The closer national parks and wildlife sanctuaries from the project site are highlighted in Table 13.1-12, but all of which are more than 15 km apart. (Figure 13.1-3)

Table 13.1-12 The list of environmental conservation areas

Item	No	Name	Place	Size (km^2)
A	1	Bhawal National Park	Gazipur	50.2
	2	Modhupur National Park	Tangail/ Mymensingh	84.4
	3	Ramsagar National Park	Dinajpur	0.3
	4	Himchari National Park	Cox's Bazar	17.3
	5	Lawachara National Park	Moulavibazar	12.5
	6	Kaptai National Park	Chittagong Hill Tracts	54.6
	7	Nijhum Dweep National Park	Noakhali	163.5
	8	Medha Kachhapia National Park	Cox's Bazar	4.0
	9	Satchari National Park	Habigonj	2.4
	10	Khadim Nagar National Park	Sylhet	6.8
	11	Baraiyadhala National Park	Chittagong	29.3
	12	Kuakata National Park	Patuakhali	16.1
	13	Nababgonj National Park	Dinajpur	5.2
	14	Shingra National Park	Dinajpur	3.1
	15	Kadigarh National Park	Mymensingh	3.4
	16	Alta Dighi National Park	Nagaon	264
	17	Birgonj National Park	Dinajpur	169
	18	Sheikh Jamal National Park	Cox's Bazar	7,085
B	1	Rema-Kalenga Wildlife Sanctuary	Hobigonj	18.0
	2	Char Kukri-Mukri Wildlife Sanctuary	Bhola	0.4
	3	Sundarban (East) Wildlife Sanctuary	Bagerhat	312.3
	4	Sundarban (West) Wildlife Sanctuary	Satkhira	715.0
	5	Sundarban (South) Wildlife Sanctuary	Khulna	369.7
	6	Pablakhali Wildlife Sanctuary	Chittagong Hill Tracts	420.9
	7	Chunati Wildlife Sanctuary	Chittagong	77.6
	8	Fashiakhali Wildlife Sanctuary	Cox's Bazar	32.2
	9	Dudh Pukuria-Dhopachari Wildlife Sanctuary	Chittagong	47.2

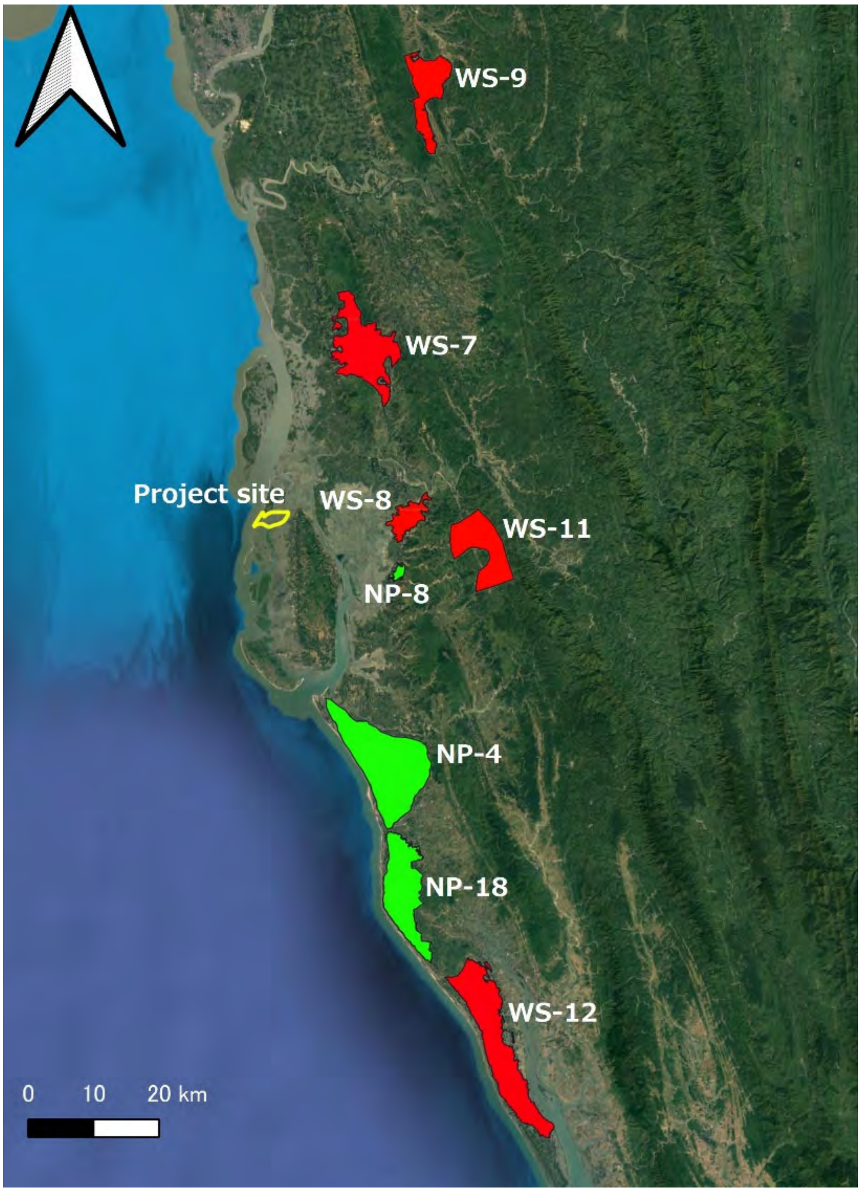
Item	No	Name	Place	Size (km²)
	10	Hazarikhil Wildlife Sanctuary	Chittagong	29.1
	11	Sangu Wildlife Sanctuary	Bandarban	57.6
	12	Teknaf Wildlife Sanctuary	Cox's Bazar	116.2
	13	Tengragiri Wildlife Sanctuary	Barguna	40.5
	14	Sonar Char Wildlife Sanctuary	Patuakhali	2,026
	15	Dhangmari Wildlife Sanctuary	Sundarban, Bagerhat	340
	16	Chandpai Wildlife Sanctury	Sundarban, Bagerhat	560
	17	Dudmukhi Wildlife Sanctuary	Sundarban, Bagerhat	170
	18	Nagarbari-Mohanganj Dolphin Sanctuary	Pebna	408
	19	Nazirganj, Dolpin Sancturay	Pebna	146
	20	Shilanda-Nagdemara Dolpine Snactuary	Pebna	24.17

Source: Bangladesh The 6th National Report for Convention on Biological Diversity (2019)

Table 13.1-13 The list of environmental conservation areas

Item	No	Name	Place	Size (km²)
F	1	The Sundarbans	Bagerhat, Khulna, Satkhira	7,620.3
	2	Cox's Bazar (Teknaf, Sea beach)	Cox's Bazar	104.7
	3	St. Martin Island	Cox's Bazar	5.9
	4	Sonadia Island	Cox's Bazar	49.2
	5	Hakaluki Haor	Moulavi Bazar	183.8
	6	Tanguar Haor	Sumamganj	97.3
	7	Marjat Baor	Jhinaidha	2
	8	Gulshan-Banani-Baridhara Lake	Dhaka	-
	9	Rivers (Buriganga, Turag, Sitalakhya and Balu) around Dhaka city	Dhaka	-

Source: Biodiversity National Assessment and Programme of Action 2020), DOE Bangladesh, 2010



Note) ●NP-means National Park, ●WS-means Wildlife Sanctuary
Location number is corresponding Table 13.1-12.
Source: Study Team based on UNEP-WCMC and IUCN (2021), Protected Planet

Figure 13.1-3 Location map of the protected areas

13.1.3 Overview of related organizations

The Ministry of Environment, Forest and Climate Change (MoEFCC: renamed in 2018) is responsible for the environmental administration of Bangladesh, and it handles all matters related to environmental policies and regulatory issues.

MoEFCC was established in 1989 as the ministry to replace the Ministry of Forests in response to the growing importance of environmental issues.

MoEFCC is now the permanent member of the Executive Committee of the National Economic Council. National Economic Council is the main decision-making body for economic policy issues and is responsible for approving all publicly funded projects.

DOE is a bureau of MoEFCC and is represented by the Director General of the Environment (DG). DG generalizes the entire DOE. The authority of DG stipulated by law is summarized as follows.

(1) DG has the authority to suspend activities that are deemed harmful to human life or the environment. The business operator has the right to appeal and the procedures for doing are stipulated, but there is no

opportunity to appeal unless the urgency is recognized.

(2) DG has the authority to declare the bio-protected area for contaminated areas. Department of Environment (DOE) manages the work/correspondence and process in these areas.

(3) Prior to the development of new project, the project entity must obtain the environmental approval from DOE. The procedure for obtaining such approval is as described above.

When failures to comply with Nature Conservation Law (ECA1995), it will be resulted in imprisonment of up to 5 years, a fine of up to 100,000 Taka, or both.

The Forest Bureau, which belongs to MoEFCC, is responsible for the protection and management of all protected forests in Bangladesh. The staff of the headquarters also belong to the union level in the area where the protection forest is located. Forestry officials are also responsible for the protection of wildlife in the forest. Other environmentally related organizations are as follows.

(1) Ministry of Land (MoL): Responsible for land use and zoning /planning, and responsible for the land acquisition process related to the project.

(2) Water Resources Agency (Bangladesh Water Development Board (BWDB)): Responsible for water resources management and flood / storm surge management.

(3) Ministry of Fisheries and Livestock: Responsible for the conservation of fish stocks.

13.1.4 Land acquisition and Resettlement

(1) Comparison of land acquisition and resettlement system between JICA ESC Guidelines and Bangladesh legal system

Table 13.1-14 shows a comparison of land acquisition and resettlement between the JICA ESC Guidelines and Bangladesh's legal system. In this project, land acquisition and resettlement will not occur.

Table 13.1-14 Comparison of land acquisition and resettlement system between JICA ESC Guidelines and the legal system

No.	JICA ESC Guidelines	Legal system in Bangladesh	Identification of gaps
1	When, after such an examination, avoidance is proved unfeasible, effective measures to minimize impact and to compensate for losses must be agreed upon with the people who will be affected.	Although measures are taken against the affected people, no measures are provided for non-eligible people.	It must be confirmed by monitoring.
2	People who must be resettled involuntarily and people whose means of livelihood will be hindered or lost must be sufficiently compensated and supported by project proponents etc. in a timely manner.	With the Acquisition and Requisition of Immovable Property Act, which came into force in 2017, land and permanent property compensation will be double the market price, loss of crops and trees, and economic loss associated with expropriation and relocation will be same amount of compensation for losses, which is a significant improvement. (In the case of acquisition for non-governmental organizations, the compensation amount will be tripled). In addition, the same amount as the market price will be compensated for damage to crops and trees, costs associated with changing housing and business bases, and reduced profits during the land acquisition period. In addition, crop compensation payments to peasants (bargadar) are obligatory. *The previous system (Acquisition and Requisition of Immovable Property Ordinance, 1982) stipulated that the amount of compensation for land was	As it is not considered whether the compensation payment is appropriate, the livelihood restoration measures are necessary. Although land acquisition and resettlement will not occur in this Unit 3/4 project, it is necessary to support the implementation of livelihood restoration process due to land acquisition and resettlement by the Unit 1/2 project.

No.	JICA ESC Guidelines	Legal system in Bangladesh	Identification of gaps
		115% of the market value, and trees / crops, structures/ movables and their loss, as well as cost of relocation of office or resident was not 100% allowed	
3	Compensation, at full replacement cost, must be provided as much as possible.	(ditto)	No gap is identified.
4	Compensation and other supports must be provided prior to the resettlement.	The new law stipulates that compensation should be filed and paid within 60 days after the application for compensation is made.	As it is desirable to pay in advance for the resettlement, it is necessary to confirm the timing arrangements.
5	In preparing a resettlement action plan, consultations must be held with the affected people and their communities based on sufficient information made available to them in advance.	A land acquisition notification is to be issued in accordance with Article 3 of the Acquisition and Requisition of Immovable Property Act.	Under the legal system in Bangladesh, it is not required for public consultation, and residents without land rights are not eligible to receive formal notifications, but the consultation meetings have been held for the Unit 1/2 project.
6	When consultations are held, explanations must be given in a form, manner, and language that are understandable to the affected people.	No regulation.	The literacy rate of affected people is not considered for consultation in Bangladesh. Actual measures taken in the Unit 1/2 project will be confirmed.
7	Appropriate participation by affected people and their communities must be promoted in the planning, implementation, and monitoring of resettlement action plans and measures to prevent the loss of their means of livelihood.	A land acquisition notification is to be issued based on Article 3 of the Acquisition and Requisition of Immovable Property Act.	Public consultation is not required for land acquisition in Bangladesh, and people without land rights are not eligible to receive a formal notification. Actual measures taken in the Unit 1/2 project will be confirmed.
8	In addition, appropriate and accessible grievance mechanisms must be established for the affected people and their communities.	According to the Acquisition and Requisition of Immovable Property Act, if there is an objection to the compensation amount, the arbitrator can file a petition for revision of the amount (up to a 10% increase in the amount decided by the prefectural governor). The decision will be made by the appeal arbitral tribunal.	Proceedings regarding the amount of compensation have been partially granted, but no objection to qualification requirements have been accepted. In the Unit 1/2 project, a grievance mechanism has been set up based on the requirements of the JICA ESC Guidelines.
9	Displaced persons may be classified in one of the following three groups: (a) those who have formal legal rights to land (including customary and traditional rights recognized under the laws of the country); (b) those who do not have formal legal rights to land at the time the census begins but have a claim to such land or assets--provided that such claims are recognized under the laws of the country or become recognized through a process identified in the resettlement plan (see Annex A, para. 7(f)); and20 (c) those who have no recognizable legal right or claim to the land they are occupying. (WB OP4.12 para.15)	According to the Acquisition and Requisition of Immovable Property According to the Act, the project operator will provide cash compensation for damage to land prices, real estate, crops and trees, with 50% of the assessed amount.	According to the Act, the project proponent will provide cash compensation for damage to land prices, real estate, crops and trees, with 50% of the assessed amount. Actual measures taken in the Unit 1/2 project will be confirmed.
10	Preference should be given to land-based resettlement strategies for displaced persons whose livelihoods are land-based. (WB OP4.12 para.11)	No regulation.	There is a gap. Actual measures taken in the Unit 1/2 project will be confirmed.

No.	JICA ESC Guidelines	Legal system in Bangladesh	Identification of gaps
11	the displaced persons are; provided assistance (such as moving allowances) during relocation, and offered support after displacement, for a transition period, based on a reasonable estimate of the time likely to be needed to restore their livelihood and standards of living (WB OP4.12 para.6, (a), (c))	No regulation for the livelihood means.	There is a gap. Actual measures taken in the Unit 1/2 project will be confirmed.
12	To achieve the objectives of this policy, particular attention is paid to the needs of vulnerable groups among those displaced, especially those below the poverty line, the landless, the elderly, women and children, indigenous peoples,15 ethnic minorities, or other displaced persons who may not be protected through national land compensation legislation. (WB OP4.12 para.8)	No regulation for supporting vulnerable group.	There is a gap. Actual measures taken in the Unit 1/2 project will be confirmed.

Source: Study Team

13.1.5 Correspondences and Comparison between JICA ESC Guidelines and Bangladesh's procedure for EIA

Table 13.1-15 shows Correspondences and Comparison between JICA ESC Guidelines and Bangladesh's procedure for EIA.

Table 13.1-15 Comparison between JICA ESC Guidelines and Bangladesh's procedure for EIA

Item	JICA ESC Guidelines	Bangladesh's procedure	Gap between JICA ESC Guidelines and Bangladesh's procedure / Action to be taken
Underlying Principles	Environmental impacts that may be caused by projects must be assessed and examined in the earliest possible planning stage. Alternatives or mitigation measures to avoid or minimize adverse impacts must be examined and incorporated into the project plan. (Appendix 1.1)	Although there is no legal system statement regarding the alternative plan, DOE is usually required to individually request the results of the consideration of the alternative plan to be included in EIA report during the review of EIA TOR.	Since there is no written provision for alternatives in national system/procedure, it will be considered at the stage of preparing IEE.
Information disclosure	_EIA reports (which may be referred to differently in different systems) must be written in the official language or in a language widely used in the country in which the project is to be implemented. When explaining projects to local residents, written materials must be provided in a language and form understandable to them; _EIA reports are required to be made available to the local residents of the country in which the project is to be implemented. The EIA reports are required to be available at all times for perusal by project stakeholders such as local residents and copying must be permitted. (Appendix 2)	There is no provision about language for EIA reports. There are no provisions about the disclosure of EIA reports.	In stakeholder meeting and explanations to residents, their explanations will be given in language that can be understood by local people (Bengali), and it will be made efforts of plenty of use of illustrations and photographs for more consideration due to low literacy rate. It should be taken to make EIA reports available to local residents.

Item	JICA ESC Guidelines	Bangladesh's procedure	Gap between JICA ESC Guidelines and Bangladesh's procedure / Action to be taken
Social Acceptability	_Projects must be adequately coordinated so that they are accepted in a manner that is socially appropriate to the country and locality in which they are planned. For projects with a potentially large environmental impact, sufficient consultations with local stakeholders, such as local residents, must be conducted via disclosure of information at an early stage, at which time alternatives for project plans may be examined. The outcome of such consultations must be incorporated into the contents of project plans. （Appendix 1 Social Acceptability 1） _In preparing EIA reports, consultations with stakeholders, such as local residents, must take place after sufficient information has been disclosed. Records of such consultations must be prepared. _Consultations with relevant stakeholders, such as local residents, should take place if necessary throughout the preparation and implementation stages of a project. Holding consultations is highly desirable, especially when the items to be considered in the EIA are being selected, and when the draft report is being prepared. (Appendix 2)	Although it is not specified in legal system, DOE usually requires individual consultations to be held during the review of EIA TOR.	Stakeholder meetings should be held at the time of scoping and draft EIA preparation based on JICA ESC Guidelines.

Item	JICA ESC Guidelines	Bangladesh's procedure	Gap between JICA ESC Guidelines and Bangladesh's procedure / Action to be taken
Scope of Impacts to be Assessed	_ The impacts to be assessed with regard to environmental and social considerations include impacts on human health and safety, as well as on the natural environment, that are transmitted 28 through air, water, soil, waste, accidents, water usage, climate change, ecosystems, fauna and flora, including trans-boundary or global scale impacts. These also include social impacts, including migration of population and involuntary resettlement, local economy such as employment and livelihood, utilization of land and local resources, social institutions such as social capital and local decision-making institutions, existing social infrastructures and services, vulnerable social groups such as poor and indigenous peoples, equality of benefits and losses and equality in the development process, gender, children's rights, cultural heritage, local conflicts of interest, infectious diseases such as HIV/AIDS, and working conditions including occupational safety. (Appendix 1 3. Scope of Impacts to be Assessed 1) _ In addition to the direct and immediate impacts of projects, their derivative, secondary, and cumulative impacts as well as the impacts of projects that are indivisible from the project are also to be examined and assessed to a reasonable extent. It is also desirable that the impacts that can occur at any time throughout the project cycle should be considered throughout the life cycle of the project. (Appendix 1 3. Scope of Impacts to be Assessed 2)	There are no provisions for impact assessment items, which are approved by DOE during the review of EIA TOR. There are no provisions for derivative / secondary impacts, cumulative impacts, and impact associated with indivisible projects.	It is envisioned that multiple consultations will be held with DOE at an early stage in coordination with CPGCBL and with the cooperation of EIA survey subcontractor consultant. At the discussion, the outline of Units 3/4 project will be explained. EIA procedure, the relevant laws and systems will be confirmed. And the opinions against TOR of EIA survey, the views on the construction impact of the Units 1/2 project will be heard. Moreover, it will be heard opinions on environmental impact items, derivative / secondary impacts, cumulative impacts, and impact associated with indivisible projects that DOE will pay attention.

Item	JICA ESC Guidelines	Bangladesh's procedure	Gap between JICA ESC Guidelines and Bangladesh's procedure / Action to be taken
Monitoring / Grievance mechanism	_Project proponents etc. should make efforts to make the results of the monitoring process available to local project stakeholders. (Appendix 1 Monitoring 3) _When third parties point out, in concrete terms, that environmental and social considerations are not being fully undertaken, forums for discussion and examination of countermeasures are established based on sufficient information disclosure, including stakeholders' participation in relevant projects. Project proponents etc. should make efforts to reach an agreement on procedures to be adopted with a view to resolving problems. (Appendix 1 Monitoring 4)	There are no provisions regarding the disclosure of monitoring results and grievance mechanism.	Based on the monitoring of the Units 1/2 project and the method and evaluation of grievance handling, it is necessary to consider the monitoring plan and grievance mechanism.
Ecosystem and Biota	_Projects must not involve significant conversion or significant degradation of critical natural habitats and critical forests. (Appendix 1 Ecosystem and Biota)	Critical natural habitats and critical forests are designated and protected by law as protection areas.	The distribution of protected areas should be identified surrounding the proposed project site. It should be careful not to affect to them.
Cultural property	_If there are any impact to Areas with unique archeological, historical, or cultural value due to the project, it must avoid impacts.	Areas of unique archaeological, historical and cultural value are designated for protection.	Areas of archaic, historical, and cultural value should be identified surrounding the proposed project site. It should be careful not to affect to them.
Indigenous Peoples	_Any adverse impacts that a project may have on indigenous peoples are to be avoided when feasible by exploring all viable alternatives. When, after such an examination, avoidance is proved unfeasible, effective measures must be taken to minimize impacts and to compensate indigenous peoples for their losses. (Appendix 1 Indigenous Peoples 1)	There are no provision on indigenous peoples.	Indigenous peoples should be identified surrounding the proposed project site. It should be careful not to affect to them.

Source: Study Team

13.2 Scoping and TOR for the Survey on Natural and Social Environment

13.2.1 Scoping Results

Table 13.2-1 shows the scoping results prepared based on the generally expected impacts by coal-fired thermal power plant project.

Table 13.2-1 Scoping Results for the project

Item			Rating		Results
			Pre- / construction phase	Operation phase	
Pollution Control	1	Air Quality	✓	✓	**Construction phase:** - Production of dust is expected by land preparation and other construction work, but the impact will be temporary. - Generation of air pollutants (SOx, NOx, etc.) is predicted from the operation of heavy machinery and trucks, but the impact will be limited to only the surrounding area. **Operation phase:** - SOx, NOx, PM, and hazardous substances (mercury) will be generated by the operation of the power plant. - Dust may raise in ash yard and coal transport. - Air pollutants in exhaust gas from related vehicles will be generated. Impact along transport route is assumed.
	2	Water Quality	✓	✓	**Construction phase:** - Water turbidity is anticipated by excavation work, but the impact will be temporary. - The impact of concrete wastewater and oil-containing wastewater is anticipated. **Operation phase:** - The impact of plant wastewater, oil-containing wastewater, domestic wastewater, thermal effluent, etc., are expected by the plant operation.
	3	Soil Quality	✓	✓	**Construction phase:** - Possibility of soil pollution caused by leakage of lubricants and fuel oil from construction vehicles and machinery. **Operation phase:** - Possibility of soil pollution caused by leakage of lubricants and fuel oil used for the unit operation.
	4	Sediment	✓	✓	**Construction phase:** - Possibility of sediment pollution in case construction wastewater flows into Bengal bay and the surrounding rivers. **Operation phase:** - Possibility of sediment pollution in case plant wastewater and domestic wastewater flows into Bengal bay and the surrounding rivers.
	5	Noise and Vibration	✓	✓	**Construction phase:** - Impact of noise and vibration is predicted caused by the operation of heavy machinery and trucks, but will be limited to the surrounding area. **Operation phase:**

Item			Rating: Pre- / construction phase	Rating: Operation phase	Results
					- Impact of noise and vibration is predicted caused by plant operation.
	6	Odor	✓	✓	**Construction phases:** - If domestic waste from the workers' camp is not appropriately treated, foul odor may emanate from the rotten waste. **Operation phases:** - If domestic waste from the maintenance workers' office is not appropriately treated, foul odor may emanate from the rotten waste. -Ammonia used in de-nitration system is malodorous substance.
	7	Wastes	✓	✓	**Construction phase:** - General waste and hazardous waste are generated by the construction work. **Operation phase:** - General waste and hazardous waste such as coal ash are generated
	8	Subsidence	✓	✓	**Construction and Operation phases:** - There is no subsidence during Units1/2 construction work. This study for Unit 3/4 is also conducted based on soil survey
Natural Environment	9	Protected Area	✓	✓	**Construction and Operation phases:** Sonadia Island ECA is located around the study site (17 km away to the south)
	10	Ecosystem	✓	✓	**Construction phase:** No sandbar nor mangrove but sandy beach exists within the study site. Sea turtles and birds, sea mammals such as dolphin, listed within IUCN Red List, may occur therein, so that negative impacts on rare species and/or local ecosystem, due to construction activities, would not be negligible. **Operation phase:** No sandbar nor mangrove but sandy beach exists within the study site. Sea turtles and birds, sea mammal such as dolphin, listed within IUCN Red List, may occur therein, so that negative impacts on rare species and/or local ecosystem, due to discharge of both wastewater (oil may be contained) and coolant water from power plant into the Kohelia Channel, and accidental kills of certain amounts of aquatic species due to intake of large amount of river water during the operation phase, would not be negligible.
Social Environ-ment	11	Resettlement	✓	-	**Pre-construction phase:** Even though no new land will be acquired in the Unit 3/4 project, it is necessary to confirm the progress and current status of the resettlement of residents as the land acquired in the Unit 1/2 project will be used for the Unit 3/4 project. Even if there is no land acquisition for Unit 3/4, the land acquired in the Unit 1/2 project will be used, so it is necessary to investigate the progress and current status of the resettlement.
	12	Poor people	✓	✓	**Pre-construction phase:** As poor people are included in the resettled persons for the

Item			Rating		Results
			Pre- / construction phase	Operation phase	
					Unit 1/2 project, it is necessary to confirm the current livelihood means. In addition, it will be confirmed if there are any migration of poor people after the land acquisition for the Unit 1/2 project, the impact and mitigation measures will be considered as needed. **Operation phase:** It will be confirmed whether it is possible to benefit from the livelihood restoration measures and the social services and improved accessibility to the market through the road development and improvement such as paving.
	13	Ethnic minorities and indigenous peoples	✓	-	**Pre-construction phase:** It was confirmed that there were no ethnic minorities or indigenous peoples in and around the project site for the Unit1/2 project, but it is necessary to confirm if there has been migration after the survey for the Unit 1/2. If there is migration, impact and mitigation measures will be considered.
	14	Local economy such as employment and livelihood means	✓	✓	**Pre-construction phase:** It is not expected that this project will cause additional loss of livelihood for owners and workers of salt fields and shrimp farm. But the progress of current status of livelihood restoration of owners and workers of salt fields and shrimp farms those who have lost their livelihood means in the Unit 1/2 project will be confirmed. And the changes and current status of fishermen's livelihood and fishing fields will be confirmed. **Construction phase:** As employment of local residents was planned in the Unit 1/2 project, the possibility of increase of employment in the Unit 3/4 project will be considered based on the actual employment status in the Unit 1/2 project. **Operation phase:** It is expected that the discharge of cooling water from the power plant affect salt production, shrimp farm and fisheries. On the other hand, employment opportunities at the power plant are expected to increase.
	15	Land Use and Utilization of Local Resources	✓	✓	**Pre-construction phase:** The implementation of the Unit 1/2 project has changed the land use, and there is a possibility that the use of local resources will also have an impact on the conventional local economy (salt fields, shrimp farms and fisheries). **Operation phase:** According to the prediction of impacts of the current and water temperature distribution, assess the impact on local resources (fisheries products).
	16	Water usage	✓	✓	**Construction phase:** There is a possibility that soil improvement works, excavation / embankment work, and leakage of oil / chemical substances affect the amount and quality of groundwater. In addition, there is a possibility that rainwater drainage and domestic wastewater from power plants affect salt fields using seawater.

Item			Rating		Results
			Pre- / construction phase	Operation phase	
					Operation phase: Rainwater drainage, domestic wastewater, intake and discharge of cooling water from power plants may affect the use of salt-making seawater.
	17	Existing Social Infrastructure and Services	✓	✓	**Construction phase:** It is expected that the increase in marine traffic affect the marine transportation and fishing activities of local residents due to the transportation of construction materials and equipment from the sea. In addition, it is expected that the increase in traffic volume of construction-related vehicles affect roads and bridges and the social services for residents. **Operation phase:** The impact of an increase in the traffic volume of power plant-related vehicles is expected. On the other hand, it is expected that the improvement and pavement of surrounding roads and the opening and sharing facilities of the power plant to residents will benefit to access to social services and markets throughout the year.
	18	Social institutions such as social infrastructure and local decision-making institutions	✓	✓	**Pre-construction & Operation phase:** The land acquisition, resettlement and compensation for the Unit 1/2 project are led by the Deputy Commissioner's office, and the Chittagong Port Authority has responsible for the port facilities, and Bangladesh Water Development Board (BWDB) is responsible for coastal protection facilities, Roads and Highways Department (RHD) and Local Government Engineering Department (LGED) are responsible for development and maintenance of infrastructure. The relations with the project will be studied.
	19	Misdistribution of benefits and compensation	✓	✓	**Pre-construction phase:** It is necessary to confirm whether unfairness or complaint are raised because of gaps between the compensation procedures under the previous ordinance and the enactment of ‘The Acquisition and Requisition of Immovable Property Act, 2017’. **Operation phase:** There is a possibility that unfairness may occur between residents in the surrounding area who will benefit from the improvement of social infrastructure and social services by implementing this project, and residents who will be resettled or lose their livelihood.
	20	Local conflicts of interest	✓	✓	**Pre-construction phase:** Residents who are dissatisfied with the coverage may conflict with other residents and staffs of Cox's Bazar District who are in charge of compensation payment practices. **Construction phase:** There is possibility that disputes arise between local residents and outside workers who do not understand local customs.

Item			Rating: Pre- / construction phase	Rating: Operation phase	Results
					Operation phase: There is a possibility that unfairness feeling occur in the residents who have not been compensated because some residents benefit from the compensation or the improvement of social infrastructure and services due to this project.
	21	Cultural heritage	✓	✓	It was confirmed that there was no historical, cultural and archaeological property and heritage existing on or around site during the previous study, but it is necessary to confirm the community level property again in this project.
	22	Landscape	-	-	There is no picturesque scenery existing on or around the site.
	23	Gender	✓	✓	**Pre-construction phase:** Due to the Unit 1/2 project there are women among those to be resettled and/or lose their livelihood means, and wives of men who lose their land or jobs may suffer from adverse effects on their household economy. **Construction phase:** There is possibility that a gender difference occurs in employment related to construction **Operation phase:** Improvements and development of surrounding roads may benefit women to access to social services and markets throughout the year.
	24	Children’s Rights	✓	✓	**Pre-construction phase:** There is a possibility that many cases where children are borrowed for work and cannot attend school. **Construction phase:** There is a possibility that children are borrowed for the construction work. Children of households who were resettled or lost livelihood means by the Unit 1/2 project, are affected. **Operation phase:** Improvements and development of surrounding roads may benefit children to access to social services and markets throughout the year.
	25	Infectious diseases such as HIV/AIDS	✓	-	**Construction phase:** It is possible that infectious diseases and infectious diseases spread due to the influx of construction workers.
	26	Work environment (including work safety)	✓	✓	**Construction phase:** There is a possibility of occupational accidents during construction work. **Operation phase:** There is a possibility of occupational accidents for workers.
other	27	Accidents	✓	✓	**Construction phase:** There is a possibility of accidents during construction work, traffic accidents of construction vehicles on surrounding roads, and accidents of vessels related to construction.

Item			Rating		Results
			Pre- / construction phase	Operation phase	
					Operation phase: There is a possibility of accidents in power plant operation and maintenance activities, fires, and traffic accidents on surrounding roads.
	28	Cross-boundary Impact and Climate Change	✓	✓	**Construction phase:** - CO_2 will be generated by construction work. Impact during construction work is temporary. **Operation phase:** - CO_2 generated by transport is temporary, but CO_2 generated by coal-fired power plant shall be estimated.

Note: '✓' is attached to items that are expected to be affected by the project or that cannot be determined at the scoping stage before / during construction and during operation. '-' is attached to items for which no impact is expected.
Source: Study Team

13.2.2 TOR

The survey will be implemented according to the Environmental Conservation Act (1995) determining the EIA procedure and requirements, and the related Environmental Conservation Rules (1997). In addition, the JICA ESC Guidelines (April 2010) will also be taken into consideration.

The survey items, methods and assessment procedures concerning the power plant survey are shown in Table 13.2-2.

Table 13.2-2 Survey Items, Method, Prediction Assessment and Countermeasures

Environmental Items	Survey Items	Literature research	Survey Method	Prediction Assessment and Countermeasures
Air Quality	- Relevant environmental standards - Meteorology - Current status of air quality	Units 1/2 monitoring report	- Obtain ambient air quality standards and emission gas standards. - Obtain meteorological data (temperatures, moisture, wind directions, wind speeds, etc.) from the nearby weather centers. - Measurement of air pollutants (SO_2, NO_2, PM_{10}, etc.): conducted in the rainy and dry seasons to reflect seasonal change. - Use of existing monitoring results	**Construction phase** - Taking preventive measures for air pollution. **Operation phase** - Satisfying exhaust gas standards by installing pollution prevention facilities - Predicting atmosphere diffusion by using simulation models and confirming that they meet air quality standards.
Water Quality	- Relevant environmental standards - Geographical features of the sea bottom	Units 1/2 monitoring report	- Obtain water quality standards and effluent standards. - Water depth measurement - Survey of tidal	**Construction phase** - Taking preventive measures for water pollution **Operation phase** - Satisfying effluent standards by installing wastewater

Environmental Items	Survey Items	Literature research	Survey Method	Prediction Assessment and Countermeasures
	- Current status of tidal current - Current status of water quality		current (tidal direction, current speed): conducted in the rainy and dry seasons to reflect seasonal change. - Measurement of marine water quality (temperatures, salinity, COD, nutrients): conducted in the rainy and dry seasons to reflect seasonal change. - Use of existing monitoring results	treatment facility for domestic and other types of water. - Predicting thermal effluent diffusion by using simulation models and confirming the range of the diffusion.
Soil Quality	- Relevant environmental standards - Current status of groundwater	Units 1/2 monitoring report	- Measurement of ground water quality (turbidity, BOD, heavy metals): conducted in the rainy and dry seasons to reflect seasonal change. - Use of existing monitoring results	**Construction phase** - Oil contamination countermeasures shall be developed **Operation phase** - The same as those addressed in “Construction phase”
Sediment	- Current status of sea bottom	Units 1/2 monitoring report	-Measurement of sea bottom (mud temperature, sulfide, heavy metals): conducted in the rainy and dry seasons to reflect seasonal change. - Use of existing monitoring results	**Construction phase** - Taking prevention measure for water quality
Noise and Vibration	- Relevant environmental standards - Current status of noise and vibration	Units 1/2 monitoring report	- Obtain noise level standards - Measurement of noise and vibration levels: conducted in the rainy and dry seasons to reflect seasonal change. - Use of existing monitoring results	**Construction phase** - Taking preventive measures for noise and vibration **Operation phase** - Taking preventive measures for noise and vibration - Predicting noise levels by using simulation models and confirming that they meet the noise standard.
Odor	- Relevant environmental standards	Units 1/2 monitoring report	- Obtain environmental standards for smell sources (odor). - Use of existing monitoring results -Interview survey(grievance, request, concerns)	**Construction phase** - Taking preventive measures for handling domestic waste **Operation phase** - In case a de-nitration system using ammonia is introduced, ammonia handling plan should be developed.

Environmental Items	Survey Items	Literature research	Survey Method	Prediction Assessment and Countermeasures
Wastes	- Relevant environmental standards	Units 1/2 monitoring report	- Obtain waste handling standards/ manuals/ guidelines. -Interview survey(grievance, request, concerns)	**Construction phase** - Establishing a disposal plan for industrial, domestic, and hazardous waste **Operation phase** - The same as those addressed in “Construction phase”
Subsidence	- Current status of soil conditions	Units 1/2 monitoring report	- Soil quality survey - Use of existing monitoring results	**Construction phase** - The amount of groundwater used should be measured. **Operation phase** - The same as those addressed in “Construction phase”
Protected Area	- Current floral/ faunal condition (e.g., mammal, bird, reptile, amphibian, fish, lagoon species, rare, endangered species such as migratory birds, sea turtle, dolphin and others).	Official Information of DOE	- Collect relevant information through literature review, field survey, interviews with local peoples and others.	- Assess impacts on protected area based on numerical results of both regional air pollution and spreading of discharged water from power plant, to be conducted within this study.
Ecosystem	- Current conditions of important local ecosystem (e.g., mangrove, coral reef, lagoon and others) - floral / faunal condition (e.g., mammal, bird, reptile, amphibian, fish, lagoon species, rare, endangered species such as migratory birds, sea turtle, dolphin and others).	Units 1/2 monitoring report	- Investigate floral/ faunal condition.	- Develop relevant mitigation program to conserve ecologically important areas (e.g., mangrove, coral reef, lagoon and others) based on assessment results if necessary. - Asses the order of magnitude of relevant impacts when any rare and/or endangered species occurs within and/or near the study site and/or relevant affected areas, to be identified from numerical simulation results of air quality, water quality and spreading of coolant discharge from power plant. Develop relevant mitigation measures when severe impacts are expected to occur. In particular, it is important to assess if any “critical natural habitat” areas, specified within GL, exist within the area of concern (the study site included). If so, requirements listed in GL and FAQ shall be confirmed. - Environmental monitoring for Unit 1/2 is on-going based on

Environmental Items	Survey Items	Literature research	Survey Method	Prediction Assessment and Countermeasures
				EMP/EMoP of EIA of Unit 1/2 project (as of February 2021). Upon reviewing monitoring results, any findings and/or remarks, obtained from that review, shall be incorporated into the development of study ToR of Unit 3/4 project smoothly.
Resettlement	- Current status of the affected people of land acquisition and resettlement - Assets of the affected people - Life and livelihood of affected people	Monitoring results during construction of Unit 1/2 project (Interview survey)	- Interviews / questionnaire surveys with the proponent and affected people - Identify gaps between the new land acquisition act 2017 and the actual procedures for the Unit 1/2 project - Grasp the progress of land acquisition, resettlement, and compensation - Socio-economic survey for non-compensated persons (questionnaire, interview, focus group discussion, etc.)	In the Unit 3/4 project, there is no additional land acquisition and resettlement will not occur, but the current status of land acquisition, resettlement and compensation by the Unit 1/2 project will be confirmed and propose appropriate countermeasures based on the monitoring survey results and this survey.
Poor people	- Current situation of the poor people of the affected people - Migration of poor people in the project area after the land acquisition	Monitoring results during construction of Unit 1/2 project (Interview survey)	- Interviews / questionnaire surveys with the proponent and affected people - Identify gaps between the new land acquisition act 2017 and the actual procedures for the Unit 1/2 project of land acquisition, resettlement, and compensation - Socio-economic survey for non-compensated persons (questionnaire, interview, focus group discussion, etc.)	- Grasp the current situation such as changes in livelihood means due to the implementation of the Unit 1/2 project, and based on the monitoring results, predict the impact of the construction and operation of the Unit 3/4 project, and propose to plan the livelihood restoration and support measures.

Environmental Items	Survey Items	Literature research	Survey Method	Prediction Assessment and Countermeasures
Ethnic minorities and indigenous people	- Current situation of the ethnic minorities and indigenous people of the affected people - Migration of ethnic minorities and indigenous people in the project area after the land acquisition	Interview survey)	- Fact of migration	- Grasp the current situation such as changes in livelihood means due to the implementation of the Unit 1/2 project, and based on the monitoring results, predict the impact of the construction and operation of the Unit 3/4 project, and propose to plan the livelihood restoration and support measures.
Local economy such as employment and livelihood means	- Current status of household occupations and livelihoods affected by the Unit 1/2 project - Current status of employment related to the construction works of the Unit 1/2 project - Regional economic development plan	Monitoring results during construction of Unit 1/2 project (Interview survey)	- Interviews and questionnaire surveys with the proponent - Socio-economic survey of non-compensated persons (questionnaire, interview, focus group discussion, etc.)	- Propose to prepare the livelihood restoration/ improvement support plan
Land Use and Utilization of Local Resources	- Current land use after the land acquisition for the Unit 1/2 project - Current status of household occupations and livelihoods affected by the Unit 1/2 project - Confirm regional economic development plan	Monitoring results during construction of Unit 1/2 project (Interview survey)	- Collect maps of land use, satellite images, GIS data, etc. and regional development plans - Interview with farmers, salt farmers, shrimp farmers and fishermen about the changes of livelihoods	- Propose to prepare the livelihood restoration/ improvement support plan
Water usage	- Well water usage conditions - Seawater quality and drawing point for salt-making	Monitoring results during construction of Unit 1/2 project (Interview survey)	- Interview with well water users - Interview with salt farmers	- If problems such as depletion of well water occur, countermeasures will be considered. - Propose proper measures for prevention of water pollution during construction - Predict the area of cooling water from the power plant - For domestic wastewater and other wastewater produced by construction workers,

Environmental Items	Survey Items	Literature research	Survey Method	Prediction Assessment and Countermeasures
				each wastewater standard will be satisfied by installing a wastewater treatment facility.
Existing Social Infrastructure and Services	- Current status of traffic volume - Road maintenance / development status	Monitoring results during construction of Unit 1/2 project (Interview survey)	- Collect statistical data on traffic volume - Confirm a plan of opening some facilities in the power plant to residents - Confirm considerations on smoothing construction schedule	- Propose to formulate a vehicle operation schedule during construction works
Social institutions such as social infrastructure and local decision-making institutions	- Recognitions on the project by the relevant organizations, such as Deputy Commissioner's Office, BWDB, RHD, LGED, DOE etc.	Monitoring results during construction of Unit 1/2 project (Interview survey)	Interview/ questionnaire survey with the relevant organizations will be shared and coordinated with related organizations	- Identify the status of social infrastructure development of related organizations - Propose regional support measures such as the use of facilities and the expansion of accessibility as necessary
Misdistribution of benefits and compensation	- Occupation and livelihood of households affected by the Unit 1/2 project	Monitoring results during construction of Unit 1/2 project (Interview survey)	- Assess the possibility of misdistribution of benefits and compensation based on collecting information on local employment status and income - Assess the unfairness in compensation based on interview/ questionnaire survey with the target households	- Propose regional support measures such as facility use and accessibility expansion as necessary
Local conflicts of interest	- Occupation and livelihood of households affected by the Unit 1/2 project	Monitoring results during construction of Unit 1/2 project (Interview survey)	- Assess the possibility of local conflict of interest because of misdistribution of benefit based on collecting information on local employment status and income - Assess the possibility of local	- Propose regional support measures such as facility use and accessibility expansion as necessary

Environmental Items	Survey Items	Literature research	Survey Method	Prediction Assessment and Countermeasures
			conflict of interest because of unfairness in compensation based on interview/ questionnaire survey with the target households	
Cultural heritage	Cultural and historical resources of national, regional and community level	Literatures	Interview community and relevant authorities	- Propose proper method for protection and awareness
Gender	Gender in affected people and surrounding areas	Monitoring results during construction of Unit 1/2 project (Interview survey)	- Grasp the gender among PAPs based on the socio-economic survey - Grasp the gender based on interview woman group at focus group discussion	- Propose to prepare the livelihood restoration/ improvement support measures as necessary
Children's Rights	- Number of children among affected residents - Enrollment rate - Access to medical facilities - Vaccination rate	Monitoring results during construction of Unit 1/2 project (Interview survey)	- Grasp the current population based on interview survey at the upazila office, Union, ward, since the the census after the 2011 Census will be conducted in 2021 - Grasp the assurance of children's right based on the socio-economic survey and Interview survey	- Propose to prepare the livelihood restoration/ improvement support measures as necessary
Infectious diseases such as HIV/AIDS	- Hygiene measures implementation status	Monitoring results during construction of Unit 1/2 project (Interview survey)	- Grasp the actual situation of implementing safety measures based on the interview with the proponent and workers after analyzing the monitoring results.	- Propose formulation an occupational health plan for the construction works
Work environment (including work safety)	- Implementation status of occupational health, safety and environment measures	Monitoring results during construction of Unit 1/2 project (Interview survey)	- Grasp the actual situation of implementing health measures based on interview with the proponent and workers after analyzing the	- Propose formulation of occupational safety plans during construction and operation

Environmental Items	Survey Items	Literature research	Survey Method	Prediction Assessment and Countermeasures
			monitoring results.	
Accident	- Status of on-site accidents, traffic accidents, and marine accidents - Accident prevention measures	Monitoring results during construction of Unit 1/2 project (Interview survey)	- Grasp the occurrence of accident and implementing the accident prevention measures based on interview with the proponent after analyzing the monitoring results.	- Propose preparation of accident prevention and response measures during the construction and operation
Cross-boundary Impact and Climate Change	- None	-Use of existing monitoring results -Information from DOE	- None	**Construction phase** - CO_2 emission amount from heavy machinery is estimated. **Operation phase** - CO_2 emission amount is estimated based on consumption of fuel

Source: Study Team

13.3 Survey results about environmental and social aspect

13.3.1 Air quality

(1) Meteorology

Refer to clause 5.1.1 (1) Meteorology and Appendix 5.1.1.

The weather at the project site based on meteorological model has not changed significantly in the last three years.

The average temperature in 2020 is 18.2°C in January, which is the lowest in the year, and 27.6°C in June and July, which is the highest in the year.

In the dry season of January and February, the westward wind is predominant, and in the rainy season of May to August, the southerly wind is predominant. The average annual wind speed is 3.4m/s, and the average wind speed tends to be higher in the rainy season than in the dry season.

(2) Air pollutants

Refer to clause 5.1.1 (2) Air Pollutants and Appendix 5.1.1.

The concentration of suspended Particulate Matter (SPM), SOx and NOx near the project site were below air quality standards.

13.3.2 Noise / Vibration

Refer to clause 5.1.2 Noise / Vibration and Appendix 5.1.2.

(1) Noise

Noise level of Matarbari village, Dhalghata village exceeded Noise standards, corresponds “Complex area (mainly residential area, and also applied to commercial and industrial area)”

Noise level at the boundary of the project site on the residential area side is below the standard value applied to the commercial / industrial area, but slightly exceeds the standard value applied to the residential area.

(2) Vibration

Ground characteristics of Matarbari village and Dhalghata village, have a tendency of soft ground/soil.

Vibration level values of Matarbari village and Dhalghata village are low, therefore, there is almost no effect of vibration.

13.3.3 Odor

Refer to clause 5.1.3 Odor and Appendix 5.1.3.
No malodorous substances were detected at the site during construction.

13.3.4 Water quality

Refer to clause 5.1.4 Water Quality and Appendix 5.1.4.

(1) Water quality
(1-1) Surface water (Sea area)
The water quality in the sea area around the project site did not change significantly before and during the construction of Units 1/2.

(1-2) Surface water (Kohelia Channel)
The quality of surface water (Kohelia Channel) is did not change significantly before and during the construction of Units 1/2.

(1-3) Groundwater
About water quality of wells that located in Matarbari village, Dhalghata village, Turbidity, SS, Nitrogen (Total), Coliform have exceed drinking quality standards.
About the quality of ground water in project site, Fecal Coliform has exceeded drinking water quality standard, in addition, other items have not exceeded.
When drinking groundwater at the project site and its surroundings, sterilization/ disinfection/filtration are required.

(2) Sediment (Sea area)
In accordance with concentration guidelines that the National Oceanic and Atmospheric Administration (NOAA) [11] in United States has, the measurement result does not exceed ERL (Effects Range-Low) [12] that affect benthic organisms.

13.3.5 Hydrographic Conditions

(1) Kohelia Channel
Refer to Chapter 5 for details of the survey.
As a result of investigating the particle size of the sediment at 14 locations in Kohelia Channel, it was found that the composition ratio of sand was 73 to 100% and its status was sandy. For this reason, the movement of sand is the main movement of Kohelia Channel.
According to bathymetry survey crossing channel, the width is narrow (about 50～70m) and water depth is shallow on the north side of Kohelia Channel (about 2.0m). However, as survey location moves to south, channel width becomes wider (about 100～200m) and water depth becomes deeper (about 3.0m).
Wave height and flow velocity of Kohelia Channel show same tendency from north side to south side, and flow direction is predominantly 180° to 360° (S→W→N). The tide level fluctuations tended to be similar to those in sea area.

(2) Marine Part
Refer to clause 5.1.5 and Appendix 5.1.5.
Surveys regarding current condition were conducted at three locations in sea around the project site. In the dry season survey from February to March 2021, the average current velocity was 0.4 to 0.6 m/s, and the current direction was south to southeast at low tide and north to northwest at high tide.

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[11] NOAA (USA): Sediment Quality Guidelines for the National Status and Trends Program (http://response.restoration.noaa.gov/book_shelf/121_sedi_qual_guide.pdf (1999))
[12] Regarding ranking value that corresponds to 10% of the total from the low concentration side. It is defined that adverse effects rarely occur at lower concentrations.

Similar fluctuations were observed about the tide level at the survey point on the side of Bengal Bay and the survey point on Kohelia Channel.

13.3.6 Soil

Refer to clause 5.1.6 Soil and Appendix 5.1.6.
According to "The Environmental Monitoring Report Conducted on Units 1/2 Construction Work", arsenic, chromium, and lead has been confirmed, but mercury has not been detected.

13.3.7 Topography and geology

In this survey, ground survey was conducted at the project site, and information on ground characteristics, stratigraphic layer thickness, ground strength, and compressibility was obtained for the basic design of necessary important structures and buildings Refer to Chapter 5 for details of the survey.

In Bangladesh, seismic zones are classified into four categories, and the design strength of buildings is determined in accordance with the seismic zone. The project site is required having the medium design strength as Chittagong.

13.3.8 Flora / Fauna

No significant change of the local flora/fauna around the study site is recognized, compared with those of both pre-construction and construction phases of Units 1/2 Project. No sandbar but mangrove vegetation and sandy beach exist around the study site. Footprint of Fishing Cat (Prionailurus viverrinus) was found in the mangrove vegetation of Kohelia Channel. Fishing Cat is a Nationally Endangered species (IUCN Bangladesh 2015a, see Clause 5.2.3 of Chapter 5 and Appendix 5-2 for more detailed descriptions) as well as Globally Vulnerable species.

13.3.9 Social consideration

(1) Resettlement

Since Units 3/4 will be constructed within the project site of the preceding Units 1/2 project, there will be no new land acquisition and no resettlement in Units 3/4 project.

Although some of the compensation for affected persons after the land acquisition for the Units 1/2 project has not yet been completed, support for the compensation process is being provided under the initiative of CPGCBL with the cooperation of the DC Office, NGOs and consultants.

With the support of NGOs, CPGCBL continues to inform the affected persons, and in December 2019, January and February 2020, promoted the identification of affected persons and the notification of procedures called the ‘resettlement fair, for implementing appropriate compensation procedures.

In addition, since the whereabouts of 58 wage workers who were initially applied for as affected residents were not contacted unknown, a list of total labors including traceless PAPs was hung during September 2018, and the NGO conducted door to door survey into Matarbari and Dhalghata, and in February 2019 a list of total labors including persons traceless who didn't submit their file was handed over to the chairman/ villagers during February 2019, but no response from PAPs, villagers and the chairman/other representatives and villagers. After that, the consultant team went to the address at the time of application, but could not confirm it, and in August 2020, the list of traceless persons was published on the CPGCBL website, and also posted in local newspapers and national newspapers. The situation has not changed, although efforts are being made to find the traceless persons.

As a part of the monitoring survey of Units 1/2 project, consulting meetings with people in Matarbari and Dhalghata have been held almost regularly in the villages around the project site. It was held 7 times in 2018, 13 times in 2019, and 6 times in 2020 under COVID-19 situation Although a complaint from informal resident about the delay of compensation was raised in the meeting held in May 2018, no similar complaints were raised during the period until November 2020 with the provision of residents, one-time payment and relocation payment progress of compensation, and any complaint from such PAPs. In addition, any complaint of compensation has not been to the GRC. According to the questionnaire and interview survey with the randomly selected 267 household incomes of those 267 households are increased.

(2) Poor people

The households that were forced to relocate due to the acquisition of land for the Units 1/2 project have received compensation for relocation and are living in housing provided by the CPGCBL and are receiving vocational training.

In addition, wage earners who received compensation for the Units 1/2 project are also receiving vocational training. However, the residents living near the power plant who are not affected by the project have high expectations for increased employment opportunities.

(3) Ethnic minorities and indigenous peoples

With reference to the 2011 National Census results and the Unit 1/2 Project Preparatory Survey Report (2013), it was confirmed that there are no minority ethnic groups or indigenous peoples in and around the project implementation area in the survey results at that time. In addition, in the field survey in February 2021, it was confirmed that there are still no ethnic minorities and indigenous people living in the area.

(4) Local economy such as employment and livelihood means

Affected residents who lost their means of livelihood due to the acquisition of land for the Units 1/2 project have been given opportunities for job training along with compensation payments, 339 persons have participated the training program, and 128 persons have engaged in jobs.

In addition, the total number of employees in Units 1/2 project is 4,396, of which 1,126 from the local Matarbari, Dhalghata, and Badalkari unions were employed as skilled and non-skilled persons. Through resident consultations in the monitoring survey, stakeholder meetings and FGD in this study, there are high expectations for increased employment opportunities, and especially priority employment of residents of both Matarbari and Dhalghata.

There have been many complaints of disturbance to fisheries and water cabs due to the construction of the Units 1/2 project. However, appropriate measures have been taken by the project operators, including those involved in the construction.

On the other hand, economic benefits have also been recognized, such as an increase in the number of small stores, an increase in local transportation needs represented by rickshaws and CNG (three-wheeled autos), and an expansion of the scale of the bazaar.

However, some residents complain of poverty due to the rising cost of living.

(5) Land Use and Utilization of Local Resources

The land use classification of the 651 hectares targeted for land acquisition for the Units 1/2 project is about 90 percent salt fields/shrimp ponds, about 10 percent intertidal zone and sand dunes, and there is little change in the use classification of residential areas with forest land, farmland, and house forests.

The Rangakhali channel, which meandered from the northern part of the plant to the southeastern part and connected to the Kohelia Channel, was partially reclaimed during the construction of the Units 1/2 project.

It is said that this was requested because the Kohelia Channel was prone to flooding due to backflow when the water level (tide level) was high.

However, after prolonged flooding damage during the rainy season of 2018, which was pointed out to be caused by the reclamation, a Channel along the slope of the retaining wall on the north side of the power plant was excavated and a gate was installed connecting it to the Channel parallel to the Kohelia Channel.

Although the results of the monitoring survey associated with the Units 1/2 project did not indicate any comments from residents on the subsequent long-term flooding damage, the focus group discussions in this survey did indicate some concerns about the impact on flooding damage.

The focus group discussions on this project also indicated that the need to use pumps due to the lower inflow of seawater and lower salinity, and the higher costs involved.

(6) Water usage

The current situation regarding the use of seawater in the salt fields is as described in the previous section, and the majority of drinking water sources are tube wells.

There has been no change in water quantity or quality due to the construction of Units 1/2.

(7) Existing Social Infrastructure and Services

A port has been constructed on the west side of the project site for the Units 1/2 project and is already being used to transport materials and equipment for the construction.

For this reason, fishermen and boat drivers have pointed out the impact of construction-related vessels in the Units 1/2 environmental monitoring survey.

A management plan for marine traffic has been formulated by the construction company.

In the focus group discussion of this study, complaints were also heard about the impact of construction-related vessels on fisheries and water traffic.

The only overland roads to Matarbari Island are from the mainland side via the RJD-maintained zilla road (county road) and Bandakhali Bridge to Moheshkhali Island, and from Moheshkhali Island via the LGED-maintained upodilla Road (county road) and Matarbari Bridge to the north side of Matarbari Union.

There is no direct road into Dhalghata Union from Moheshkhali Island.

On Matarbari Island, the LGED-maintained Union Road runs north-south and connects Matarbari Union and Dhalghata Union, but since it was cut off due to the development of the power plant project site, an alternative road is under construction as of August 2021, with a temporary detour and transportation by minibus provided by CPGCBL as alternatives.

During the environmental monitoring survey, it has been observed that there is an increase in traffic on Union Road, congestion and damage to the road.

And during the community consultations conducted as part of the environmental monitoring study, many complaints were expressed about the congestion and road damage.

In addition, in 2018, the project supported the construction of a 7.5km section from Rajghat to Muhurighona by RHD. It has also rehabilitated the section between Rajghat and Sairer Deil in Matarbari Island three times in consultation with the Union chairman.

Similar complaints about the road condition were also expressed during the focus group discussion of the study.

(8) Social institutions such as social infrastructure and local decision-making institutions

Within Matarbari Island, LGED is responsible for the maintenance of public facilities such as roads, schools, and mosques, as well as the planning and maintenance of community development plans at the upodilla level.

BWDB is also responsible for the management of the embankments surrounding Matarbari Island, which also serve as transportation routes for residents. A port has been constructed in the proposed project area, but it will be transferred to CPA for management in the future.

As mentioned above, the RHD does not have direct jurisdiction over roads in Matarbari Island. However, RHD is in charge of the main road from the national highway to Moheshkhali Island, and the access road to the planned Matarbari Port is under the jurisdiction of RHD.

As a local decision-making body, each union has an elected chairperson and members elected from the villages and wards of the union to form a parishad.

Gender considerations are taken into account so that there are three women among the members.

The Union in the county is overseen by the County Administrator, who chaired the stakeholder consultation in this case.

The County Administrator's Office is in charge of the procedures related to the acquisition of the land.

The statements made by the chairpersons of Matarbari Union and Dhalghata Union in the stakeholder consultation did not differ from the opinions of the residents in the focus group discussion, and the social organization seems to be functioning well.

(9) Misdistribution of benefits and compensation

There have been no complaints from the affected residents in the community consultation conducted as part of the environmental monitoring survey of the Units 1/2 project, except in the early stages of the compensation payment procedure. In addition, no complaints have been received at the project's grievance counter.

According to the results of the interviews with the affected residents in this study, the standard of living of the residents who received compensation tends to improve on average, and there is no clear sense of unfairness among the affected residents.

In addition, in the focus group discussions, complaints were heard from residents who have not been compensated. However, it is difficult to distinguish between the impact of the Unit 1/2 project and the geographical, social infrastructure and other characteristics of this area originally. Specifically, it is thought that the dissatisfaction and requests for the Unit 1/2 project are being raised in response to the road conditions, flooding damage, etc. CPGCBL is focusing on the process of confirming compensation eligibility, and is taking measures such as consultation meeting with residents based on the causal relationship between various issues and this project.

(10) Local conflicts of interest

From the perspective of the grievances mentioned in the previous section, the following interest conflicts within the region can be assumed: conflicts overcompensation for affected residents, conflicts in road access and community mobility, and conflicts arising from unfairness in employment.

It is employment that is seen as a conflict of interest with the attributes of specific districts and residents.

There is a concern that the gap between the high expectations for employment in the power plant construction and the low hiring rate due to the evaluation of skills, as well as the unfairness of hiring people from outside Matarbari, are causing conflicts of interest.

However, there are no signs of the conflict becoming more serious, as workers from outside the community are also living in the local community, respecting local customs.

(11) Cultural heritage

There are no nationally or regionally designated cultural heritage sites within a 15km radius of the project site, and no cultural heritage sites in communities, villages or unions were identified during the interviews with residents on Matarbari Island.

(12) Gender

In the Union Parishad, it has been decided that for every nine male members, three female members will be elected. Although it cannot be said to be completely gender equal, gender is taken into consideration.

In the focus group discussion conducted for this study, 29 women from various age groups participated, all of whom were housewives and most of whom were illiterate.

Due to the unique culture of this region, women are very conservative and not interested in working outside the home. They balance their roles in the household by taking on multiple domestic responsibilities, including childcare, and take pride in the fact that their protection of the house allows other household members, especially their husbands, to work outside the home and in this sense contribute to the family income.

Most of the women said that they are able to make decisions about the household, but some said that it is stressful for them to run the household due to their low income as responsible family members, and that men are the leaders and decision makers in decision making on major family issues, although they may consult their wives.

(13) Children’s right

In the Units 1/2 environmental monitoring survey, patrols were conducted to ensure that no children were working during construction, and no children were found to be working.

In the questionnaire survey of the affected residents conducted in this study, all of them indicated that they were willing to send their children to school (Bengali education system, national curriculum) or madrasa (Arabic, national curriculum).

In addition, all women in the FGDs were willing to send their children to school.

While they were willing to send their children to school and madrassas, they also mentioned that they might drop their children out of school due to economic stress in the family.

In the FGDs in the villages north of the power plant that are affected by flooding, there were comments that there are times when children cannot go to school due to flooding.

(14) Infectious diseases such as HIV/AIDS

A number of educational programs on measures against infectious diseases such as HIV/AIDS have been implemented for the construction workers of the Units 1/2 project, and there have been no reports of cases.

As a countermeasure against Covid-19, posters are being displayed in various places to inform people of measures to prevent the spread of the disease, blood pressure and body temperature are being measured by the medical team, and disinfectants are being sprayed.

(15) Work environment (including work safety)

In the Units 1/2 project, the environmental monitoring survey was conducted to check the toilet facilities for EHS management, to interview the EHS manager of the contractor and the safety manager of the subcontractor, to check the personal protective equipment (PPE) of the workers, to check the occupational health and safety management in the cement silos, and to check the status of waste management, and waste management. The results of the survey were positive, although some combustible waste was found in the cigarette butt receptacles and expired fire extinguishers were left in place.

As for occupational accidents, 28 accidents had occurred by December 2020, two of which were fatal. As accident prevention measures, under the direction of CPGCBL, the contractor has taken measures such as a flow line plan to prevent accidents, strengthening of the security system, posting of signs, and strengthening of safety equipment.

(16) Accidents

As for traffic accidents caused by construction-related vehicles and vessels, countermeasures have been taken each time.

13.4 Natural and Social environmental impact assessment

In the consideration of the impact assessment of Units 3/4 project, the status of other projects around the project site was confirmed because there is a possibility of cumulative impact with the impact of other projects in the vicinity.

For other projects around the project site, the EIA reports published by related organizations were referred to, and those without information on the concept stage or concrete plan were excluded from the study.

The cases that could be obtained and confirmed as the reports were 2 roads, 1 transmission line, and 1 port (FS).

Table 13.4-1 Other projects around the project site

Report name/Project name	Organization name	Outline
JICA Matarbari Port Development Preparatory Survey Project (2018)	_Roads and Highways Department _Ministry of Road Transport and Bridges _Road Transport and Highways Division	Matarbari Port Access Road o Road Length: 25.7 km o Number of Bridges: 17 (total 7,104 m) o Number of Intersections: 4 (3 at-grade, 1 grade separated) o Number of Railway Crossing: 2 Dohazari-Cox's Bazar Railway; and Rail Spur Link to Matarbari Dike Road o Road Length: 1.8 km 
Detailed Design and Supervispn of Acess road Construction Component of Matarbari Ultra Super Critical Coal Fired Power Project (RHD PART) JICA LOAN BD-P76&BD-P88 Environmental Impact Assessment	_Roads and Highways Department _Ministry of Road Transport and Bridges _Road Transport and Highways Division	The proposed 7.35 km embankment cum road will be utilized for the purposes of connecting Matarbari to Dhlaghata Union 
Construction of 20km 132kV transmission line from Chakaria to Matarbari CPGCBL power plant proposed and 10MVA 33/11kV REB distribution sub-station with renovation 33kV, 11kV&0.415kV distribution network Project	CPGCBL (Application dated 07/09/2015)	_20km 132kV transmission line from Chakaria to Matarbari CPGCBL power plant _10MVA 33/11kV REB distribution sub-station with renovation 33kV, 11kV&0.415kV distribution network
Preparatory Survey on the Matarbari Port Development in People's Republic of Bangladesh (December 2018)	Japan International Cooperation Agency (JICA) The Overseas Coastal Area Development Institute of Japan Oriental Consultants Global Co., Ltd Nippon Koei Co., Ltd PADECO Co., Ltd	The Survey for investigating the further detailed plan of Matarbari port development

Source: Study Team

In addition, CPGCBL has announced the development plans for power plants around the project site on his website, but CPGCBL responded that all of projects were in the planning stage and has not publish the reports yet.

Based on the above, the environmental impact assessment in this survey considers the impact of this project and Units 1/2 project.

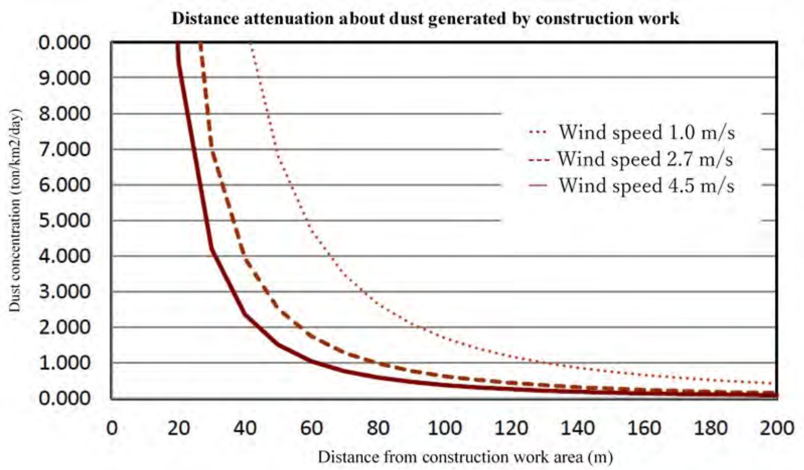
The operation is planned to start in 2024, and the construction of Units 3/4 project will start after the start of the operation of Units 1/2 project.

This chapter describes the prediction and impacts assessment of environmental issues related to power plant projects. In the prediction of environmental impact, it was examined based on analysis by numerical simulation, avoidance or mitigation measures. Avoidance and mitigation measures for environmental impacts are described in detail in Chapter 13.5 Environmental Management Plan.

(1) Design stage and Construction phase
(1-1) Pollution control
(1-1-1) Air quality
(a) Ambient environment under construction

The construction site for the power plant has already been prepared and large-scale construction is not expected, but air pollutants (SOx, NOx, etc.) will be generated due to the operation of heavy machinery and construction vehicles during ground improvement work, construction work, etc. And Study Team assumes that the impact will be limited to the area around the construction area.

Since the construction area is almost bare land, the wind may cause to rise dust on the ground, but impact due to dust will extremely less over 100 m from the construction area.



Note: As the premise, dust amount generated by Dredging construction work is set 17,000t/km2/day and 70% of which is reduced by water spray, above figure shows distance attenuation of dust concentration. Condition of on-going project is different from above mentioned condition. But it helpful about the grasp of tendency of distance attenuation.

Figure 13.4-1 Distance attenuation about dust generated by construction work

According to the Beaufort scale (Table 13.4-2), dust on the ground rises at wind speeds of more than 6 m/s. According to the wind rose in Figure 13.4-2, the appearance of wind speeds of more than 6 m/s around the site is about 6% per year (Table 13.4-3), and considering the wind direction (south wind) toward the residential side (Matarbari village), the appearance rate is will be lower.

Table 13.4-2 Beaufort Scale

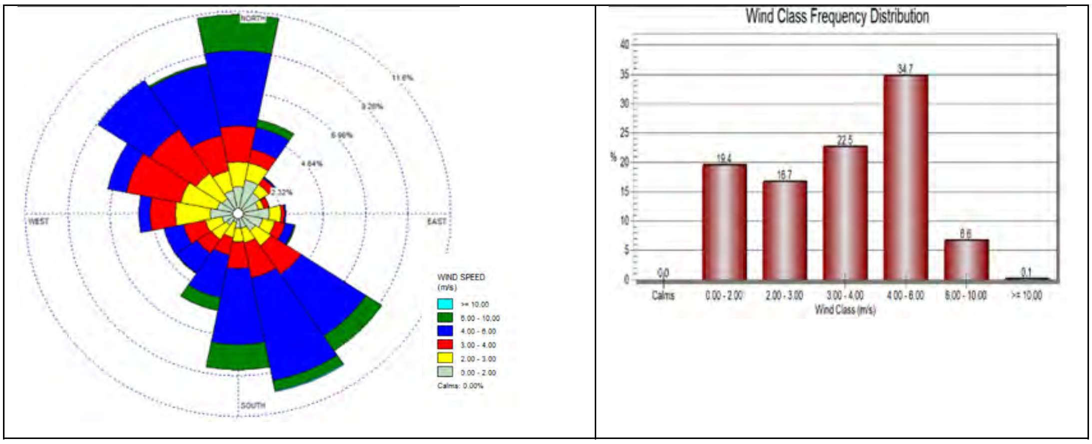
Force	Speed knot(m/s)	Description	Specification(for use at sea/for use on land)
0	0-1 (0-0.5)	Calm	_Sea like a mirror. _Calm; smoke rises vertically.
1	1-3 (0.5-1.5)	Light Air	_Ripples with the appearance of scales are formed, but without foam crests. _Direction of wind shown by smoke drift, but not by wind vanes.
2	4-6 (2.1-3.1)	Light Breeze	_Small wavelets, still short, but more pronounced. Crests have a glassy appearance and do not break. _Wind felt on face; leaves rustle; ordinary vanes moved by wind.
3	7-10 (3.6-5.1)	Gentle Breeze	_Large wavelets. Crests begin to break. Foam of glassy appearance. Perhaps scattered white horses. _Leaves and small twigs in constant motion; wind extends light flag.
4	11-16 (5.7-8.2)	Moderate Breeze	_Small waves, becoming larger; fairly frequent white horses. **_Raises dust and loose paper; small branches are moved.**
5	17-21 (8.7-10.8)	Fresh Breeze	_Moderate waves, taking a more pronounced long form; many white wave are formed. _Small trees in leaf begin to sway; crested wavelets form on inland waters.
6	22-27 (11.3-13.9)	Strong Breeze	_Large waves begin to form; the white foam crests are more extensive everywhere. _Large branches in motion; whistling heard in telegraph wires; umbrellas used with difficulty.
7	28-33 (14.4-17.0)	Near Breeze	_Sea heaps up and white foam from breaking waves begins to be blown in streaks along the direction of the wind. _Whole trees in motion; inconvenience felt when walking against the wind.
8	34-40 (17.5-20.6)	Gale	_Moderately high waves of greater length; edges of crests begin to break into spindrift. The foam is blown in well-marked streaks along the direction of the wind. _Breaks twigs off trees; generally impedes progress.
9	41-47 (21.1-24.2)	Severe Gale	_High waves. Dense streaks of foam along the direction of the wind. Crests of waves begin to topple, tumble and roll over. Spray may affect visibility _Slight structural damage occurs (chimney-pots and slates removed)
10	48-55 (24.7-28.3)	Storm	_Very high waves with long overhanging crests. The resulting foam, in great patches, is blown in dense white streaks along the direction of the wind. On the whole the surface of the sea takes on a white appearance. The tumbling of the sea becomes heavy and shock-like. Visibility affected. _Seldom experienced inland; trees uprooted; considerable structural damage occurs.
11	56-63 (28.8-32.4)	Violent Storm	_Exceptionally high waves (small and medium-size ships might be for a time lost to view behind the waves). The sea is completely covered with long white patches of foam lying along the direction of the wind. Everywhere the edges of the wave crests are blown into froth. Visibility affected. _Very rarely experienced; accompanied by wide-spread damage.
12	64-71 (32.9-36.5)	Hurricane	_The air is filled with foam and spray. Sea completely white with driving spray; visibility very seriously affected.

Source: National Weather Service (https://www.weather.gov/mfl/beaufort)

Table 13.4-3 Appearance rate of wind speed more than 6m/s

Wind direction	Frequency	Wind speed ＞6m/s	Occurrence ratio (%)
NNE	503	50	0.6
NE	206	1	0
ENE	142	0	0

Wind direction	Frequency	Wind speed >6m/s	Occurrence ratio (%)
E	223	0	0
ESE	243	7	0
SE	787	85	1.0
SSE	918	60	0.7
S	758	112	1.3
SSW	515	87	1.0
SW	378	3	0.0
WSW	360	1	0.0
W	436	1	0
WNW	600	0	0.0
NW	811	1	0.0
NNW	777	13	0.1
N	764	114	1.3
Calm	363	-	-
Annual	8784	535	6.1



Note: Wind rose by MM5 at project site [GL 3m] (2020.1.1-2020.12.31)
Source: Study Team

Figure 13.4-2 Wind rose

Currently, in the Units 1/2 construction work, regular maintenance of generators, heavy machinery, trucks, etc., exhaust gas inspection, and regular air environment monitoring are being carried out as measures against exhaust gas.

In addition, the construction area is implementing measures against dust by sprinkling water. Owing to the effects of these measures, the air environment in the construction area and near the boundary of the site is favorable according to the monitoring report on Units 1/2 Construction Work (refer to clause 5.1.1).

As for Units 3/4 construction work, also referring the status of Units 1/2 construction work, Study Team assumes that the impact of the construction work on the atmospheric environment can be minimized by taking measures against exhaust gas and monitoring activities.

(b) Air quality near the road due to construction vehicles

After the access road is completed, it is conceivable that construction vehicles such as trucks will pass through.

The impact of automobile exhaust gas along the road will be examined using the following formula with reference to the “Environment Impact Survey Guideline for Waste Treatment Facility” (Ministry of Environment, Japan).

[Wind speed (more than 1.0m/s)]

$$c(x,y,z) = \frac{Q}{2\pi\sigma_y\sigma_z u}\cdot exp\left(-2\frac{y^2}{2\sigma_y^2}\right)\left[exp\left\{\frac{-(z+H)^2}{2\sigma_z^2}\right\} + exp\left\{\frac{-(z-H)^2}{2\sigma_z^2}\right\}\right]$$

[Symbols/Marks]

C: Pollutant concentration on ground at R (m)

Q: Exhausted pollutant amount from source (mg/s)

[Exhausted pollutant amount at each time]

$$Q_t = V_w \times \frac{1}{3600} \times \frac{1}{1000} \times \sum_{i=1}^{2}(N_{it} \times E_i)$$

Qt: Exhausted pollutant amount per second (mg/m・s)

Vw: Conversion factor (mg/g)

NOx: 523ml (20ºC, 1atm), SPM: 1000mg/g

Ei: Exhausted pollutant amount intensity (g/km・vehicle)

NOx (small vehicle): $=-0.902/V-0.00578V+0.0000439V^2+0.261$

NOx (large vehicle): $=-7.12/V-0.0895V+0.000735V^2+3.93$

SPM (small vehicle): $=-0.138/V-0.000456V+0.00000317V^2+0.0218$

SPM (large vehicle): $=0.0318/V-0.00310V+0.0000227V^2+0.158$

V: Average speed (km/h)

Nit: Traffic amounts (Vehicles/h)

u: Wind speed (m/s)

H: Height of exhaust gas (m)

x: Distance to leeward (m)

y: Right angle horizontal distance against x axis (m)

z: Right angle vertical distance against x axis (m)

σz: Parameter for right angle vertical distance (m)

$$\sigma_z = \sigma_{z0} + 0.31L^{0.83}$$

σ_{z0}: Initial parameter (m)

L: Distance from edge of road (L = x-W/2)

W: Width of road (m) (In case of x < W/2, $\sigma_z = \sigma_{z0}$)

σy: Parameter for right angle horizontal distance (m)

$$\sigma_y = W/2 + 0.46L^{0.81}$$

(In case of x < W/2, σy＝W/2)

[Calm (less than 1.0m/s)]

$$c(x,y,z) = \frac{Q}{(2\pi)^{3/2}\alpha^2\gamma}\left[\frac{1-exp\left(-\frac{l}{t_0^2}\right)}{2l} + \frac{1-exp\left(-\frac{m}{t_0^2}\right)}{2m}\right]$$

$$l = \frac{1}{2}\left[\frac{x^2+y^2}{\alpha^2} + \frac{(z-H)^2}{\gamma^2}\right]$$

$$m = \frac{1}{2}\left[\frac{x^2+y^2}{\alpha^2} + \frac{(z+H)^2}{\gamma^2}\right]$$

$$t_0 = \frac{W}{2\alpha}$$

α=0.3, γ=0.18(day time), 0.09(night time)

This survey estimated the impact of air pollutants along the road from the number of construction vehicles (large) passing by per hour (Table 13.4-4, Table 13.4-5).

Basic concept of access road is as below (Figure 13.4-3).

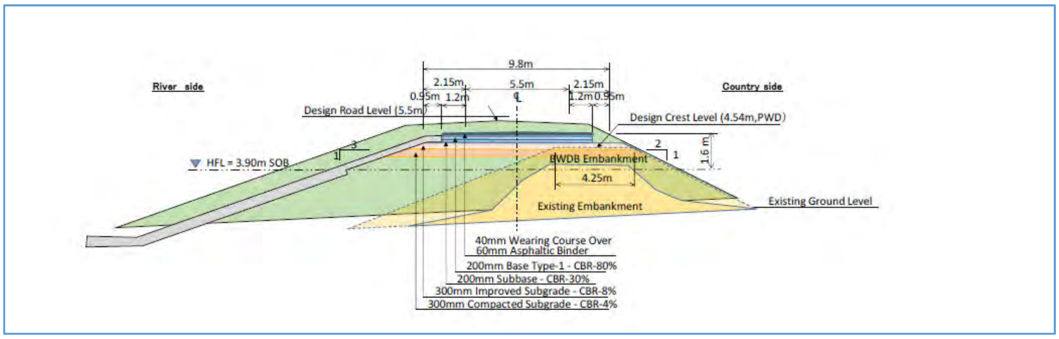


Figure 13.4-3　Basic concept of access road

Note: Road basic concept is as below.

Item	Design
Crest width	9.80 m
Carriage way width	5.5 0m
Shoulder	2.15 m

Source: Bangladesh Coal-Fired Power Plant Construction Project Preparatory Survey Report Final Report on Units 1/2 Construction Project

Air pollutants (nitrogen oxides, suspended particulate matter) are expected to be generated as construction vehicles pass by. However, Study Team assumes that the generation of air pollutants can be reduced by reducing the number of construction vehicles, leveling the number of passing vehicles, complying with traffic rules, and regularly monitoring as much as possible.

Table 13.4-4　Nitrogen oxides concentration near the road (μg/m^3)

Items		Wind speed 3m/s		Calm	
		Vehicle speed (km/h)			
		40	50	40	50
Vehicles amounts per hour	10	0.02	0.02	0.03	0.02
	20	0.04	0.03	0.05	0.05
	30	0.06	0.05	0.08	0.07

Source: Study Team

Table 13.4-5　Suspended particulate matter concentration near the road (μg/m^3)

Items		Wind speed 3m/s		Calm	
		Vehicle speed (km/h)			
		40	50	40	50
Vehicles amounts per hour	10	0.001	0.001	0.001	0.001
	20	0.002	0.002	0.003	0.002
	30	0.003	0.003	0.004	0.004

Source: Study Team

(1-1-2) Water quality

Units 3/4 construction work does not assume large-scale excavation work like Units 1/2 construction work, but rainwater, domestic wastewater from worker dormitories, and waste water mixed lubricant for heavy machinery will be generated. The impact of the drainage on the surrounding area is assumed.

In Units 1/2 construction work, waterways, settling ponds, storage tanks, oil and wastewater treatment tanks are installed around the construction area, and measures are taken to prevent the construction wastewater from being discharged directly to the outside of the site. In addition, underground penetration prevention sheets are laid to take measures against groundwater pollution.

	
Tentative storage pond for wastewater at worker camp site	Wastewater treatment facility near worker camp

Source: Study Team

Figure 13.4-4 Countermeasures for wastewater during construction within the project site (Units 1/2 Project)

According to the monitoring report, no deterioration of the water quality environment of the surrounding sea area, Kohelia Channel, and groundwater has been confirmed.

In Units 3/4 construction work, Study Team assumes that the impact of the construction work on seawater, river water, and groundwater can be minimized by taking the same measures and monitoring activities as in Units 1/2 construction work.

(1-1-3) Soil pollution

In the construction area, there is a possibility of soil contamination due to leakage of oils and chemical substances during construction.

In Units 1/2 construction work, oils and chemical substances are stored in an appropriate storage place, regular inspections by contractors, and soil monitoring rigs are carried out. The soil environment in the construction area is the same as before the construction.

	
Oil Storage tank	Chemical substances in storage house

Source: Study Team

Figure 13.4-5 Storage of oils and chemical substances during construction within the project site (Units 1/2 Project)

In Units 3/4 construction work, Study Team assumes that soil contamination due to construction work can be minimized by taking the same measures and monitoring activities as in Units 1/2 construction work.

(1-1-4) Sediment pollution (Sea bottom)

In Units 3/4 construction work, there is no construction plan for large-scale sea area like Units 1/2 construction work, but construction in sea area will be planned in the intake and outlet construction. Drainage from the construction area may cause sediment pollution due to inflow into the surrounding sea area and rivers.

In Units 1/2 construction work, waterways, settling ponds, storage tanks, oil and wastewater treatment tanks are installed around the construction area, and measures are taken to prevent the construction wastewater from being discharged directly to the outside of the premises. According to the monitoring report, the water quality environment of the surrounding sea area, Kohelia Channel, and groundwater has not been confirmed to deteriorate before and after the construction work.

In Units 3/4 construction work, it is considered that the impact on sediment pollution can be minimized by taking the same measures, monitoring activities for Units 1/2 construction work and managing the construction wastewater.

(1-1-5) Noise and Vibration

(1-1-5-1) Noise

(a) Construction noise

Noise due to the operation of heavy machinery and trucks is generated, but the impact is limited to the area around the construction area.

According to the “Bangladesh Coal-Fired Power Plant Construction Project Preparatory Survey Report Final Report on Units 1/2 Construction Project”, the impact of noise due to construction is predicted to be below the noise standards and IFC/WB EHS Guidelines 2007.

The monitoring results for Units 1/2 construction work also show that the noise standards and IFC/WB EHS Guidelines 2007 values (residential area: daytime) are almost satisfied during the daytime when the work is carried out.

Referring to “Bangladesh Coal-Fired Power Plant Construction Project Preparatory Survey Report Final Report on Units 1/2 Construction Project”, dump trucks, truck cranes, backhoes etc. will be used in Units 3/4 construction area. (Table 13.4-6).

Table 13.4-6 Noise level of the main construction machines

Location	Machine	Capacity	Noise Power level (dB)	Number of machines	Location	Machine	Capacity	Noise Power level (dB)	Number of machines
①	Truck crane	11t	107	4	④	Generator	250kVA	99	10
	Truck	11t	109	1		Engine Compressor	75m^3/min	99	2
②	Crawler crane	50t	107	3	⑤	Truck crane	11t	107	6
	Truck crane	11t	107	11		Concrete Mixer	4.5m^3	110	18
	Truck	11t	109	9		Backhoe	1.4m^3	114	10
	Forklift	-	96	2		Concrete pump	70m^3/min	114	6
	Vehicle for height work	-	109	2		Generator	250kVA	99	10
③	Crawler crane	50t	107	3		Engine Compressor	75m^3/min	99	2
	Truck crane	11t	107	11	⑥	Crawler crane	50t	107	5
	Truck	11t	109	9		Concrete Mixer	4.5m^3	110	4
	Forklift	-	96	2		Small Truck crane	4t	80	3
	Vehicle for height work	-	109	2		Vehicle for height work	-	80	2
④	Truck crane	11t	107	6	⑦	Backhoe	1.4m^3	114	1
	Concrete Mixer	4.5m^3	110	18		Concrete Mixer	4.5m^3	110	1
	Backhoe	1.4m^3	114	10	⑧	Backhoe	1.4m^3	114	1
	Concrete pump	70m^3/min	114	6		Concrete Mixer	4.5m^3	110	1

Note: 1) Noise level was calculated based in A weighted noise level at 7m distance from construction machine.
2) Locations of noise sources

Source: Study Team

When examining the noise level due to the operation of construction machinery, there is the following noise propagation formula*.

*ISO 9613: Acoustics-Attenuation of sound during propagation outdoors
Part 1: Calculation of the absorption of sound by the atmosphere
Part 2: General method of calculation

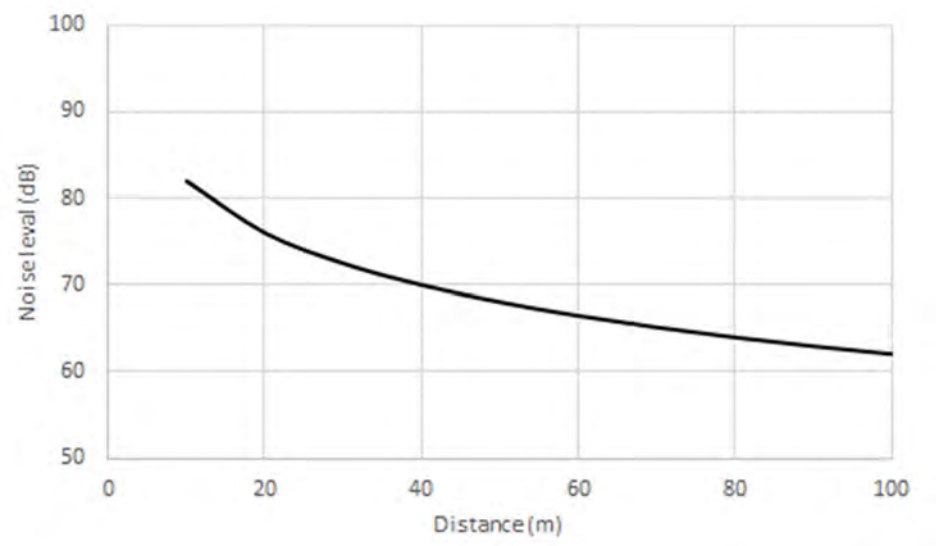
$$L_{PA} = L_{WA} - 20 \cdot \log_{10} R - 8 - A_{\gamma} - A_{E}$$

[Symbol/Marks]

L_{PA} : Predicted noise level at certain location (dB)
L_{WA} : A-weighted sound pressure level (dB)
R : Distance from noise source to certain location
A_{γ} : Attenuation due to barrier (dB)
A_{E} : Attenuation due to air absorption (dB)

Noise from heavy machinery with a noise level of about 110 dB is attenuated by about 40 dB at a distance of 100 m from the noise source.

The construction site of Units 3/4 is more than 100 m away from the boundary of the construction area and the residential area, and the influence of noise due to the construction is considered to be limited (Figure 13.4-6).



Source: Study Team

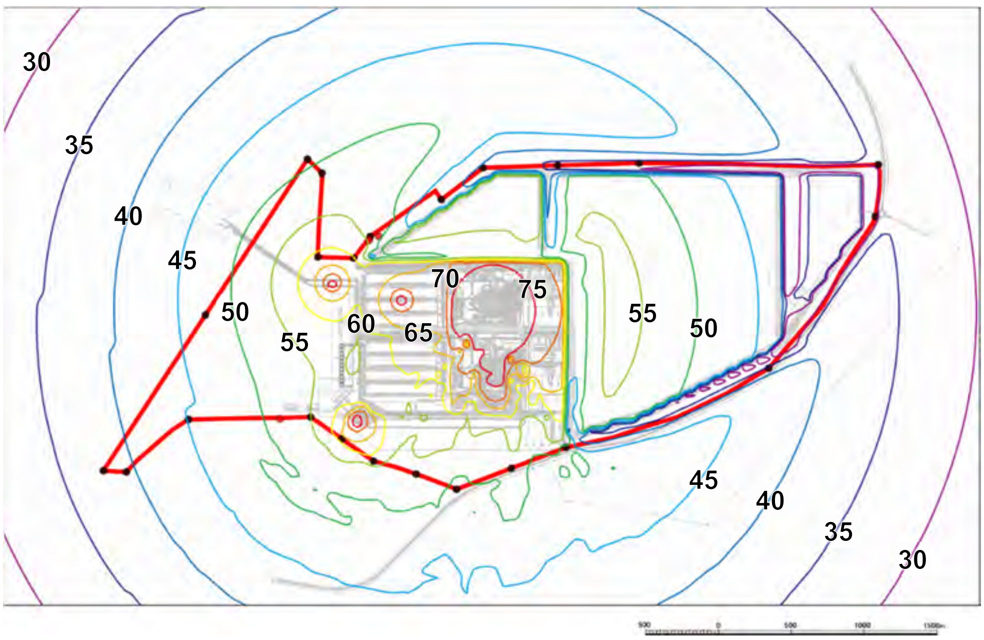
Figure 13.4-6 Attenuation of noise level against distance

In addition, during construction, it will coincide with the operation period of Units 1/2. Predicted noise level due to construction work under the operation of Units 1/2 is shown in the following figure. Predicted noise level is 28 to 64 dB (A) at the boundary of the site and 52 to 55 dB around the residential area (north and south sides).

As results, predicted noise level at the boundary and in residential areas (day time) can be complied with Bangladesh standards and IFC/WB EHS Guidelines 2007 values.

For this reason, as prevention measures against noise from construction work, night construction will not be carried out as much as possible, Units 3/4 construction work likewise, heavy machinery and construction vehicles shall be arranged appropriately according to the construction scale, the number of operating units should be reduced by efficient use. And low-noise construction machinery must be introduced.

Study Team assumes that the effects of noise can be minimized by maintaining performance through appropriate inspection and maintenance, and by regularly monitoring.



Note: detailed result

No	Noise Level (dBA)	DOE Limit Standard	IFC/WB EHS Guidelines 2007
1	49.3	Industrial Zone; Day 75 Night 70	Industrial Zone; Day 70 Night 70
2	51.0		
3	61.4		
4	60.5		
5	54.2		
6	41.5		
7	38.7		
8	34.2		
9	32.8		
10	32.1		
11	28.1		
12	36.2		
13	47.7		
14	53.9		
15	49.3		
16	53.6		
17	58.9		
18	64.1		
19	55.0		
20	45.1		
21	39.3		
22	37.8		
23	47.4		
24	53.1	Residential Zone: Day 55 Night 45	Residential Zone: Day 55 Night 45
25	54.8		
26	51.5		

Source: Study Team

Figure 13.4-7 Predicted noise level (Units 1/2 operation, Units 3/4 construction work)

(b) Noise near the road due to construction vehicles

After the access road is completed, it is conceivable that construction vehicles such as trucks will pass through. The Acoustical Society of Japan has proposed the following formula for the equivalent noise level (L_{Aeq}) of road traffic.

$$L_{\mathrm{Aeq},T} = L_{\mathrm{A}E} + 10\log_{10}\frac{N_T}{T}$$

$$L_{\mathrm{A}E} = 10\log_{10}\left(\frac{1}{T_0}\sum_i 10^{L_{\mathrm{A},i}/10}\cdot\Delta t_i\right)$$

$$L_{\mathrm{A},i} = L_{W\mathrm{A},i} - 8 - 20\log_{10} r_i + \Delta L_{\mathrm{cor},i}$$

$$L_{W\mathrm{A}} = a + b\log_{10}V + C$$

$$\Delta L_{\mathrm{cor},i} = \Delta L_{\mathrm{dif},i} + \Delta L_{\mathrm{grnd},i} + \Delta L_{\mathrm{air},i}$$

[Symbol/Marks]

L_{Aeq} : A-weighted equivalent noise level (dB)
$L_{\mathrm{A}E}$: A-weighted Single noise level (dB)
$L_{\mathrm{A},i}$: A-weighted sound pressure level at certain location (dB)
Δt_{i} : Time of source staying in certain area (s)
$\mathrm{N_T}$: Traffic amounts (number)
T : Certain time (=3,600)
T_0 : Base period (s) (=1)
$\mathrm{L}_{W\mathrm{A},i}$: A-weighted noise level from certain vehicle (dB)
r_i : Distance from source to certain location (m)
$\Delta L_{\mathrm{cor},i}$: Correction term about Attenuation factors (dB)
a, b : Constant term (a=Large vehicle：53.2, Small vehicle：46.7, motor cycle：49.6, b=30)
V : Speed (km/h)
C : Correction term for the reference value (=0)
$\Delta L_{\mathrm{dif},\,i}$: Correction term for diffraction (dB) (=0)
$\Delta L_{\mathrm{grnd},\,i}$: Correction term for ground surface (dB) (=0)
$\Delta L_{\mathrm{air},\,i}$: Correction term for air absorption (dB) (=0)

This survey estimated the noise level along the road from the number of construction vehicles (large) passing by per hour.

Along the road, a noise level of about 60 dB is assumed due to the passage of construction vehicles (Table 13.4-7). Study Team will reduce the impact of road traffic noise by reducing the number of construction vehicles, leveling the number of passing vehicles, and complying with traffic rules as much as possible. Study Team also assumes that regular monitoring will enable us to take prompt action and minimize the effects of road traffic noise.

Table 13.4-7 Estimation of A-weighted equivalent noise level (L_{Aeq}) near the road

(Unit: dB(A))

Item		Speed (km/h)	
		40	50
Vehicles amounts per hour	10	53	55
	20	56	58
	30	58	60

Source: Study Team

(1-1-5-2) Vibration

(a) Construction vibration

The attenuation of the wave that the vibration source travels on the ground is affected by factors such as distance and soil quality. And generally, there is the following vibration propagation formula.

$$VL = VL_0 + 20\log_{10}(r_0/r)^n + (20\log_{10}e)(r_0 - r)\,\alpha$$

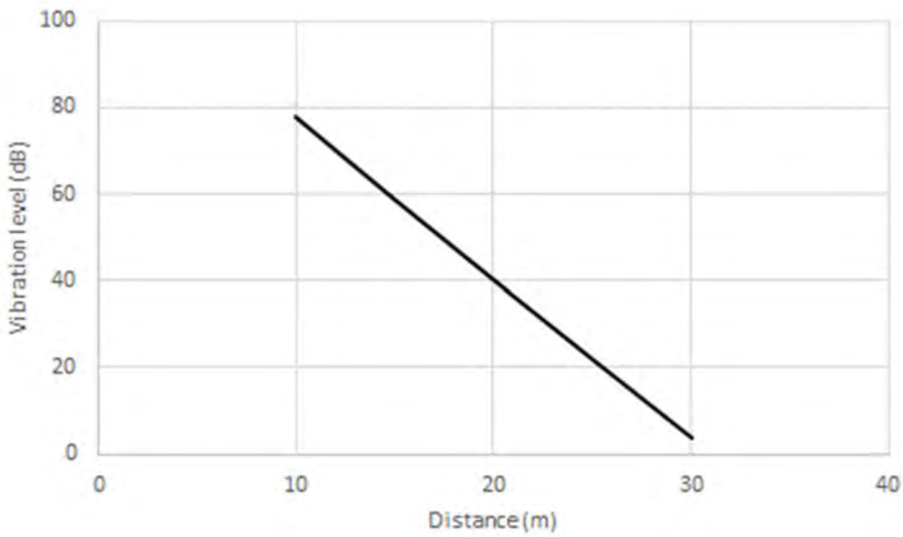
[Symbols/Marks]

VL : Vibration level at certain location (dB)
VL_0 : Vibration level at reference point (dB)

r_0：Distance from source to reference point (m)
r：Distance from source to certain location (m)
$20\log_{10}e=8.68$
n：Geometric damping constant：0.5
α：Ground damping constant：Clay：0.02-0.01, Sand・Silt：0.03-0.02

For example, a vibro hammer with vibration level of about 90 dB (Construction Work Vibration Prevention Guide (Ministry of Environment, Japan)) has a considerably smaller effect of vibration at a distance of 30 m (Figure 13.4-8).

The construction site of Units 3/4 is more than 100m away from the residential area, and it is conceivable that there is almost no effect of vibration.



Source: Study Team
Figure 13.4-8 Distance attenuation of vibration level

Since there is no regulation standard for vibration in Bangladesh, vibration standard for Japan is shown in Table 13.4-8 for reference. The standard of vibration of construction work is 75 dB at the boundary of the site.

Table 13.4-8 Vibration standard for factory (Japan)
(Unit: dB)

Item	Day time	Night time
Residential area	60-65	55-60
Commercial Industrial area	65-70	60-65

Source: Japanese vibration law

Vibration is generated by the operation of heavy machinery and construction vehicles, but like noise, its effect is limited to the surrounding area. By taking mitigation measures such as leveling the amount of work, introducing low-vibration equipment, and examining construction methods (pile driving with vibration is carried out during the daytime), the impact of vibration on the surroundings will be reduced as possible.

(b) Vibration near the road due to construction vehicles

After the access road is completed, it is conceivable that construction vehicles such as trucks will pass through. The vibration level along the road was estimated from the number of construction vehicles (large) passing by per hour with reference to the vibration propagation formula proposed by the Public Works Research Institute (Ministry of Land, Infrastructure, Transport and Tourism, Japan) (Table 13.4-9).

$$L_{10} = alog_{10}(log_{10}Q^{*}) + blog_{10}V + clog_{10}M + d + \alpha_{\sigma} + \alpha_{f} + \alpha_{s} - \alpha_{L}$$

[Symbols/marks]

L_{10}：Predicted 80% Vibration level (dB)

Q^{*}：Traffic amounts in 500second per 1 lane (number/500s/lane)

$Q^{*}=500/3600\times 1/M\times (Q_1+13Q_2)$

Q_1：Small vehicle (number/h)

Q_2：Large vehicle (number/h)

v：Speed (km/h)

M：Lane of inbound and outbound

α_{σ}：Correction value due to road surface flatness (dB) (Asphalt 8,2log (σ))

α_{f}：Correction value due to predominant frequency (dB) (f≧8Hz -17.3logf,　f<8Hz; -9.2logf-7.3)

α_{s}：Correction value due to road structure (flat: 0dB)

α_{l}：Distance attenuation value (dB) (Clay0.068L_{10}-2.0,　Sand 0.13L_{10}-3.9)

a, b, c, d：Contant term [flat] (a=47,b=12,c=3.5,d=27.3)

Table 13.4-9　Estimation of vibration level near the road

(Unit: dB)

Item		Speed (km/h)	
		40	50
Vehicles amounts per hour	10	31	32
	20	37	38
	30	39	40

Source: Study Team

There is no vibration standard in Bangladesh. For reference Japanese traffic vibration standards are shown in the following table.

(Unit: dB)

Item	Day time	Night time
Residential area	65	60
Commercial, industrial area	70	65

Source: Japanese vibration law

Near the road, vibration level of about 40 dB is estimated as vehicles pass. Study Team assumes that the impact of road traffic vibration can be reduced by reducing the number of construction vehicles, leveling the number of passing vehicles, and complying with traffic rules.

(1-1-6) Odor

If human waste from workers' camp and household waste are not properly treated, it will cause odor.

In Units1/2 construction work, household waste from the worker's camp is thoroughly separated and collected, the quality of domestic wastewater is been checking, regular patrols are carried out, and odor monitoring are been carrying out.

According to the monitor rig report, no malodorous substances (ammonia, hydrogen sulfide) were detected in the construction area.

In Units 3/4 construction work, Study Team assumes that the generation of odors can be minimized by taking the same measures as in Units 1/2 construction work.

(1-1-7) Waste

During construction, waste such as metal pieces, waste plastic, wood chips, waste glass, and waste oil will be generated. In addition, household waste such as empty cans, bottles, and kitchen waste are generated from the worker's camp.

In Units 3/4 construction work likewise, these waste will be thoroughly separated and collected, recycled and reused, and non-recyclable wastes will be disposed of by an appropriate contractor in accordance with the law.

(1-1-8) Ground subsidence

Ground subsidence is not expected because groundwater is not pumped up for causing land subsidence.

(1-2) Natural environment

(1-2-1) Protected Area

Sonadia Island ECA is located about 17 km away to the south. No large-scale earthwork nor reclamation is to be conducted within 3/4 Construction Project. Also, based on survey results of on-going environmental monitoring activity of 1/2 Construction Project, initiated in 2017, no significant change in local floral/faunal condition of this ECA is recognized. So that, no significant negative impact on Sonadia Island ECA by 3/4 Construction Project is expected to occur. Regarding the spreading of dust and/or exhausted gas, to be emitted during the operation phase, based on the simulation results conducted within this study, it is not likely that relevant plumes and/or gas would not reach those protected area. It is noted that it is important to review environmental monitoring results of Phase 1 Project continuously in case of possible environmental accidents. Any specific vessel routes around the project site during the operation phase are not determined yet. So that, it would be preferable to consider existences of those protected area within the determination of those shipping route as much as possible.

(1-2-2) Ecosystem

No large-scale earthwork nor reclamation is to be conducted within 3/4 Construction Project. Also, based on survey results of on-going environmental monitoring activity of 1/2 Construction Project (e.g., natural environmental factors of pre-construction phase such as temporal variations of the fish catch, number of sea turtle nesting, benthic species, zooplankton, phytoplankton), initiated in 2017, it is found that a relatively good-conditioned local natural environment is maintained around the project site and the living trace of the fishing cat (VU: IUCN-International and EN: IUCN-Bangladesh) is observed therein within the flora/fauna study of 3/4 Construction Project. So that, no significant negative impact on nearby local ecosystem is expected to occur as long as good coordination between both EMPs of 1/2 and 3/4 Construction Projects. It is noted that there are always environmental risks such as the accidental spill of construction effluents into surrounding water bodies. Thus, it is important to implement continuous environmental monitoring such as the water quality, the activity of local fishery as well as local flora/fauna. In particular, a regional conservation activity of Fishing Cat around the coastal area of the Bay of Bengal is popular (e.g., West Bengal and Orissa of India). Many international environmental conservation NGOs such as Fishing Cat Conservation Alliance. Fishing Cat Conservancy seem to have concerns on that activity. So that, appropriate information disclosures of the environmental monitoring activity would be important.

In general, the impact prediction methods of the biological environment are classified into following two categories, i.e., (i) quantitative methods (e.g., HES and/or HEP), and (ii) qualitative methods. Upon considering features of this Phase II Project, it is appropriate to explain the qualitative methods, considering various environmental monitoring parameters of both Phase I and Phase II environmental monitoring activities. It is noted that Phase I monitoring activities is on-going whereas that of Phase II is under preparation.

As described in Chapter 5, natural environmental features of the surrounding condition of the study site are broadly classified as either of the wetland, lagoon and beach. So that the close, continuous long-term observation of monitoring parameters such as the water quality (e.g., pH, DO, TSS, COD and other) that would sustain the healthy ecosystem for both local terrestrial and aquatic flora/fauna, and survey results of the phytoplankton, zooplankton and benthic fauna, possible preys for large carnivores around the study site, are essential for meaningful impact prediction.

Environmental monitoring activity of Phase I has been initiated in 2017 and huge volume of relevant environmental monitoring data has been accumulated continuously. So, based on those environmental monitoring database, it would be possible to conduct an impact prediction, provided that changes of the local topographic conditions, the land use pattern and/or other relevant events are closely linked with those environmental monitoring data.

It is found that no precise record of construction activities (e.g., site-specific earthwork, dredging and effluent discharge from the construction site) nor physical changes of surrounding local land use pattern is linked within the on-going environmental monitoring activities of Phase I. So, it is important that relevant environmental monitoring activities of Phase II shall be adaptive and flexible, considering the progress of each construction activities while having a quick, on-site diagnostic review of monitoring results by the third party in order to have a rational on-site judgement of necessity of additional monitoring activities.

Also, it would be beneficial to invite surrounding local communities (e.g., fishermen) to participate the future environmental monitoring activities of Phase II during the construction phase since the area of concerns is huge and its monitoring period would take several years. They usually do their social activities every day and tend to be quicker and easier to notice unusual events of the local environment. By taking these outside observations and/or reporting within the framework of monitoring activity of Phase II, it would be beneficial to implement more detailed survey as well as relevant mitigation measures. To achieve this, establishment of a flexible and adaptive environmental management and monitoring framework is essential, eventually leading to the more meaningful impact prediction based on both environmental monitoring activities of Phases I and II.

(1-3) Social environment

(1-3-1) Resettlement

There will be no new land acquisition for Units 3/4 project and no impact on resettlement is expected.

But measures will be taken as necessary while sharing the results of the monitoring survey after resettlement for Units 1/2 project.

(1-3-2) Poor people

The households that were forced to relocate due to the acquisition of land for Units 1/2 project have received compensation for relocation and are living in houses provided by CPGCBL. Therefore, no negative impact from the planning and construction of Units 3/4 project is expected, and a positive impact from the creation of employment opportunities is expected.

In addition, compensation was paid to the wage workers among the affected people by Units 1/2 project, employment would be provided during the construction of the power plant, and vocational training have been provided, but there are some complaints about the actual employment situation, so it is necessary to consider employment for the affected people and low-income groups in the area during the construction of Units 3/4.

(1-3-3) Ethnic minorities and indigenous peoples

It is confirmed that there are no ethnic minorities or indigenous peoples living in this area, and no impact is expected.

(1-3-4) Local economy such as employment and livelihood means

Increase of employment of local people in Units 3/4 construction activity is expected. But there are complaints for employment during Units 1/2 construction. Therefore, it is necessary to avoid the sense of dissatisfaction and unfairness among applicants by providing job training and offering easy-to-understand employment conditions according to the level of skill. And also, based on the skillness of local people and scope of work in the project, it will be considered that they can be given priority as construction worker.

In addition, there have been complaints of interference from fishermen and boat drivers in the construction of Units 1/2 project. Therefore, it is necessary to continue to prevent the impact of the project by informing the public in advance and adjusting the water area to be used by the project proponent including the contractor.

During the construction of Units 3/4, Units 1/2 are expected to be in operation, which is expected to have a positive impact on the local economy by increasing employment and human flow.

(1-3-5) Land Use and Utilization of Local Resources

There is no change in land use and local resource use due to Units 3/4 project. But there have been complaints about the impact of Units 1/2 project on salt fields, shrimp farming and fisheries. In order to address those complaints, measures should be taken as necessary while sharing the monitoring of Units 1/2 project.

(1-3-6) Water usage

Water to be used for the construction of Units 3/4 project is planned to be connected from other sources and stored in tanks, so no impact on local water use is expected.

In addition, rainwater and domestic wastewater from the power plant will be properly treated and discharged, so no impact on the surrounding water environment is expected.

On the other hand, there is a possibility of groundwater contamination due to ground improvement works and spills of oil and hazardous substances, so groundwater monitoring should be continued.

(1-3-7) Existing Social Infrastructure and Services

Construction materials for Units 3/4 project will be transported from the sea, and in addition, once Units 1/2 is in operation, the marine traffic related to power plant is expected to increase, requiring measures such as coordination with coastal fisheries and transportation, and the installation and dissemination of route signs.

With the construction of Units 3/4 the operation of Units 1/2 to Traffic jams and road deterioration are expected due to the increase in commuting vehicles for both Units 3/4 construction and Units 1/2 operation. In addition, it is desirable for the project proponent to coordinate and promote consultations with LGED, Union Chairmen and residents on measures for road repair and maintenance.

(1-3-8) Social institutions such as social infrastructure and local decision-making institutions

Units 3/4 project is not expected to have any impact on social organizations such as social capital and local decision-making bodies. However, in addition to the potential impact on existing social infrastructure and social services mentioned in the previous section, it is desirable to share local issues and coordinate measures as necessary. Since an initiative is already functioning under the coordination of the Prime Minister's Office, in which authorities and administrations involved in the development of the project in the Maheshkhali-Matarbari region share information and make adjustments as necessary, it is assumed that this initiative function will be effective for each project.

(1-3-9) Misdistribution of benefits and compensation

As there is no land acquisition in Units 3/4 project, no misdistribution of benefits and compensation is not expected. However, the impact of the construction work on existing social infrastructure and social services, and the possibility that the disparity between the residents affected by Units 1/2 project and those who were not compensated will become apparent, as well as the possibility that dissatisfaction with the misdistribution of benefits and compensation will increase due to the addition of problems such as inundation.

As a member of this society, the project proponent will be expected to contribute to the improvement of local social infrastructure and social services, as well as to the resolution of problems, in cooperation with social authorities, and to contribute to local communities through promotions of employment and CSR activities. For the employment, based on the skillness of local people and scope of work in the project, it will be considered that they can be given priority as construction worker.

Although the new Real Estate Acquisition and Expropriation Law was enacted in 2017, it is confirmed that the Unit 1/2 project will be implemented based on the system in place at the time of the procedure, and the compensation is based on the JICA ESC Guidelines, so no inequity is observed.

(1-3-10) Local conflicts of interest

There is little dissatisfaction with the compensation due to Units 1/2 project, and the DC office, the project proponent, NGOs, and consultants are working together to complete the compensation for Units 1/2 project, and no axis of conflict is recognized.

Since there is a high expectation for employment in this area, it is necessary to take into consideration that not only can a positive impact be assumed as an increase in employment opportunities related to the construction of the Units 3/4 project, but it can also be a source of conflict of interest within the region. It is desirable for the project operator and EPC contractor to work together to explain the project to the local community, devise vocational training programs that also take literacy into consideration, and secure the actual number of employees.

In addition, the project should be prepared in consideration of the consistency with the employment for the for Units 1/2 operation.

(1-3-11) Cultural heritage

There are no nationally or regionally designated cultural heritage sites within a 15km radius from the project site, and there are no cultural heritage properties at the settlement, village, or union level around the project site, and no impact is expected by Units 3/4 project.

(1-3-12) Gender

The gender consideration in the construction of Units 3/4 is expected to be the employment of women in construction-related activities.

However, considering the low literacy rate and lack of experience of women in this area, as well as the cultural and religious roles of women, it is desirable to provide employment opportunities that include a vocational training component.

It is also desirable to develop an employment plan that includes vocational training that takes into account the family structure and income of the women, considering that the improvement of livelihoods is also important as a gender consideration, given the role of women in this area.

(1-3-13) Children’s right

No children were found to be working in the construction of Units 1/2, and the same monitoring should be conducted in the construction of Units 3/4 project. In addition, in order to protect children's health and ensure their school attendance, it is desirable to conduct activities to contribute to the development of social infrastructure and improvement of social services, considering the importance of improving livelihoods and ensuring safe routes to school.

(1-3-14) Infectious diseases such as HIV/AIDS

There is a possibility of the risk that the infectious diseases such as HIV/AIDS will be introduced with migration of workers for Units 3/4 construction. In the construction of Units 1/2 awareness-raising, education, and training related to HIV/AIDS have been implemented, and have had a certain effect. Therefore, it is desirable to implement similar activities and monitoring during the construction of Units 3/4.

(1-3-15) Work environment (including work safety)

In the construction of Units 1/2 project, considerations have been given to the hygiene, safety and environment of the working environment and monitoring, such as sanitary equipment in the worker's dormitory, waste management, deployment of personal protective equipment, and deployment of fire extinguishers. The effect on the safety of the working environment has been confirmed. It is desirable to carry out similar activities and monitoring during the construction of Units 3/4 project.

On the other hand, during the construction of Units 1/2 project, two fatal accidents, a traffic accident of construction-related vehicles, and a marine accident of construction-related vessels occurred. In order to prevent the occurrence of these accidents, it is necessary to carry out training, education and enlightenment using posters and videos, and improvement of flow lines and signs in detail.

(1-3-16) Accidents

There is a possibility of traffic accidents on land and at sea during the construction of Units 3/4 project.

Therefore, it is desirable to promote not only safety education for construction workers and distribution of educational materials such as posters and videos, but also, to the extent possible, implementation of measures to prevent traffic accidents on surrounding roads, installation of signs at sea, and placement of educational posters on traffic safety at jetty and port.

(2) Operation phase
(2-1) Pollution control
(2-1-1) Air quality
(a) Exhaust gas from power plant
i. Air pollutants
i) Specification of exhaust gas

Sulfur oxides (SOx), nitrogen oxides (NOx), and soot dust (PM) will be generated by operation of the power plant.

This project will install desulfurization system (calcareous gypsum), electrostatic precipitator, low NOx burner and denitrification system (Selective catalytic reduction (SCR)).

The concentration of air pollutants in the exhaust gas is shown in the table below. Exhaust gas from Units 3/4 also complies with the exhaust gas standards and IFC/WB EHS Guidelines (Thermal Power Plants; 2017 draft) (Table 13.4-10).

This is based on the stricter standard values than the current IFC/WB EHS Guidelines (Thermal Power Plants; 2008) taking into consideration the cumulative impact with Units 1/2 currently under construction.

Table 13.4-11 shows the amount of exhaust gas, exhaust gas temperature, exhaust gas velocity, NOx, SOx, and PM emissions rate.

Table 13.4-10 Air pollutants in exhaust gas

Item	Unit	Units 1/2	Proposed Concentration of Units 3/4	Emission Standards of Bangladesh	IFC/WB EHS Guidelines (Thermal Power Plants; 2008)
SOx	mg/Nm^3	820	200	---	850
NOx	mg/Nm^3	309	62	600	510
PM	mg/Nm^3	50	25	500	50

Note: 1) There is no regulation of SOx.
2) O2＝6%
3) As reference; IFC/WB EHS Guidelines (Thermal Power Plants; 2017 draft)

Item	Unit	IFC/WB EHS Guidelines	
		NDA	DA
SOx	mg/Nm^3	200-600	200
NOx	mg/Nm^3	500	200
PM	mg/Nm^3	40	25

NDA = Non-degraded airshed; DA = Degraded airshed; Air quality in the project site is less than environmental standard value. Since air quality is favorable, NDA is referred.

Source: Study Team

Table 13.4-11 Specification of exhaust gas

Item	Unit	Units 1/2	Units 3/4
Emission volume (wet)	Nm^3/h	2,228,822	2,228,822
Exhaust temperature	ºC	93 (366K)	93 (366K)
Exhaust speed	m/s	6.7	6.7
Actual stack height	m	275	275
SOx	kg/h/unit	1,828	446
NOx	kg/h/unit	689	138
PM	kg/h/unit	111	56

Note: The process calculation of specification (parameters) of exhaust gas is as below.

Item	Target value	Calculation process		Parameter	For confirmation
SOx	200 mg/Nm^3	[before FGD] 5,572kg/h (=2,500mg/Nm3 x 2,228,822Nm3/h)	Desulfurization efficiency 92% (=1 - (200/2500) x100%)	[After FGD] 446kg/h (=5,572x0.08)	446kg/h (=200mg/Nm3 x 2,228,822Nm3/h)
NOx	62 mg/Nm^3 (as NO_2)	[before SCR] 668.7kg/h (=309mg/Nm3 x 2,228,822Nm3/h)	Denitration efficiency considering NOx fluctuation of 80% (=1 - (62/ (309)) x100%)	[After SCR] 138kg/h (= 668.7x0.2)	138kg/h (=62mg/Nm3 x 2,228,822Nm3/h)
PM	25 mg/Nm^3	[before EP] 19,167kg/h (=8,600mg/Nm3 x 2,228,822Nm3/h)	Electrostatic precipitator efficiency 99.7% (=1 - (25/8600) x100%)	[After EP] 56kg/h (= 19,167x0.003)	56kg/h (=25mg/Nm3 x 2,228,822Nm3/h)
Remarks	Target value for design was decided, based on IFC/WB EHS	(1-1) Coal specification: Performance coal (Sub-bituminous coal) of Units 1/2 project. (1-2) Sulfur content is about 1% in fuel. (3) Prerequisite			(1) Exhaust gas (Wet): 2,228,822Nm3/h (2) PM is predicted.as PM10/PM2.5

Item	Target value	Calculation process		Parameter	For confirmation
	Guideline (Thermal Power Station; 2017 draft)	[before FGD] By the design document for Units1/2 [before SCR] NOx concentration: 309mg/Nm3 is able to be achieved at boiler outlet by the balanced draft furnace with low NOx burners and over fire (two stage firing) system and pulverized coal from vertical shaft roller type mills [before EP] By the design document for Units1/2			

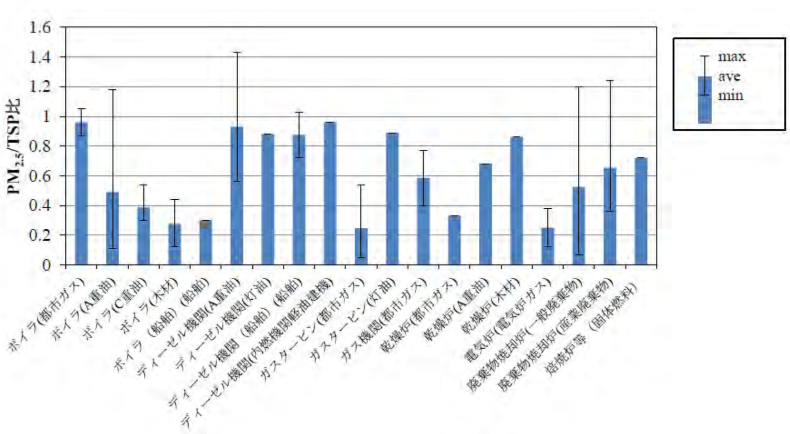
Source: Study Team

ii) PM/PM10/PM2.5

As for specification of exhaust gas, PM2.5 is referred to the past study reports.

PM2.5 in exhaust gas differs depending on the fuel type and combustion method.

The figure below is a survey report on PM2.5 / TSP (PM). PM2.5 is able to be estimated from TSP (PM).



Note: 1) X axis; Facilities that generated exhaust gas Y axis; Ratio PM2.5/TSP

2) From left;

Boiler (City gas), Boiler (A type heavy oil), Boiler (C type heavy oil), Boiler (Wood), Boiler (Ship), Diesel engine (A type heavy oil), Diesel engine (C type heavy oil), Diesel engine (Ship), Diesel engine (Light oil), Gas turbine (Liquefied natural gas), Gas turbine (kerosene), Gas engine (Liquefied natural gas), Drying furnace (Liquefied natural gas), Drying furnace (A type heavy oil), Drying furnace (Wood), Electric furnace, Incinerator (domestic waste), Incinerator (Industrial waste), Roasting furnace (solid fuel)

Source: The report of suspended particulate matter investigation committee 2020 (Tokyo metropolitan)

Figure 13.4-9　PM2.5/TSP (PM) in exhaust gas

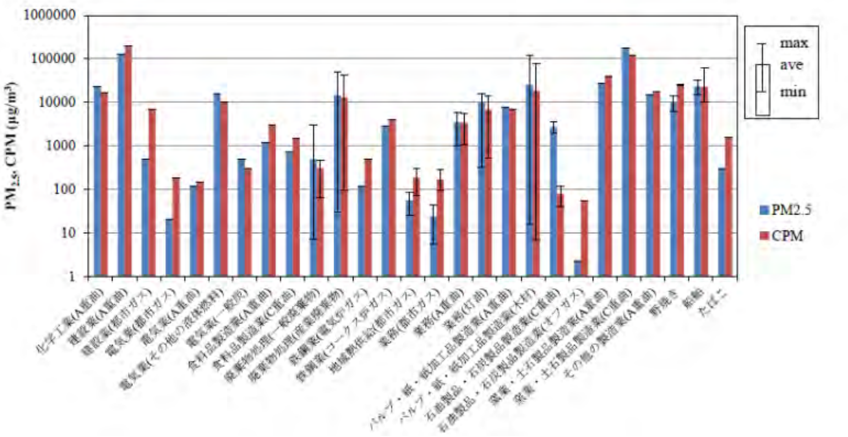
PM2.5 is composed of primary particles (Filterable Particular Matter (FPM)) in exhaust gas and secondary particles (Condensable Particular Matter (CPM)) condensed after emission from the stack.

CPM is gas, immediately after combustion, but after released into the atmosphere, gas becomes particulate due to being cooled. Therefore, it is difficult to add in the inventory at the time of discharge.

Figure 13.4-10 shows the result about the relation PM2.5to CPM. It is assumed PM2.5 is regards to CPM. On the other hand, Table 13.4-12 shows the result about the relation PM2.5to CPM.

It is difficult to certainly indicate the relation FPM to CPM.

In this study, about impact assessment of PM2.5, it is assumed, as that of PM.



Note: 1) X axis; Facilities (from each Sector) that generated exhaust gas Y axis; Ratio PM2.5/TSP

2) From left;

Chemical industry (A heavy oil), Construction industry (A heavy oil), Construction industry (City gas), Power sector (City gas), Power sector (A type heavy oil), Power sector (Solid fuel), Power sector (General furnace), Food manufacture (A type heavy oil), Food manufacture(C type heavy oil), Incinerator (domestic waste), Incinerator (Industrial waste), Steel manufacture (Electric furnace), Steel manufacture (Coke furnace), District heating, Office (City gas), Office (A type heavy oil), Office (Kerosene), Paper manufacture (A type heavy oil), Paper manufacture (Wood), Pastorium product manufacture (C type heavy oil), Pastorium product manufacture (Off gas), Ceramic industry (A type heavy oil), Ceramic industry (C type heavy oil), Others (A type heavy oil), Open burning, Ship, Cigarette

Source: The report of suspended particulate matter investigation committee 2020 (Tokyo metropolitan）

Figure 13.4-10 PM2.5, CPM in exhaust gas

Table 13.4-12 FPM2.5, CPM in exhaust gas

Table 3. Filterable PM (FPM) and condensable PM (CPM) emission factors of various combustion sources.

Source	Fuel Type (Facility Type)	TPM ($PM_{2.5}$)	$FPM_{2.5}$	$CPM_{2.5}$	$CPM_{2.5}/FPM_{2.5}$	Unit	Note
Korea NIER [12]	LNG	206.67	3.79	202.88	53.53	mg/m^3	boiler (uncontrolled)
	Light oil	65.78	3.38	62.40	18.46	mg/L	boiler (uncontrolled)
	B-C oil	371.47	143.83	227.64	1.58	mg/L	boiler (uncontrolled)
	Bituminous	71.65	6.55	65.10	9.94	g/ton	power plant (controlled)
US EPA AP-42 [20]	LNG (1997)	1.217	0.304	0.913	0.481	$kg/10^4m^3$	residential boilers
	Propane (1997)	0.084	0.024	0.060	0.300	kg/m^3	industrial boilers
	Propane (1997)	0.084	0.024	0.060	0.300	kg/m^3	commercial boilers
	Butane (1997)	0.096	0.024	0.072	0.359	kg/m^3	industrial boilers
	Butane (1997)	0.096	0.024	0.072	0.359	kg/m^3	commercial boilers
	distillate fuel oil (1999)	0.255	0.099	0.156	0.188	kg/m^3	residential combustion
	Anthracite (1975–1980)	0.399	0.363	0.036	0.045	kg/ton	stoker-fired boilers
	Bituminous (1999)	1.742	1.724	0.018	0.005	kg/ton	residential combustion
USA [21]	Bituminous (A—1994)	105	73	33	696	kg/kWh	power plant (controlled)
	Bituminous (A—2003)	84	23	60	4024		
	Bituminous (B)	101	14	87	10,261		
	Bituminous (D)	116	34	82	3653		
	Bituminous (E)	71	25	46	2956		
	Bituminous (F—1999)	190	51	139	4194		
	Bituminous (F—2003)	79	23	56	3792		
USA [22]	LNG with flue gas recirculation unit	1.96	0.11	1.86	1.96	kg/kWh	boiler (controlled)
	LNG with Selective Catalytic Reduction	1.63	0.09	1.55	1.63		heater (controlled)
	LNG with Selective Catalytic Reduction	4.78	0.14	4.64	4.78		turbine (controlled)
Taiwan [23]	Coal and Oil with EP	2.90	0.75	2.15	2.87	mg/m^3	power plant (controlled)
	Coal with bag house	46.20	16.90	29.30	1.73		boiler (controlled)
	Waste with bag house	0.32	0.15	0.17	0.53		incinerator (controlled)
	Electricity with bag house	4.65	2.12	2.53	1.19		arc furnace (controlled)
China [24]	Waste incineration power plant stack 1	1308	46.83	1261	26.93	$\mu g/ m^3$	SNCR + carbon adsorption + bag filter (controlled)
	Waste incineration power plant stack 2	748	51.70	696	13.47		

Source: Analysis of National PM2.5 (FPM and CPM) Emissions by Past, Current, and Future Energy Mix Scenarios in the Republic of Korea (Aug 2019, Multidisciplinary Digital Publishing Institute)

iii) Hazardous substances (mercury)

Hazardous substances (mercury) contained in coal are gasified during the combustion process. There is no information on the mercury content of coal procured in this project, and this survey will be examined with reference to the literature.

According to Table 13.4-13, the mercury content is reported to be 29-119 μg/kg depending on the coal type.

Table 13.4-13 Coal composition

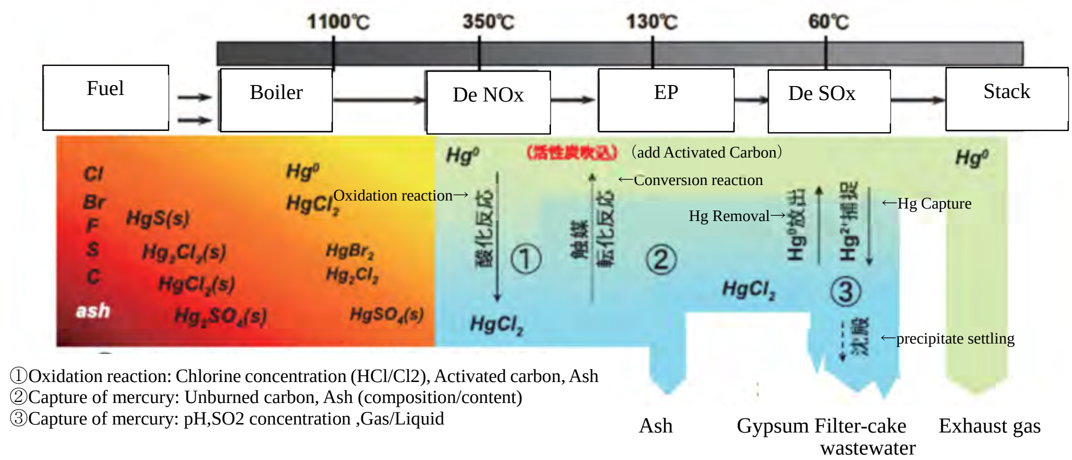
	Analysis value (wt%)	Analysis value (dry ash free wt%)	mg/kg	μg/kg

	Volatile	Coal	Moisture	Ash	C	H	O	N	S	Cl	Hg
Coal-A	33.1	55.4	1.7	9.8	82.8	5.3	9.8	1.6	0.6	233	114
Coal-B	27.4	57.7	2.3	12.6	85.4	5.2	7.3	1.9	0.3	408	49
Coal-C	27.6	60.0	4.2	8.2	82.9	4.8	10.0	2.0	0.3	176	29
Coal-D	26.0	58.8	4.6	10.6	81.1	4.4	12.0	1.8	0.67	2304	44
Coal-E	40.9	41.5	3.1	14.5	78.2	5.9	13.6	1.3	1.08	176	119

Source: "Behavior of Mercury and Suppression Technology in Coal Combustion Process" Hiroshi Moritomi (Global Environment 2008)

According to the past research reports, it has been confirmed that mercury is removed in the process of exhaust gas treatment equipment (Denitration, Dust removal, Desulfurization) as shown in Figure 13.4-11 and Table 13.4-14.

In this project, smoke exhaust treatment equipment (Denitration equipment, Electrostatic precipitator, Desulfurization equipment) will be installed, so some mercury will be removed during the treatment process.



Facility	Fuel	Coal washing	Bottom ash	EP	De Sox	Stack	Remarks
Pulverized coal boiler	Bituminous coal	10-50%	10%	0-27%	-63%	10-81%	US EPA et.al
Pulverized coal boiler	Sub Bituminous coal	10-50%	10%	18-81%	1-41%	2-52%	US EPA et.al
Stoker furnace			17%	17%		56%	Wang et.al
Pulverized coal boiler(small scale)			7%	23%		70%	Wang et.al
Incinerator				30-60%	6-40%	15-60%	Pirrone et.al
Incinerator(Small scale)			1.8%	13.9%	77%	7.3%	Nakamura et.al

Source: "Behavior of Mercury and Suppression Technology in Coal Combustion Process" Hiroshi Moritomi (Global Environment 2008)

Figure 13.4-11 Mercury removal in exhaust gas treatment process

Table 13.4-14 The removal of mercury by the treatment facility

Constitution		Bituminous coal	Bituminous coal	Lignite
Dust collector	Low EP	36%	3%	-4%
	High EP	9%	6%	N/A
	Bug filter	90%	72%	N/A
	Scrubber	N/A	9%	N/A
Dust collector + Spray dryer (SDA)	SDA+EP	N/A	35%	N/A
	SDA+ Bug filter	98%	24%	0%
	SDA+ Bug filter+ SCR	98%	N/A	N/A
Dust collector + Flue gas desulfurization	Scrubber+ FGD	12%	-8%	33%
	Low EP+ FGD	74%	29%	44%
	High EP+ FGD	50%	29%	N/A
	Bug filter+ FGD	98%	N/A	N/A

Source: Naoki Fujiwara: Merqury behavior by coal combustion(2010)

According to the study reports, the combination of electrostatic precipitator and desulfurization system can be expected to remove about 40% of mercury in the exhaust gas.

There is regulation (0.2 µg/Nm3 (200 µg/Nm3)) on mercury emission standards for coal-fired power generation in Bangladesh, Japan has 8 µg/Nm3 due to the amendment of the Air Pollution Control Act in 2018, and the United States has 1.3 g/GWh (Gross output) [Coal plant], 18 g/GWh (Gross output) [Lignite plant][13].

As for Table 13.4-15, the hourly coal (Sub-bituminous coal) consumption of Units 3/4 is 282 t/h. As mentioned above, the mercury content is 29 to 119 µg/kg, and amount of mercury emitted into the atmosphere is assumed as shown in the following table. As a result, it can comply with regulation in Bangladesh. Depending on coal condition, it may be able to meet the criteria of Japan, United States. Therefore, it is important to select coal that contents rate of mercury is low.

For the study about dispersion of air pollutant (mercury) in exhaust gas, mercury exhausted by Units 3/4 is assumed 9µg/Nm3.

Table 13.4-15 Amount of mercury emitted into the atmosphere (Units 3/4)

Item	Unit	Value	Remarks
Higher heating value, HHV	kcal/kg	4,600	Sub-bituminous coal
Lower heating value, LHV	kcal/kg	4,240	
Plant Net power Output	MW/unit	600	per unit
Fuel consumption	t/h/unit	282	564t/h (2 units)
Content of mercury (600MW basis)	µg/kg	29～119	
Mercury concentration in exhaust gas（as assumption）	g/h	8～34	
	g/GWh	14～56	
Mercury concentration after reduction by effort of EP+FGD	g/GWh	8～34	Removal ratio; 40％
As reference; USA standard	g/GWh	1.3 / 18	Coal / Lignite
Amount of exhaust gas	Nm3/h	2,228,822	per unit
Mercury concentration in exhaust gas（as assumption）	µg/Nm3	4～16	per unit
Mercury concentration after reduction by effort of EP+FGD	µg/Nm3	2～9	Removal ratio; 40％ per unit
As reference; Japanese standard	μg/Nm3	8	In case of new plant

Source: Study Team

Table 13.4-16 Mercury concentration in exhaust gas

Item	Unit	Units 1/2	Units 3/4
Emission volume (wet)	Nm^3/h	2,228,822	2,228,822
Exhaust temperature	ºC	93 (366K)	93 (366K)
Exhaust speed	m/s	6.7	6.7
Actual stack height	m	275	275
Mercury	kg/h/unit	0.040	0.020

Note：The mercury concentration of Units 1/2 is also assumed double concentration because PM concentration in exhaust gas of Units 1/2 was twice that of Units 3/4.

Source: Study Team

[13] Source: Emission standard USA (IEA clean coal centre), 40 CFR Parts 60 and 63 [EPA–HQ–OAR–2009–0234; EPA–HQ–OAR– 2011–0044; FRL–9789–5]

ii. Diffusion of air pollutants

i) The diffusion calculation by AERMOD

The diffusion calculation of air pollutants is performed by AERMOD (AMS (Advanced monitoring system) / EPA Regulatory MODEL) recommended by US Environmental Protection Agency and introduced in IFC/WB EHS Guidelines 2007.

AERMOD provides functions of processing for meteorological data (on ground and upper level), topographical data, and information for any structures related the project.

AERMOD gives the diffusion calculation results including special weather condition of downwash (Stack) / downwash (Building) and so on.

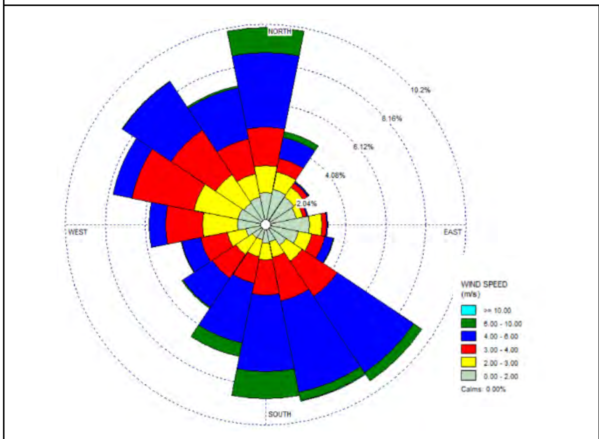
[Meteorological data]

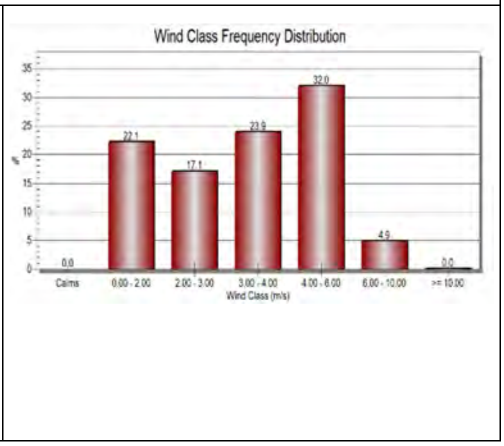
The diffusion calculation used meteorological data of hourly basis from 1st January 2018 to 31st December 2020 (during 3 years) provided by MM5 (at GL 3m).

Note; S.R.O Sl no. 75-Act/2020 issued on March 18th, 2020 requests the use of meteorological data of at least 3years to the project proponents.

The wind direction and speed distribution from 2018 to 2020 at the project site is shown as below.

2018.1.1-2020.12.31





Source: Study Team

Figure 13.4-12 Wind rose from 2018 to 2020

[Topographical data]

AERMAP that is combined to AERMOD proceeds terrain data that was taken from SRTM（Shuttle Radar Topography Mission) database.

The topographical conditions around this project are shown in the figure below, and there is a hilly area of about 50m high on the east side of the project site.

Figure 13.4-13 The topographical conditions around this project

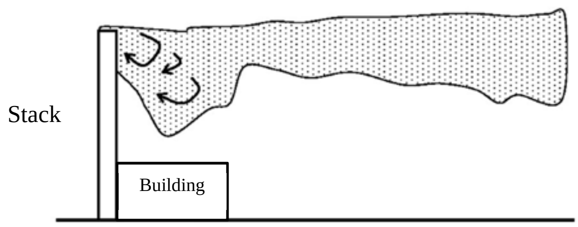
Source: Study Team

ii) Others; Study results of air pollutants under special weather condition

According to Units 1/2 FS report, the diffusion of air pollutants under special weather conditions was investigated, and the same study was also conducted in this survey. In the examination, we referred to "Regulation- Manual on total allowable volumes of Nitrogen Oxides" (Pollution Research Countermeasures Center) and "Guide for Environmental Impact Assessment of Power Plants" (Ministry of Economy, Trade and Industry).

[Consideration of Downwash (Stack) / Downwash (Building) for Units 3/4]

According to Briggs formula, downwash may occur when the exhaust gas velocity is less than 1.5 times of the wind speed at the stack outlet.



Source: Ministry of Economy, Trade and Industry, Guide for Environment Impact Assessment of Power Plant

Figure 13.4-14 Downwash (Stack)

The exhaust gas velocity of this project is about 6.7 m/s, and downwash (Stack) occurs when wind speed is more than 10 m/s at the smoke outlet (275m).

In case of estimating wind speed on the ground from wind speed at the stack height, if the "power law" of vertical wind speed distribution is used, wind speed at the ground level 2m will be more than about 5 m/s.

$$u = u_2 \left(\frac{z}{2}\right)^p$$

[Symbols/Marks]

u : Wind speed at the stack (m/s)

u_2 : Wind speed at 2m height (m/s)

z : Stack height (m)

p : power index (0.3)

The following proposed formula is used to calculate the diffusion of air pollutants.

$$c(x,y,z) = \frac{Q_p}{2\pi\sigma_y\sigma_z u} \cdot exp\left(-2\frac{y^2}{2\sigma_y^2}\right)\left[exp\left\{\frac{(z-He)^2}{2\sigma_z^2}\right\} + exp\left\{\frac{(z+He)^2}{2\sigma_z^2}\right\}\right]$$

[Symbols/Marks]

C : Pollutant concentration on ground at x (m)

Qp: Exhausted pollutant amount from source (g/s)

σy: Parameter for right angle vertical distance (m)

σz: Parameter for right angle horizontal distance (m)

u: Wind speed (m/s)

R: Distance from source point to receptor (m)

z: Height

He: Effective stack height (m)

He = H + ΔH

H: Stack height (m)

ΔH : Rising height (m)

Effective stack height is estimated by Briggs formula for downwash.

$$\Delta H = 2\left(\frac{V_s}{u} - 1.5\right)D$$

[Symbols/Marks]

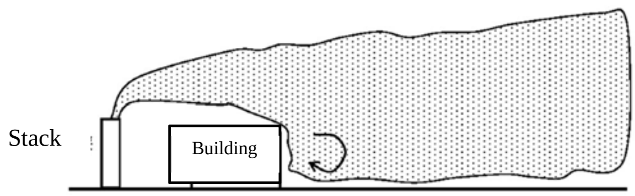
Vs: Exhaust gas velocity (m/s)

u: Wind speed at stack outlet (m/s)

D: Diameter of the stack (m)

According to Huber,. A. H. (Building wake effects on short stack effluents (1976)), building downwash may occur when the height of surrounding buildings is more than 2.5 times against the height of the stack.

If the stack height is 275m, buildings of more than 110m height are targeted, but there are no buildings in the vicinity except for the Units 1/2 stack.



Source: Ministry of Economy, Trade and Industry, Guide for Environment Impact Assessment of Power Plant

Figure 13.4-15 Downwash (Building)

[Consideration of Study of inversion layer for Units 3/4]

In the upper layer, an inversion layer is formed due to the reversal of temperature. Under the inversion layer, the concentration of air pollutants may be high. This occurs especially when the wind is weak in winter, when the surface temperature drops due to radiative cooling, and when the warm atmosphere of the sea surface flows into the cold surface.

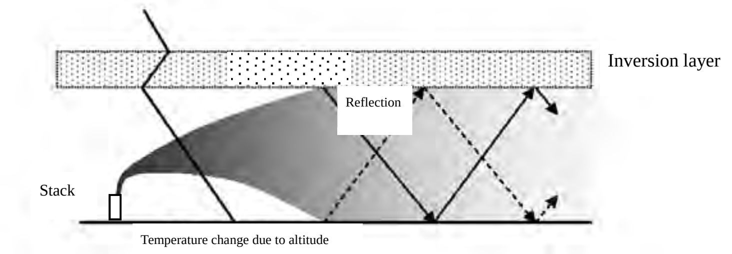
This area including the project site is warm, and the occurrence of the inversion layer is uncertainly. But this study estimated (for reference).

The lowest temperature at the project site was observed in January, for example, in case weak wind speed of 2m at stack height occurs, since there is no information on the occurrence altitude of the inversion layer, two cases of the occurrence altitude was set.

(Case 1) The height (about 620 m) at the effective stack height as with the Units 1/2 FS report

(Case 2) The height (about 440 m) at a half of rising plume in comparison with Case 1

The following proposed formulas are used to calculate the diffusion of air pollutants in the inversion layer.



Source: Ministry of Economy, Trade and Industry, Guide for Environment Impact Assessment of Power Plant

Figure 13.4-16 Inversion layer

$$\mathrm{c} = \frac{Q_p}{2\pi\sigma_y\sigma_z u}\sum_{n=3}^{3}\left\{exp\left\{\frac{(z-He+2nL)^2}{2\sigma_z^2}\right\}+exp\left\{\frac{(z+He+2nL)^2}{2\sigma_z^2}\right\}\right\}$$

[Symbols/Marks]

L : Altitude of inversion layer (m)

n: Reflection time due to inversion layer (n=3)

iv. Dispersion results

i) The diffusion calculation by AERMOD

[Air pollutants (SOx, NOx, PM) (Refer to Appendix 13.1 (1))]

The table below shows the prediction results of air pollutants from exhaust gas.

Table 13.4-17 The impacts of air pollutants from exhaust gas

Item		Units 3&4	Units 1-4
SO2	1hr value	The maximum contributed concentration was 110 μg / m3.	The maximum contributed concentration was 548 μg / m3.

		In addition, there is no value of both IFC/WB EHS Guidelines and Bangladesh air quality standard.	In addition, there is no value of both IFC/WB EHS Guidelines and Bangladesh air quality standard.
	24hr value	The maximum contributed concentration was 11.3 μg/m3. This value is lower than 365 μg/m3 of Bangladesh air quality standard. Even if the high background value observed in this study is added, it is 13.8 μg/m3, which is lower than values of both IFC/WB EHS Guidelines (125 μg/m3) and Bangladesh air quality standard.	The maximum contributed concentration was 56.7 μg/m3. This value is lower than 365 μg/m3 of Bangladesh air quality standard. Even if the high background value observed in this study is added, it is 59.2 μg/m3, which is lower than values of both IFC/WB EHS Guidelines (125 μg/m3) and Bangladesh air quality standard.
	1year value	The maximum contributed concentration was 1.3 μg/m3. In addition, there is no values of both IFC/WB EHS Guidelines and Bangladesh air quality standard.	The maximum contributed concentration was 6.6 μg/m3. In addition, there is no values of both IFC/WB EHS Guidelines and Bangladesh air quality standard.
NOx	1hr value	The maximum contributed concentration was 34.2 μg/m3. This value is lower than IFC/WB EHS Guidelines 200 μg/m3. In addition, there is no value of Bangladesh air quality standard.	The maximum contributed concentration was 200 μg/m3. This value is less than IFC/WB EHS Guidelines 200 μg/m3. In addition, there is no value of Bangladesh air quality standard.
	24hr value	The maximum contributed concentration was 3.5 μg/m3. Even if the high background value observed in this study is added, it is 8.5 μg/m3 In addition, there is no values of both IFC/WB EHS Guidelines and Bangladesh air quality standard.	The maximum contributed concentration was 20.7 μg/m3. Even if the high background value observed in this study is added, it is 25.7 μg/m3. In addition, there is no values of both IFC/WB EHS Guidelines and Bangladesh air quality standard.
	1year value	The maximum contributed concentration was 0.4 μg/m3. This value is lower than 100μg/m3 of Bangladesh air quality standard and 40 μg/m3 of IFC/WB EHS Guidelines.	The maximum contributed concentration was 2.4 μg/m3. This value is lower than 100μg/m3 of Bangladesh air quality standard and 40 μg/m3 of IFC/WB EHS Guidelines.
PM	1hr value	The maximum contributed concentration was 13.8 μg / m3. In addition, there is no value of both IFC/WB EHS Guidelines and Bangladesh air quality standard.	The maximum contributed concentration was 39.8 μg / m3. In addition, there is no value of both IFC/WB EHS Guidelines and Bangladesh air quality standard.
	24hr value	The maximum contributed concentration was 1.4 μg/m3. Assuming that all the prediction results are [PM10], it is 66.7 μg/m3 when the high background value observed in this study is added. This value is lower than 150μg/m3 of Bangladesh air quality standard and IFC/WB EHS Guidelines. Assuming that all the prediction results are [PM2.5], it is 29.3 μg/m3 when the high background value observed in this study is added. This value is lower than 65μg/m3 of Bangladesh air quality standard and 75μg/m3 of IFC/WB EHS Guidelines.	The maximum contributed concentration was 4.2 μg/m3. Assuming that all the prediction results are [PM10], it is 69.5 μg/m3 when the high background value observed in this study is added. This value is lower than 150μg/m3 of Bangladesh air quality standard and IFC/WB EHS Guidelines. Assuming that all the prediction results are [PM2.5], it is 32.1 μg/m3 when the high background value observed in this study is added. This value is lower than 65μg/m3 of Bangladesh air quality standard and 75μg/m3 of IFC/WB EHS Guidelines.
	1year value	The maximum contributed concentration was 0.2 μg/m3. Assuming that all the prediction results are [PM10], and IFC/WB EHS Guidelines, this value is lower than 50μg/m3 of Bangladesh air quality standard and 70μg/m3 of IFC/WB EHS Guidelines. Assuming that all the prediction results are [PM2.5], and Comparing Bangladesh air	The maximum contributed concentration was 0.5 μg/m3. Assuming that all the prediction results are [PM10], and Comparing Bangladesh air quality standard and IFC/WB EHS Guidelines, this value is lower than 50μg/m3 of Bangladesh air quality standard and 70μg/m3 of IFC/WB EHS Guidelines. Assuming that all the prediction results are

		quality standard and IFC/WB EHS Guidelines, this value is lower than 15μg/m3 of Bangladesh air quality standard and 35μg/m3 of IFC/WB EHS Guidelines.	[PM2.5], and Comparing Bangladesh air quality standard and IFC/WB EHS Guidelines, this value is lower than 15μg/m3 of Bangladesh air quality standard and 35μg/m3 of IFC/WB EHS Guidelines.

Note: IFC/WB EHS Guidelines in the table mean IFC/WB EHS Guidelines 2007
Source: Study Team

Table 13.4-18 Dispersion results for air pollutants

Item		Unit	Units 3&4			Units 1-4		
			1hr value	24hr value	1year value	1hr value	24hr value	1year value
SO2	Max contribution concentrations	μg/m³	110	11.3	1.3	548	56.7	6.6
	Predicted ambient concentrations (including background concentration)	μg/m³	-	13.8	-	-	59.2	-
	Distance until max contribution concentrations from power plants	km	2.4	3.3	3.4	2.6	3.1	3.5
	ECR	μg/m³	-	365	80	-	365	80
	IFC/WB EHS Guidelines 2007	μg/m³	-	125	-	-	125	-
NOx	Max contribution concentrations	μg/m³	34.2	3.5	0.4	200	20.7	2.4
	Predicted ambient concentrations (including background concentration)	μg/m³	-	8.5	-	-	25.7	-
	Distance until max contribution concentrations from power plants	km	2.4	3.3	3.4	2.1	3.1	3.5
	ECR	μg/m³	-	-	100	-	-	100
	IFC/WB EHS Guidelines 2007	μg/m³	200	-	40	200	-	40
PM	Max contribution concentrations	μg/m³	13.8	1.4	0.2	39.8	4.2	0.5
	Predicted ambient concentrations (including background concentration)[PM10]	μg/m³	-	66.7	-	-	69.5	-
	Predicted ambient concentrations (including background concentration)[PM2.5]	μg/m³	-	29.3	-	-	32.1	-
	Distance until max contribution concentrations from power plants	km	2.4	3.3	3.4	2.6	3.1	3.5
	ECR(PM10)	μg/m³	-	150	50	-	150	50
	IFC/WB EHS Guidelines 2007 (PM10)	μg/m³	-	150	70	-	150	70
	ECR(PM2.5)	μg/m³	-	65	15	-	65	15
	IFC/WB EHS Guidelines 2007 (PM2.5)	μg/m³	-	75	35	-	75	35

Note 1) The stack height of Units 1-4 is 275m
2) Regarding IFC/WB EHS Guidelines 2007 of SOx, PM[10], PM[2.5], the values of target-1 is referred to.
3) Background concentrations (bigger value is selected from monitoring survey results（24hr values）)

Location	Unit	SO_2	NO_X	PM_{10}	$PM_{2.5}$
Concentration at Matarbari village	μg/m³	<2.5	<5.0	**65.3**	27.1
Concentration at Dhalghata village	μg/m³	<2.5	<5.0	44.1	**27.9**

Source: Study Team

[Hazardous substances (Hg) (Refer to Appendix 13.1 (1))]

Table 13.4-19 shows the diffusion results of hazardous substances (Hg) in exhaust gas.

The annual average value of hazardous substances (Hg) by Units 3/4 is 0.00006µg/m3, and the annual average value of hazardous substances (Hg) by Units 1 - 4 is 0.00016µg/m3.

There is no environmental standard for mercury in Bangladesh, so, it is lower than the guideline value of 0.040 µg/m3 set by Japan.

Table 13.4-19 Dispersion results for Hazardous substances (Hg)

Item		Unit	Units 3&4			Units 1-4		
			1hr value	24hr value	1year value	1hr value	24hr value	1year value
Hg	Max contribution concentrations	µg/m^3	0.0050	0.00050	0.00006	0.0142	0.00149	0.00016
	Distance until max contribution concentrations from power plants	km	2.4	near the site	near the site	2.6	near the site	near the site
	Guideline vale by the Air Pollution Control Act, Japan	µg/m^3	-	-	0.040	-	-	0.040

Note; According to Air Quality Guidelines for Europe (WHO), mercury of estimated average daily intake (retention) of mercury compounds (µg) is shown in the table below.

Item	Mercury vapor	Inorganic mercury compounds	Methylmercury
Atmosphere	0.040-0.200	0	0

Source: Study Team

ii) Others; Study results of air pollutants under special weather condition (Refer to Appendix 13.1 (2))

Dispersion results for air pollutants under special weather condition [Units 3/4] is shown in Table 13.4-20. The impact due to Downwash is low.

Regarding the impact due to Inversion layer, it is depended on occurrence height. In the inversion layer, the temperature decreases as the altitude rises, but on the contrary, it rises. It is phenomenon that occurs when warm air flows into cold ground surface or cold sea surface.

Northwesterly winds predominate in January, when average temperatures are lowest. In this season, such phenomenon may be occurred in the southeast (on land) of the project site, but it is considered to be rarely and in limited time.

Table 13.4-20 Dispersion results for air pollutants under special weather condition (Units 3/4)

Time scale		Item	The highest concentration (µg/m^3)	The appearance distance from stack (km)	ECR (µg/m^3)	IFC/WB EHS Guidelines 2007 (µg/m^3)
Downwash		SO_2	25.7	3.3	-	-
		NO_2	8.0		-	200
		PM	3.2		-	-
Inversion layer	Occurrence height (about 550 m)	SO_2	58.5	3.4	-	-
		NO_2	16.1		-	200
		PM	7.3		-	-
	Occurrence height (about 410 m)	SO_2	111.4	2.1	-	-
		NO_2	34.5		-	200
		PM	14.0		-	-

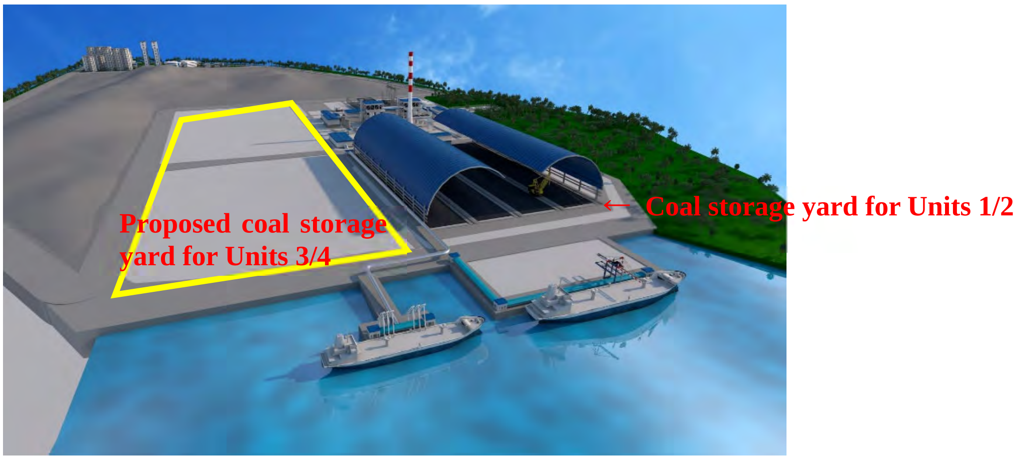
Source: Study Team

(b) Dust from coal storage yard and ash disposal area

When loading and unloading coal at a coal storage yard and disposing of coal ash at an ash disposal area, dust may be rolled up by wind.

According to the Beaufort scale in Table 13.4-2, dust is hoisted at wind speeds of more than 6 m/s. Around the project site, the frequency of wind speeds of 6 m/s or higher is about 6%.

For this reason, as same countermeasures of Units 1/2, the cover will be attached to the transport belt-conveyor for coal transport, and the coal storage yard will be with shed for prevention of rolling up dust.

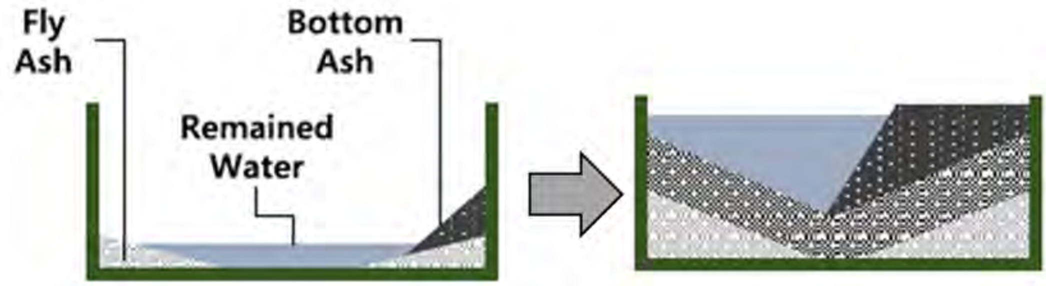


Source: CPGCBL

Figure 13.4-17　Outline of coal storage yard with shed

In addition, coal ash containing water is transported to the ash disposal area by pipe, and water is sprinkled (water filling) at the ash disposal area to prevent scattering.

It will be reduced the impact on the surrounding area by taking measures to prevent dust from rolling up.



Source: Study Team

Figure 13.4-18　Outline of the ash disposal area

(c) Air quality near the road due to construction vehicles

Refer to (1-1-1) Air quality (b) Air quality near the road due to construction vehicles.

Assuming that there are the related 30 vehicles (round trip)/h for commuting, maintenance equipment transportation during regular inspections with reference to similar cases[14], the concentrations of air pollutants along the road are as follows.

In addition, because of regular inspections of Units 1/2, the related vehicles for commuting, maintenance equipment transportation will be generated. Therefore it is necessary to consider conducting at both inspection times by different timing.

Table 13.4-21　Concentration of air pollutants along the road (μg/m3)

Items	Wind speed 3m/s		Calm	
	Speed (km/h)			
	40	50	40	50
NOx	0.06	0.05	0.08	0.07
PM	0.003	0.003	0.004	0.004

Source: Study Team

(2-1-2) Water quality

Due to the operation of the power plant, the environmental impact of wastewater from the power plant,

[14] According to the "Hirono Coal fired Power, Unit 5 and 6 Environmental Survey Report (1200MW)" (Tokyo Electric Power Co., Inc.), the number of vehicles involved during regular inspections has been planned to be 190 (one way).

oil-impregnated wastewater, domestic wastewater, and thermal effluent are predicted.

(2-1-2-1) Thermal effluent

About the cooling water used at the power plant, seawater of slightly low temperature with will be slowly taken (0.2 m/s), and thermal effluent will be discharged from the outlet at 1 km north of the port.

Water temperature of thermal effluent will be planned to keep ΔT 7 ºC compared to water taken, and it must meet the industrial wastewater standards.

The diffusion simulation of thermal effluent generated by the power plants consists of flow condition simulation and diffusion simulation of thermal effluent. Refer to Appendix 13.1 (2) for detailed information.

Table 13.4-22 shows the calculation conditions such as the amount of thermal effluent discharged generated by the power plant. As for the flow in sea area, the dominate flow was examined with reference to the results of the field survey. Sea bottom topography was referred to the nautical chart, and meteorological data such as temperature, wind speed and so on, was referred to observation data by the nearest station.

Table 13.4-22 Parameter of thermal effluent

Item	Parameter	Remarks
Intake amount	49.69m^3/s	All of unit is same value.
Discharge amount	49.52m^3/s	Same as above
Temperature	Less than 40ºC	Same as above The temperature difference between intake and discharge is secured at ΔT 7 ºC
Geographical features	Based on port design including dredging area around the outlet of thermal effluent (phase 1)	

Source: Study Team

[Summer (rainy season)]

Water temperature change area extends from the outlet to northeast at high tide and southwest at low tide according to changes in flow direction and flow velocity due to tidal changes.

Water temperature change range is limited. When Units 1/2 and Units 3/4 are operating, water temperature change of the vicinity of the outlet is less than 3.0°C.

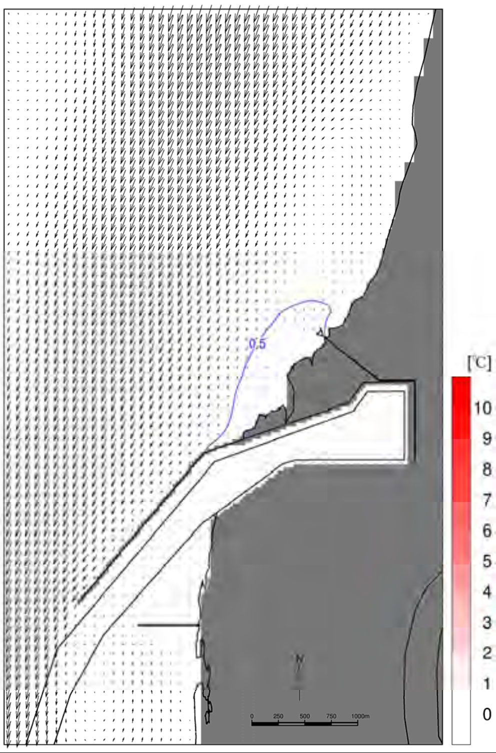
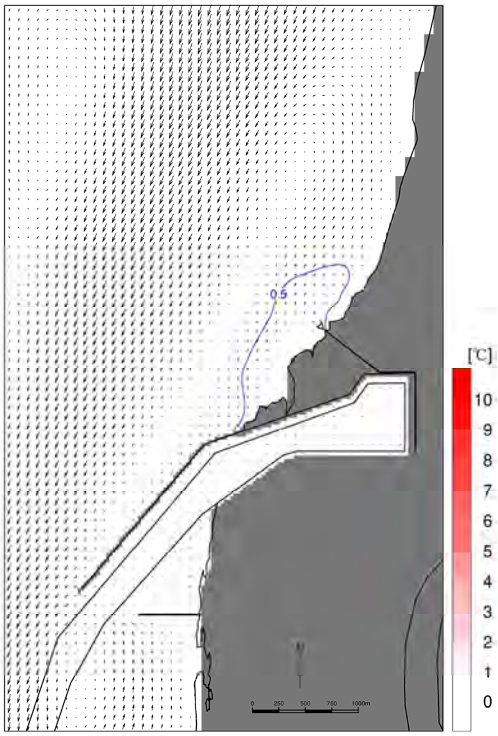
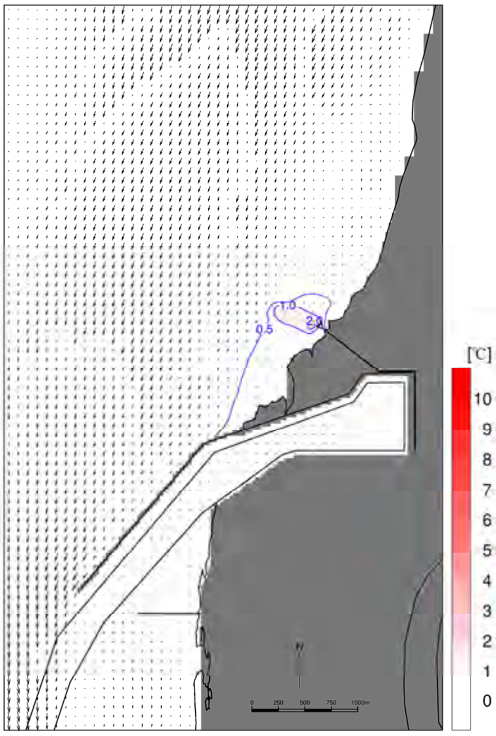
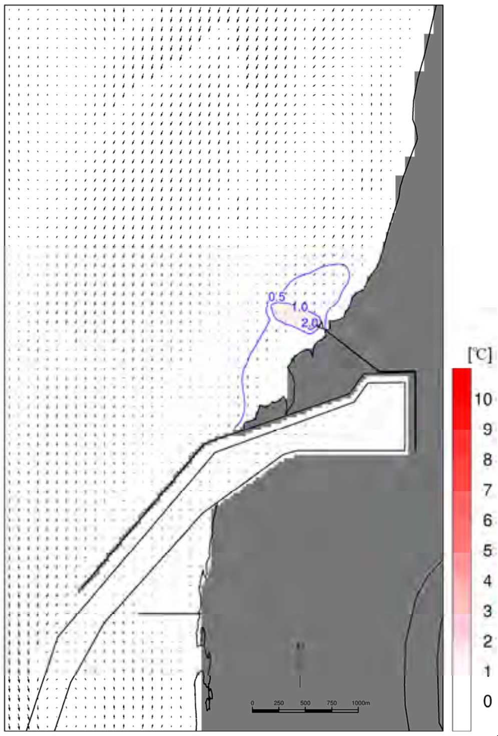
[Winter (dry season)]

Same as summer (rainy season), water temperature change area extends from the outlet to northeast at high tide and southwest at low tide along the coast.

In winter (dry season), seawater temperature is relatively low, and temperature difference from thermal effluent is large. Therefore, the influence of warm water discharged from deep layer easily reaches the surface layer.

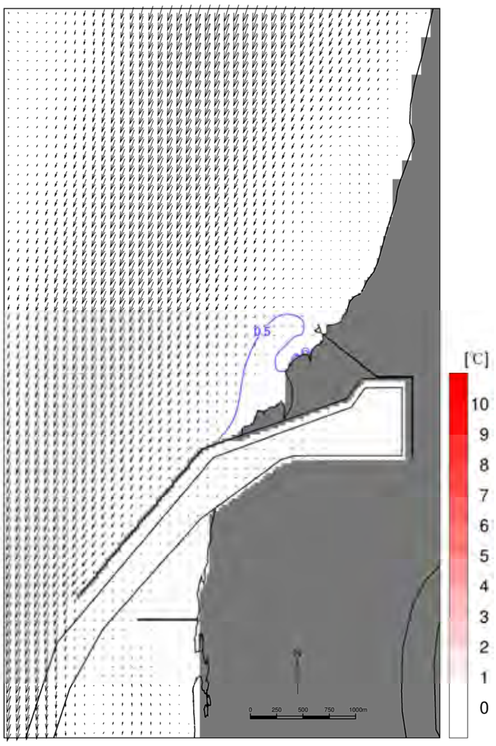
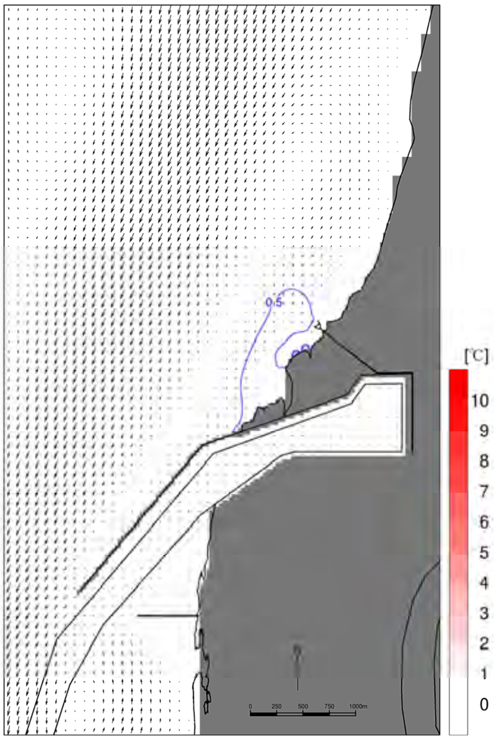
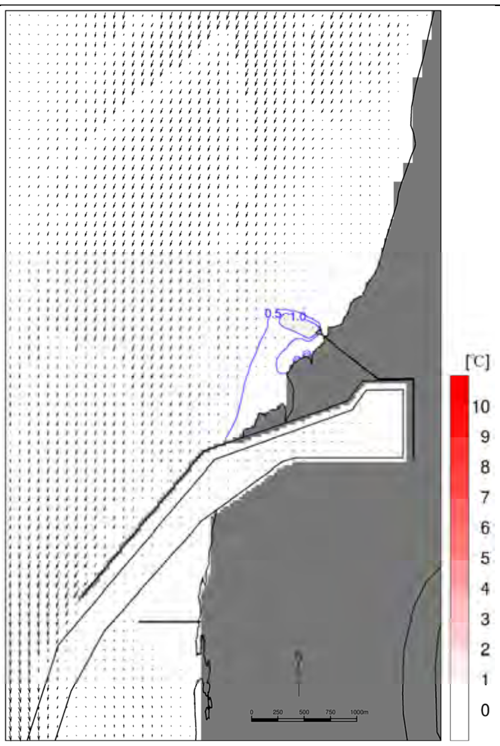
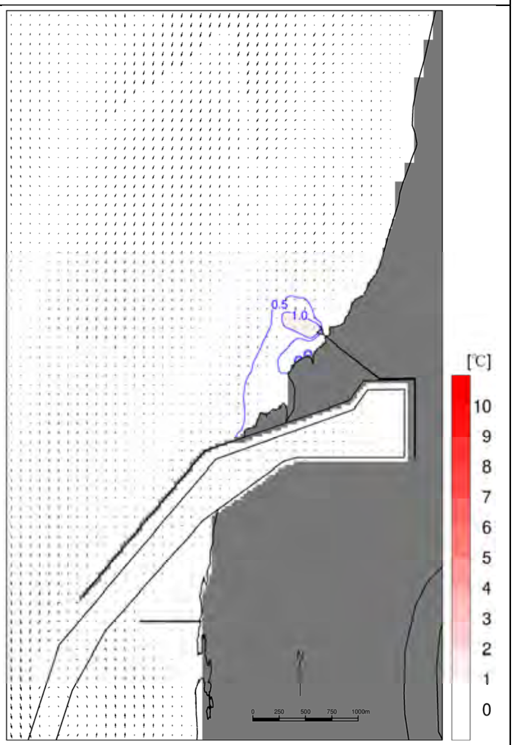
Since the flow velocity of surface layer is higher than that of lower layer, the influence of warm water that reaches surface layer spreads in northeast-southwest direction along the coast. But when Units 1/2 and Units 3/4 are operating, water temperature change of the vicinity of the outlet is less than 3.0 °C.

Diffusion simulation of thermal effluent during operation of Units 1/2 and 3/4 in summer (rainy season) and winter (dry season) is carried out in accordance with the flow conditions for 12 hours, but the figures below are partial excerpts. Refer to Appendix 13.1 for detailed results.

Time	t=1(hour) – Low tide	t=2(hour)
Surface layer		
Bottom layer		

Remarks
(1) The change in water temperature shows the difference from the case without thermal effluent.
(2) The “time” shown in the figure indicates the time when t = 1 (hour) is set at low tide after reaching steady change in accordance with the tide of the 12-hour cycle.
Source: Study Team

Figure 13.4-19 Changes in water temperature, flow direction / flow velocity due to thermal effluent in summer (rainy season) [Units 1/2 and 3/4 are operating]

Time	t=1(hour) – Low tide	t=2(hour)
Surface layer		
Bottom layer		

Remarks
(1) The change in water temperature shows the difference from the case without thermal effluent.
(2) The “time” shown in the figure indicates the time when t = 1 (hour) is set at low tide after reaching steady change in accordance with the tide of the 12-hour cycle.

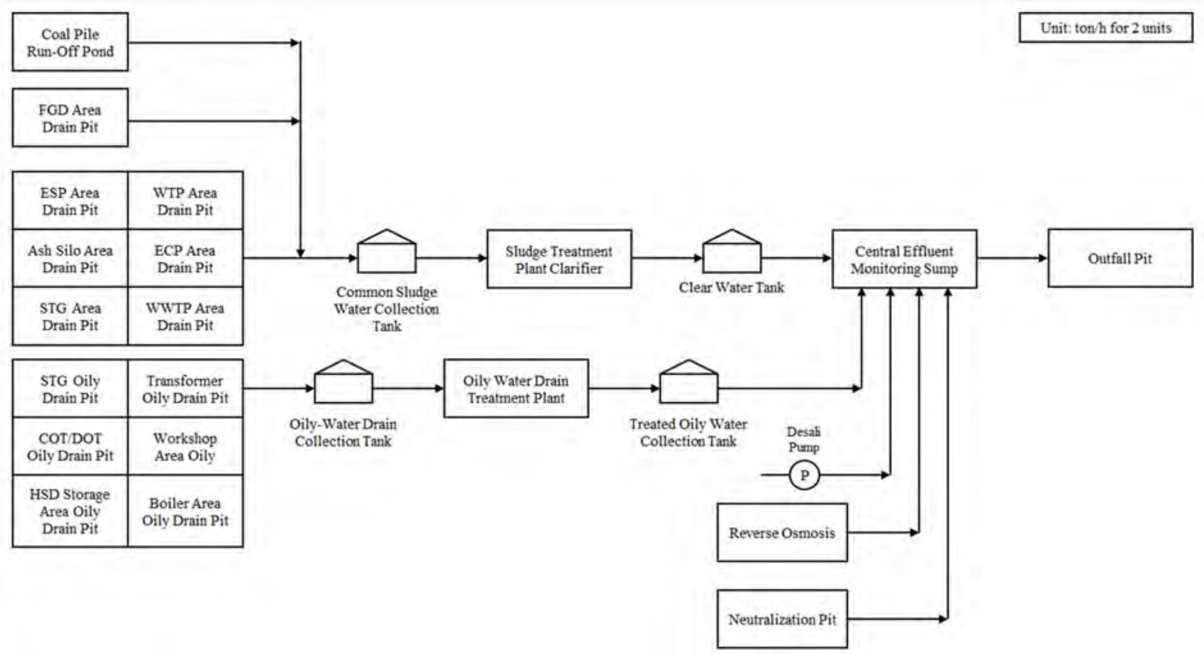
Source：Study Team

Figure 13.4-20　Changes in water temperature, flow direction / flow velocity due to thermal effluent in winter (dry season) [Units 1/2 and 3/4 are operating]

(2-1-2-2) Wastewater from the power plant, oil-impregnated wastewater and domestic wastewater

Wastewater is generated from each facility due to operation the power plants. Same as Units 1/2, Wastewater treatment facility is composed of neutralization, coagulation sedimentation, filtration, etc., and wastewater will be treated appropriately to meet Bangladesh standards and IFC/WB EHS Guidelines (Thermal Power Plant 2008) values.

As a result, it is considered the impact of water quality to the surrounding area is limited.



Source: Study Team

Figure 13.4-21 Wastewater flow

(2-1-2-3) Coal yard and Coal ash disposal area

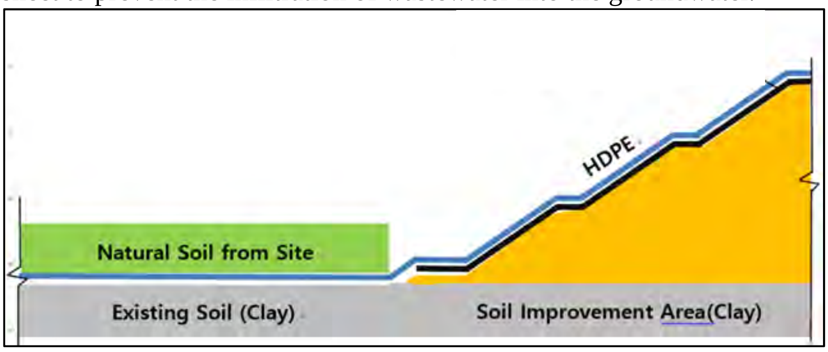
Wastewater from coal storage yard is planned to be sent to the wastewater treatment facility for proper treatment.

Wastewater from coal ash disposal area is basically treated by natural evaporation and is not discharged outside the project site.

In addition, storm water remained in coal ash disposal area will be used for greening.

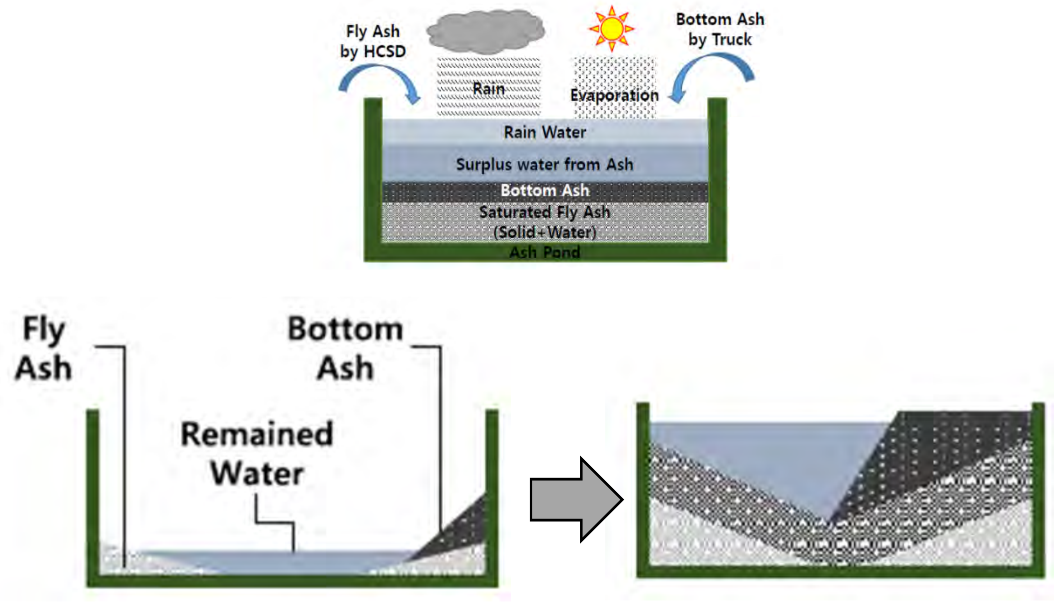
Therefore, water pollution to the surrounding area due to wastewater from coal ash disposal area is not expected.

In addition, the bottom of coal ash disposal area will be covered with HDPE (High Density Polyethylene) sheet to prevent the infiltration of wastewater into the groundwater.



Source: Study Team

Figure 13.4-22 Measures to prevent underground infiltration at coal ash disposal area



Note: HCSD means High Concentration Slurry Disposal
Source: Study Team

Figure 13.4-23 HCSD means High Concentration Slurry Disposal

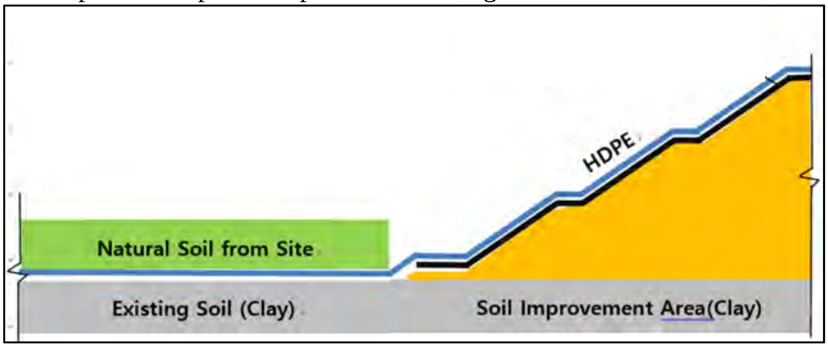
(2-1-3) Soil

(2-1-3-1) Soil

In the operation of the facility, the leakage of oil and chemical substances may cause soil contamination. How to store oils and chemical substances, and measures to prevent penetration into soil shall be added.

(2-1-3-2) Coal ash disposal area

By covering the ground surface with an HDPE (High Density Polyethylene) sheet, wastewater from coal ash disposal area prevents penetration into groundwater.



Source: Study Team

Figure 13.4-24 Measures to prevent underground infiltration at coal ash disposal area

(2-1-4) Sediment pollution (seabed)

The impact on sediment pollution can be minimized by taking the measures, such as rainwater drainage treatment from coal storage and ash dumps, installation of impermeable layers such as High Density Polyethylene (HDPE) sheet.

(2-1-5) Noise and Vibration

(2-1-5-1) Noise

(a) Operation of facility

Noise due to the operation of the power plant are predicted. Since there are residences near the site, consideration should be given to minimizing the impact of noise. Noise level due to the operation of the main equipment of the power plant was predicted by the following prediction model.

i) Prediction model of noise level

When examining the noise level, there is the following noise propagation formula*.

*ISO 9613: Acoustics-Attenuation of sound during propagation outdoors
Part 1: Calculation of the absorption of sound by the atmosphere
Part 2: General method of calculation

$$L_{PA} = L_{WA} - 20 \cdot \log_{10} R - 8 - A_{\gamma} - A_{E}$$

[Symbol/Marks]

L_{PA} : Predicted noise level at certain location (dB)
L_{WA} : A-weighted sound pressure level (dB)
R : Distance from noise source to certain location
A_{γ} : Attenuation due to barrier (dB)
A_{E} : Attenuation due to air absorption (dB)

ii) Noise source

The main equipment involved in the operation of power plants are boilers, coal mills, fans, ducts, desalination equipment, wastewater treatment facilities, coal belt conveyors, etc. Table 13.4-23 shows noise level and the number of each equipment.

Table 13.4-23 Noise level of the main equipment

Item	Equipment Type	Units 1/2		Units 3/4	
		Noise Power Level(dB)	Number of Equipment	Noise Power Level(dB)	Number of Equipment
Power plant facility	Boiler	70	2	70	2
	Coal mill	90	2	90	10
	Forced draft fan	105	2	105	4
	Air pre-heater	72	2	72	2
	EP	80	2	80	2
	FGD	70	2	70	2
	Induced draft fan	105	2	105	4
	Gas Duct	108	2	108	2
	Pump for FGD	101	2	101	4
	Circulation Pump	101	2	101	2
	Turbine building	70	2	70	2
	main transformer	90	2	90	6
Utility facility	Coal un-loader	84	2	--	---
	Coal conveyor from un-loader	87	3	87	2
	Stacker / reclaimer	84	10	84	8
	Coal conveyor to plant	87	3	87	2
	Demineralization plant	101	1	101	1
	Water treatment equipment	101	1	101	1
	Waste water treatment equipment	101	1	101	1
	Ash conveyor	101	1	101	1
	Waste water equipment for coal yard	101	1	101	1
	Switch yard	90	1	90	1

Source: Study Team

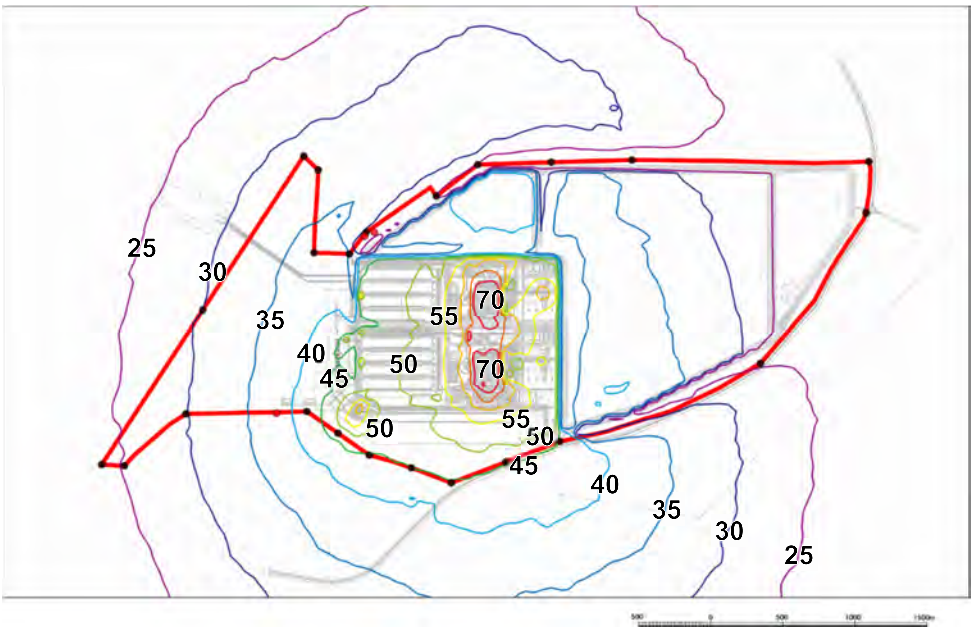
iii) Calculation conditions

The noise level was calculated on the assumption that all of equipment Units 1/2 and Units 3/4 are in operation.

iv) Calculation result

As shown in the following figure, noise level reached by the operation of both power plants is 14 to 48 dB (A) at the boundary of the site and 26 to 38 dB (A) around the residential area (north and south sides).

Bangladesh standard and IFC/WB EHS Guidelines 2007 value can be complied with.



Note: detailed result

No	Noise Level (dBA)	DOE Limit Standard	IFC/WB EHS Guidelines 2007
1	31.3	Industrial Zone; Day 75 Night 70	Industrial Zone; Day 70 Night 70
2	32.7		
3	36.7		
4	34.7		
5	28.4		
6	24.8		
7	24.7		
8	21.6		
9	18.9		
10	13.8		
11	14.0		
12	24.1		
13	43.9		
14	46.9		
15	45.5		
16	45.0		
17	44.8		
18	47.7		
19	42.1		
20	29.9		
21	25.3		

22	23.7		
23	30.0		
24	26.2	Residential Zone: Day 55 Night 45	Residential Zone: Day 55 Night 45
25	28.0		
26	38.0		

Source: Study Team

Figure 13.4-25 Predicted noise level (Units 1/2 and Units 3/4 are operated)

(b) Noise near the road due to vehicles

Refer to (1-1-5-1) Noise (b) Vibration near the road due to construction vehicles.

Assuming that there are the related 30 vehicles (round trip)/h for commuting, maintenance equipment transportation during regular inspections with reference to similar cases[15], noise near the road due to vehicles are as follows.

Table 13.4-24 Estimation of A-weighted equivalent noise level (L_{Aeq}) near the road

(Unit: dB(A))

Item	Speed (km/h)	
	40	50
30 Vehicles per hour	58	60

Source: Study Team

Along the road, a noise level of about 60 dB is assumed due to the related vehicles (Table 13.4-7). JICA Study Team will reduce the impact of road traffic noise by reducing the number of related vehicles, leveling the number of passing vehicles, and complying with traffic rules as much as possible.

Study Team also assumes that regular monitoring will enable us to take prompt action and minimize the effects of road traffic noise.

(2-1-5-2) Vibration

(a) Operation of facility

In addition to improving the ground and installing equipment and machinery on stable and solid ground, it is possible to reduce the effects of vibrations associated with the operation of the facility by suppressing vibration propagation through anti-vibration measures.

[15] According to the "Hirono Coal fired Power, Unit 5 and 6 Environmental Survey Report (1200MW)" (Tokyo Electric Power Co., Inc.), the number of vehicles involved during regular inspections has been planned to be 190 (one way).

(b) Vibration near the road due to vehicles

Refer to (1-1-5-1) Vibration (b) Vibration near the road due to construction vehicles.

Assuming that there are the related 30 vehicles (round trip)/h for commuting, maintenance equipment transportation during regular inspections with reference to similar cases[16], vibration near the road due to vehicles are as follows.

Table 13.4-25 Estimation of vibration level near the road

(Unit: dB)

Item	Speed (km/h)	
	40	50
30 Vehicles per hour	39	40

Source: Study Team

Near the road, vibration level of about 40 dB is estimated as vehicles pass. Study Team assumes that the impact of road traffic vibration can be reduced by reducing the number of construction vehicles, leveling the number of passing vehicles, and complying with traffic rules.

(2-1-6) Odor

There is the possibility that waste from the office and human waste may generate foul odor. Therefore, appropriate disposal of waste and sewage treatment equipment for human waste will be installed.

Since ammonia is used in the denitration equipment, the storage of ammonia shall be adequately carried out. As results, the odor due to leakage of malodorous substances will not affect the surrounding area.

In addition, environmental monitoring of malodorous substances will be carried out.

(2-1-7) Waste

As with Units 1/2, waste management program will be established, and 3Rs (Reduce, Reuse, Recycle) will be promoted in order to systematically collect waste and thoroughly manage storage facilities based on laws and regulations.

Specifically, the effective use of coal ash and gypsum generated from desulfurization facilities will be promoted as raw materials for cement, road-materials, and bricks.

(2-2) Natural environment

(2-2-1) Protected Area

Sonadia Island ECA is located about 17 km away to the south from the project site, so that it is expected that no significant negative impact will occur during the operation phase. It is noted that there is an environmental risk of the regional spreading of dusts and/or dispersion of exhausted gas, to be emitted from 3/4 Project site. So that, it is imperative to pay attentions to the monitoring activity of 1/2 Project that would start its operation several years earlier than 3/4 Project while incorporating possible feedback into relevant EMP of 3/4 Project.

There will be a potential environmental risk of the future maritime transport accident around the Sonadia ECA. It is important to set the coal shipping route to Matarbari Port far away from Sonadia Island ECA, considering the local coastal current conditions. Also, similar environmental risk of spreading of the ballast water, to be discharged from vessels mooring around the Matarbari Port. So, it is imperative to pay attentions to the monitoring activity of 1/2 Project that would start its operation several years earlier than 3/4 Project while incorporating possible feedback into relevant EMP of 3/4 Project.

(2-2-2) Ecosystem

There will be potential environmental risks such as the emission of the exhausted gas from the power plant, discharge of industrial effluents during the operation phase. It is essential to develop proper environmental management program and relevant mitigation measures. Besides, it is essential to identify possible important direct/indirect influenced area through a series of simulation studies while paying attentions to the monitoring

[16] According to the "Hirono Coal fired Power, Unit 5 and 6 Environmental Survey Report (1200MW)" (Tokyo Electric Power Co., Inc.), the number of vehicles involved during regular inspections has been planned to be 190 (one way).

activity of 1/2 Project and then, incorporating possible feedback into relevant EMP of 3/4 Project.

There will be potential environmental risk spreading of the ballast water, to be discharged from vessels mooring around the Matarbari Port. In particular, a regional conservation activity of Fishing Cat around the coastal area of the Bay of Bengal is popular (e.g., West Bengal and Orissa of India). Many international environmental conservation NGOs such as Fishing Cat Conservation Alliance、Fishing Cat Conservancy seem to have concerns on that activity. So that, appropriate information disclosures of the environmental monitoring activity would be important.

As mentioned above, natural environmental features of the surrounding condition around the study site are broadly classified as either of wetland, lagoon and beach. So that the close, continuous long-term observation of monitoring parameters such as the water quality (e.g., pH, DO, TSS, COD and other) that would sustain the healthy ecosystem for both terrestrial and aquatic flora/fauna, and survey results of the phytoplankton, zooplankton and benthic fauna, possible preys for large carnivores around the study site, are essential for meaningful impact prediction.

Also, it would be beneficial to invite surrounding local communities (e.g., fishermen) to participate the future environmental monitoring activities of Phase II since the area of concerns is huge and its monitoring period during the operation phase would take several years. They usually do their social activities every day and tend to be quicker and easier to notice unusual events of the local environment. By taking these outside observations and/or reporting within the framework of monitoring activity of Phase II, it would be beneficial to implement more detailed survey as well as relevant mitigation measures. To achieve this, establishment of a flexible and adaptive environmental management and monitoring framework is essential, eventually leading to the more meaningful impact prediction based on both environmental monitoring activities of Phases I and II.

(2-3) Social environment

(2-3-1) Poor people

The households that were forced to relocate due to the acquisition of land for Units 1/2 project have received compensation for relocation and are living in houses provided by the CPGCBL.

Therefore, it is not expected that they will be negatively affected by Units 3/4 operation. On the other hand, it is expected that the project will create employment opportunities and improve access to social services due to the development of infrastructure around the power plant.

In addition, compensation was paid to the wage workers among the affected people by Units 1/2 project, employment would be provided during the construction of the power plant, and vocational training have been provided, but there are some complaints about the actual employment situation, so it is necessary to consider employment for the affected people and low-income groups in the area during the construction of Units 3/4.

And low-income groups in the region will be created and access to social services will be improved.

(2-3-2) Local economy such as employment and livelihood means

It is predicted that there are no significant changes in the current and water temperature due to the discharge of cooling water from Units 3/4 project. Hence, no impact on the fisheries and salt/shrimp industries is expected.

It is assumed that the local economy will be positively affected by the increase in employment and human flow. But it should be considered that complaints on employment have been raised during the construction of Units 1/2. In order to address this dissatisfaction, it is necessary to dispel the dissatisfaction and sense of unfairness among applicants by providing vocational training and presenting easy-to-understand employment conditions according to the level of skill, thereby creating an employment promotion effect.

(2-3-3) Land use and utilization of local resources

The is no land use change, and it is predicted that there are no significant changes in the current and water temperature due to the discharge of cooling water from Units 3/4 project, and rainwater and domestic wastewater from the power plant will be discharged after appropriate treatment. Therefore, the impact on the utilization of local resources, such as seawater for salt farming and fisheries is not significant.

(2-3-4) Water usage

The freshwater process water to be used for Units 3/4 operation service will be produced by seawater desalination and stored in tanks. Therefore, no impact on local water use is expected.

Rainwater and domestic wastewater from the power plant will be properly treated and discharged to the seaside, and cooling water will also be discharged to the seaside, so no impact on the use of seawater for salt production in the salt fields is expected.

(2-3-5) Existing social infrastructure and services

Raw materials, including coal and necessary materials for the operation will be transported from the sea for the time being, which is expected to increase vessel navigation. Therefore, it is necessary to take measures such as coordination between coastal fisheries and transportation boat navigation, and installation and dissemination of route signs.

As it is expected that the number of commuting vehicles to the power plant will increase, causing traffic congestion and road deterioration. Therefore, it is necessary to take comprehensive measures such as shared ride commuting, staggered commuting, and assignment of traffic control staffs for the power plant personnel.

In addition, it is assumed that the project will have an impact on social services and easy access to markets throughout the year by improving and paving the surrounding roads and opening up and sharing the available facilities of the power plant to the residents.

(2-3-6) Social institutions such as social infrastructure and local decision-making institutions

Units 3/4 project is not expected to have any impact on social organizations such as social capital and local decision-making bodies. However, in addition to the potential impact on existing social infrastructure and social services mentioned in the previous section, it is desirable to share local issues and coordinate measures as necessary. Since an initiative is already functioning under the coordination of the Prime Minister's Office, in which the agencies and administrations involved in the development in the Maheshkhali-Matarbari region share information and coordinate as necessary, it is assumed that this initiative will be effective for each project.

(2-3-7) Misdistribution of benefits and compensation

As there is no land acquisition in Units 3/4 project, no misdistribution of benefits and compensation is not expected. However, the impact of the construction work on existing social infrastructure and social services, and the possibility that the disparity between the residents affected by Units 1/2 project and those who were not compensated will become apparent, as well as the possibility that dissatisfaction with the misdistribution of benefits and compensation will increase due to the addition of problems such as inundation.

As a member of business society, the project proponent will be expected to contribute to the improvement of local social infrastructure and social services, as well as to the resolution of problems, in cooperation with social authorities, and to contribute to local communities through CSR activities.

Although the new Real Estate Acquisition and Expropriation Law was enacted in 2017, it is confirmed that the Units 1/2 project will be implemented based on the system in place at the time of the procedure, and the compensation is based on the JICA ESC Guidelines, so no inequity is observed.

(2-3-8) Local conflicts of interest

There are high expectations for employment in this region. For this reason, it is desirable to not only assume a positive impact as an increase in employment opportunities related to the operation of Units 3/4, but also to give consideration to the fact that it may be a factor that creates conflicts of interest within the region, and to promote explanations to the region, devise vocational training that takes into account the improvement of literacy, and secure the number of actual employees.

(2-3-9) Cultural Heritage

There are no nationally or regionally designated cultural heritage sites within a 15km radius from the project site, and there are no cultural heritage properties at the settlement, village, or union level around the project site, and no impact is expected by Units 3/4 project.

(2-3-10) Gender

The gender consideration in Units 3/4 operation is expected to be the employment of women in power plant related activities.

However, considering the low literacy rate and lack of experience of women in this area, as well as the cultural and religious roles of women, it is desirable to provide employment opportunities that include a vocational training component.

It is also desirable to develop an employment plan that includes vocational training that takes into account the family structure and income of the women, considering that the improvement of livelihoods is also important as a gender consideration, given the role of women in this area.

(2-3-11) Children's right

The construction and paving of the surrounding roads may facilitate year-round access to social services and markets, which is assumed to have a positive impact on ensuring children's health and school attendance.

(2-3-12) Work environment (including work safety)

In order to prevent occupational accidents among power plant staff, it is necessary to establish a person in charge of EHS management and guidelines, and to take measures such as training program and creating posters and video materials for awareness-raising.

(2-3-13) Accidents

Since traffic accidents are expected to occur on land and at sea among the power plant personnel, it is desirable to promote safety education and training program to the personnel concerned, and distribution of educational materials such as posters and videos. Furthermore, along with this, it is desirable to implement measures to prevent traffic accidents on surrounding roads, install signs at sea, and place posters to raise awareness of traffic safety at jetty or port, to the extent possible.

13.5 Estimation about the amount of GHG (CO_2) emission

(1) Construction phase

CO_2 will be generated by operation of heavy machinery in construction work of Units 3/4.

Referring to FS report of Units 1/2, yearly CO_2 emission amount was calculated based on heavy machinery operated in 3/4 power block area. As a result, about 14 thousand ton- CO_2 is estimated.

As countermeasure for GHG emission during construction work, regular maintenance of generators, heavy machinery, trucks, etc., exhaust gas inspection, and regular air environment monitoring will be carried out.

Table 13.5-1 Yearly CO_2 emission amount for construction work

Machine	Capacity	Number of machines	Rated output (kW)	Rate of fuel consumption (L/kWh)	Fuel consumption per hour (L/h)	CO_2 emission amount (kg/h)	Total CO_2 emission amount (ton/year)
Backhoe	1.4m^3	20	164	0.175	28.7	74.0	3,128
Concrete Mixer	4.5m^3	40	118	0.078	9.2	23.7	2,006
Concrete pump	70m^3/min	12	199	0.078	15.5	40.0	1,015
Crawler crane	50ton	11	132	0.089	11.7	30.3	704
Engine Compressor	75m^3/min	4	107	0.189	20.2	52.2	441
Forklift	-	4	30	0.037	1.1	2.9	24
Generator	200kVA	20	201	0.170	34.2	88.2	3,724
Small Truck crane	4ton	3	107	0.044	4.7	12.1	77
Truck	11ton	19	246	0.050	12.3	31.7	1,273
Truck crane	11ton	38	125	0.044	5.5	14.2	1,139
Vehicle for height work	-	6	125	0.044	5.5	14.2	180
Total							13,711

Note: 1) Rated output, Rate of fuel consumption are been referring to similar EIA report.
2) Fuel of heavy machinery is light oil. CO_2 emission intensity is 2.58kg-CO_2/L (Ministry of Environment, Japan)
3) Yearly operation of heavy machinery is conservatively set as 8hours/day basis except holidays.
Source: Study Team

(2) Operation phase

(2-1) Outline

According to Intended Nationally Determined Contributions (INDC) (September, 2015) (Ministry of Environment and Forests), Bangladesh has updated its projections of future greenhouse gas emissions including the development of a “Business As Usual” (BAU) scenario by 2030.

Under Conditional contribution, Bangladesh will reduce its GHG emissions in the power sector by 16 Mt-CO_2 by 2030 or 18% below BAU emissions.

In addition, "Nationally Determined Contributions (NDCs) (26 August 2021)" (Ministry of Environment and Forests and Climate Change) has been released.

Regarding the matter that should be noted in the description of this report, CO_2 emission amount for BAU is 95.1 Mt-CO_2, that of unconditional scenario is 87.1 Mt-CO_2, and that of conditional scenario is 51.4 Mt-CO_2. "Coal power plant with Ultra super critical technology 12,147MW" is specified for the achievement of reduction target.

Table 13.5-2 The projected emissions reductions concerning the power sector by 2030

Sector	Base year (2011) (MtCO2e)	BAU scenario (2030) (MtCO2e)	BAU change from 2011 to 2030	Unconditional contribution scenario (2030) (MtCO2e)	Change vs BAU	Conditional contribution scenario (2030) (MtCO2e)	Change vs BAU
Power	21	91	336%	86	-5%	75	-18%

Note: In 2015, scenario was set with the base year as 2011 based on statistical data such as economic growth, population, energy demand, basic (action) plans and policies and so on.
Source: Intended Nationally Determined Contributions (INDC) (September, 2015) (Ministry of Environment and Forests)

Table 13.5-3 The projected emissions reductions concerning the power sector by 2030

Sector	Base year (2011) (MtCO2e)	BAU scenario (2030) (MtCO2e)	Unconditional contribution scenario (2030) (MtCO2e)	Conditional contribution scenario (2030) (MtCO2e)
Power	21.0	95.1	87.1	51.4

Source: Nationally Determined Contributions (NDCs) (26 August, 2021) (Ministry of Environment and Forests and Climate Change)

As one of mitigation programs, INDC, NDCs states that all new coal generation must be adopted super-critical technology.

Units 3/4 is a development of Ultra Super Critical Coal-Fired Power Project. Therefore, Units 3/4 meets the aim of INDC, NDCs.

Table 13.5-4 Possible mitigation actions to deliver the conditional contribution

Sector	Description	Objectives of the activity by 2030	
		INDC	NDC
Power	✓Ensure all new coal generation uses super-critical technology ✓Increased penetration of wind power ✓Implement grid-connected solar plant to diversify the existing electricity generation mix	✓100% of new coal based power plants use super-critical technology by 2030 ✓400 MW of wind generating capacity by 2030 ✓1,000 MW of utility-scale solar power plant	✓Ultra super critical technology 12,147MW ✓new combined cycle gas based power plant 5,613MW ✓Solar 2,277MW, Wind 597MW and so on

Source: Intended Nationally Determined Contributions (INDC) (September, 2015) (Ministry of Environment and Forests), Nationally Determined Contributions (NDCs) (26 August, 2021) (Ministry of Environment and Forests and Climate Change)

Regarding a concern of climate change, the confirmation of the positive/negative impact by Units 3/4 was conducted.

GHG emission was calculated in reference to “JICA Climate-FIT (Mitigation) Climate Finance Impact Tool for Mitigation, Quantitative evaluation of GHG emissions reduction (removals) 2019”.

In general, the emission reduction from the project activity is determined as the differences between the GHG emission of baseline scenario (facilities with low efficiency) and project scenario (facilities with high efficiency).

$ER_y = BE_y - PEy$

ER_y: Emission reduction through the project in a year y (t-CO_2/y)
BE_y: GHG emission from the baseline scenario in a year y (t-CO_2/y)
PE_y: GHG emission from the project scenario in a year y (t-CO_2/y)

(2-2) Calculation of Baseline emission

Baseline GHG emission is calculated based on the amount of power generated by the project and specific fuel consumption of baseline facilities.

The GHG emissions corresponding to the increased capacity is considered as emissions from the plant when using the most popular technology in the country where the project is implemented, and is calculated using the following formula.

$BE_y = \{(EG_{pj,y} - EG_{BL}) \text{ x } \eta_{BL}/\eta_{BL,\text{ country}} + EG_{BL}\} \text{ x } GE_{BL} \text{ x } NCV_i \text{ x } EF_{fuel,i}$

Where,
BE_y: GHG emission from the baseline scenario in a year y (t-CO2e/y)
$EG_{PJ,y}$: Amount of electricity generated by the project in a year y (MWh/y)
EG_{BL}: Amount of electricity generated in a year y before the project implementation (MWh/y)

η_{BL}: Power generation efficiency before the project is implemented (%)
$\eta_{BL,\ country}$: Power generation efficiency of the most popular facilities in the country where the project is implemented (%)
GE_{BL}: Specific fuel consumption of baseline facilities (t/MWh)
NCV_j: Net calorific value based on project scenario (TJ/t)
$EF_{fuel,i}$: GHG emission factor based on baseline scenario (t-CO_2/TJ)

(2-3) Calculation of Project emission

Project emission is calculated based on the consumption of fuel for power generation in the project and CO_2 emission factor of the fuel used for power generation.

$$PE_y = FC_{PJjy} \text{ x } NCV_j \text{ x } EF_{fuel,j}$$

Where,
FC_{PJjy}: Fuel consumption amount (t/y)
NCV_j: Net calorific value based on project scenario (TJ/t)
$EF_{fuel,j}$: GHG emission factor based on project scenario (t-CO_2/TJ)

(2-4) Baseline Emission Coefficient of Bangladesh

According to World energy balance 2019 (IEA), energy balance of coal fired power plants in Bangladesh is shown in Table 13.5-5.

Thermal efficiency of whole coal fired power plants in Bangladesh was estimated 32.8-35.1% using these statistics vales (from 2015 to 2017).

Table 13.5-5 Energy balance of coal fired power plants in Bangladesh

Item	In 2017	In 2016	In 2015
Total primary energy supply (Thousand tonnes of oil equivalent)	270	270	261
Electricity Generated (GWh)	1,031	1,102	997
Thermal efficiency of whole coal fired power plant (%)	32.8	35.1	32.8

Note: As for general conversion factors for energy, 1 GWh = 0.08598 Ttoe
Source: Study Team from World energy balance 2017, 2018, 2019 (IEA)

(2-5) Calculation from CO_2 emission coefficients of conventional technology and ultra-super critical technology

Firstly, “Fact finding for export of technology of coal fired power plant” prepared by Ministry of Environment, Japan states CO_2 emission factor from coal fired power plant. CO_2 emission factor from Conventional coal fired power plants (HHV: net thermal efficiency basis) is 0.867 kg- CO_2/kWh. And that of ultra-super critical coal fired power plant is 0.795 - 0.836kg - CO_2/kWh (Median 0.812).

CO_2 emission will be simply increased because of operation of Units 3/4.

However, as a hypothesis, for correspondence of future electricity demand in Bangladesh, in this survey, more concrete analysis was carried out for comparison a case of conventional coal fired power plants in Bangladesh with a case of ultra-super critical coal fired power plant (this project).

Thermal efficiency of Units 3/4 is planned 44.6% (LHV) (It was converted based on 41.1% (HHV)). This planned value is sufficiently exceeded whole coal fired power plants in Bangladesh (32.8 - 35.1%). It is clear Units 3/4 is superior to the existing other coal fired power plants in Bangladesh.

Regarding CO_2 emission factor of fuel and CO2 emission factor of electricity, they are shown in Table 13.5-6, based on generation efficiency of the existing power plants and this project.

CO_2 emission coefficients of Units 3/4 is 0.864 t-CO_2/MWh against that of whole coal fired power plants (1.176 t-CO_2/MWh (LHV)).

CO_2 emission coefficient of Units 3/4 is approaching that of ultra-super critical coal fired power plants that be operating in Japan are almost same.

Table 13.5-6 Calculation of CO2 emission coefficients of Units 3/4

Item	Unit	Value	Remarks
Plant net power output of Units 3/4	MW	1,200	600MW x 2units
Capacity factor	%	80.0	
Amount of electricity generated by the project in a year	MWh/y	8,409,600	1,200 x 8,760 x 80/100
Power generation efficiency of this project	%	41.1	44.6% (LHV) was converted based on 41.1% (HHV)
Power generation efficiency of the most popular facilities in Bangladesh where the project is implemented	%	30.2	30.2% (HHV) was concerted based on 32.8% (LHV) in 2017
Higher heating value, HHV	kcal/kg	4,600	
Lower heating value, LHV	kcal/kg	4,240	
Higher heating value, HHV	kJ/kg	19,259	
Lower heating value, LHV	kJ/kg	17,752	
Carbon content in fuel, C%	weight%	47.8	
Conversion factor of calorie to Joule	J/cal	4.1868	1cal=4.1868J
Net caloric value of the fuel used for power generation	TJ/t	0.0178	
Specific fuel consumption of this project	t/MWh	0.4916	
Specific fuel consumption of baseline facilities	t/MWh	0.6690	
CO_2 emission coefficient of the fuel used for power generation	t-CO2/TJ	98.66	Note-1)
Conversion factor of electric energy to thermal energy	TJ/MWh	0.0036	
CO_2 emission coefficient of electricity generation(In case of this project)	t-CO_2/MWh	0.864	Note-2) 3) In case of including CO_2 generated by desulfurization: 0.870 (Table 13.5-7)
CO_2 emission coefficient of electricity generation(In case of baseline facilities)	t-CO_2/MWh	1.176	Note-2)

Remarks:

1) CO_2 emission coefficient of the fuel=(C%/100)/LHV x (44.01/12.011) x10^6
2) CO_2 emission coefficient ={CO_2 emission coefficient of the fuel/(Power generation efficiency/100)}x 0.0036
3) Typical CO_2 Emissions Performance of new Thermal Power Plants (Ultra-Supercritical)

Items	Efficiency	kg-CO_2/MWh	Remarks (Sources)
IFC/WB EHS Guidelines (Thermal Power Plants; 2008)	37.6-42.7 (%Net, HHV)	676-795 (%Net, HHV)	US EPA 2006
	42 (%Net, LHV)	811 (%Net, LHV)	World Bank
	47	725	*World Bank Group Sep 2006

	(%Gross, LHV)*	(%Gross, LHV)**	** World Bank Group estimates
IFC/WB EHS Guidelines (Thermal Power Plants; 2017 draft)	39-48 (%Net, LHV)	676-934 (%Net, LHV)	US EPA 2006,2010,World Bank, IEA(2012),European Commission (2013)
	47 (%Gross, LHV)*	728-777 (%Gross, LHV)**	ESMAP (2007)

Source: Study Team

Table 13.5-7 shows a trial calculation result of CO_2 emission of the project based on the expected performance data. CO_2 emission of the project is estimated 7,319,280 t-CO_2/y (B+C in Table 13.5-7).

If CO_2 emission based on operation by baseline facilities instead of this project is estimated 9,890,606 t-CO_2/y. The difference of both values is 2,571,327 t-CO_2/y. As a result, it is deemed contribution by implementation of this project is reasonable.

Potential reduction ratio is 26.0%. It is confirmed the contribution of CO_2 emission efficient by this project adopted advance technology is guided.

In other words, it becomes help for reduction target of CO_2 emission amount against BAU by 2030 described in INDC and NDCs.

It is very important to adopt BAT (Best Available Technology) considering the countermeasure against Global warming that Climate change becomes caused (Appendix-13.5).

Table 13.5-7 CO_2 emission generated by Units 3/4

Item	Unit	Value	Remarks
Electricity generation	MWh/y	8,409,600	
CO_2 emission coefficient of electricity generation(In case of baseline facilities)	ton/MWh	1.176	
CO_2 emission coefficient of electricity generation(In case of this project)	ton/MWh	0.864	
CO_2 emission based on baseline facilities, (A)	t-CO_2/y	9,890,606	
CO_2 emission based on this project, Fuel combustion (B)	t-CO_2/y	7,267,550	
CO_2 emission based on this project, Desulfurization (C)*	t-CO_2/y	51,729	
Potential reduction of CO_2 emission	t-CO_2/y	2,571,327	(A) - (B) - (c)
Potential reduction ratio	%	26.0	(1-(B+C)/(A))*100

*Since this project uses the lime gypsum method for the desulfurization equipment, 1 mole of CO_2 is emitted per 1 mole of sulfur as shown in the following formula.

$SO_2 + CaCO_3 + 2H_2O + 1/2O_2$

$CaSO_4 \cdot 2H_2O + CO_2$

Referring to Chapter 8, 51,729 tons of CO_2 will be emitted, based on sulfur content in coal: 1.0% and SO_2 removal ratio: 91%

Item	Unit	Value	Remarks
Amount of electricity generated by the project in a year	MWh/y	8,409,600	
Specific fuel consumption of this project	ton/MWh	0.4916	
Coal consumption	ton	4,134,211	
sulfur amount based on sulfur content in coal: 1.0%, desulfurization ratio; 91%	Million -mole	1,176	
CO2 amount generated by desulfurization	t/y	51,729	

Source: Study Team

13.6 Environmental Management Plan

(1) Construction phase

As with the Units 1/2 project, during the construction, CPGCBL Project Implementation Unit (PIU) and the consultant who supervises the project will carefully consider the contents of the construction activities. They make EPC contractors understand the mitigation measures required, and implement them.

CPGCBL will organize Environmental Management Unit (EMU) consisting of persons with specialized knowledge, discuss mitigation measures with EPC contractors, and formulate plans in cooperation with supervisory consultants.

As with the Units 1/2 project, there are the migration of workers and the increase in construction vehicles due to construction work, so EMU will function to in cooperation with EPC contractors, take appropriate responses to opinions and complaints from local residents, and implement various mitigation measures.

Anytime, local residents can directly complain to EMU, EPC Contractors.

EPC contractors will have EMU and the supervisory consultants submit regular reports on the implementation status of the management plan in order to grasp the implementation status of environmental management and consider of further mitigation measures.

If there are insufficient and serious problems, PIU can take measures and orders to solve the problems, including suspension of construction.

EMU manager regularly holds consulting meetings for explanation to the local community and hearing complaints continually.

EMU shall report these complaints, implementation with the environmental management plan current status of environmental monitoring to related authority and JICA.

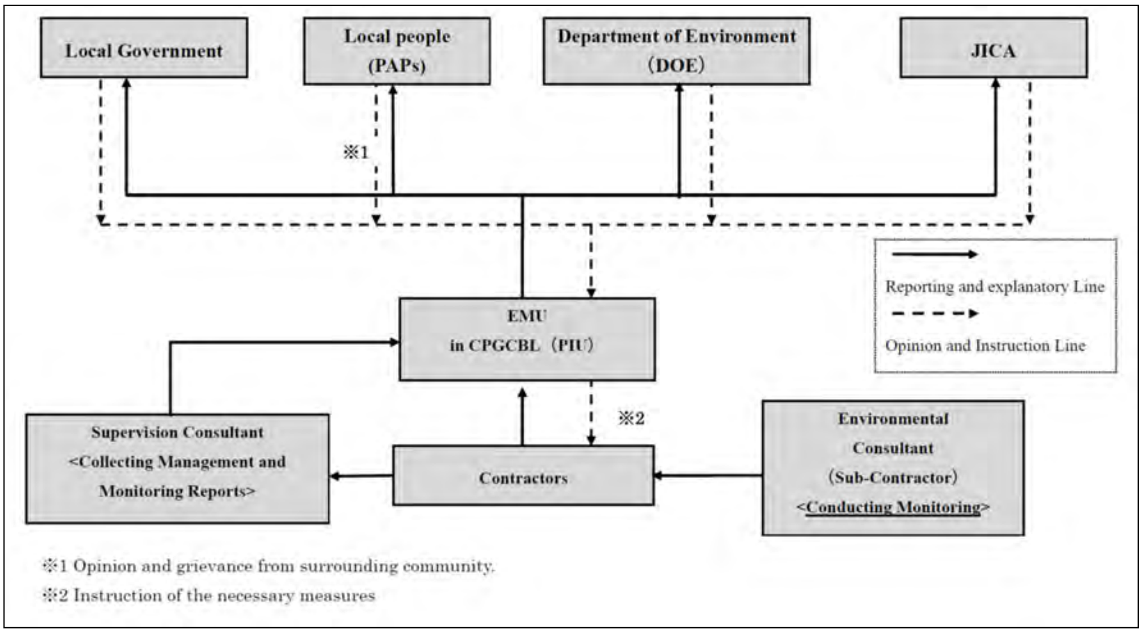
If environmental problems occur due to construction work, the EMU shall confirm the cause with the contractor as soon as possible.

In order to resolve these problems, the administrator of the EMU shall instruct the contractor and consultant regarding necessary measures.

If the problem is serious, the PIU may order the contractor to halt construction work until the problem is resolved.

From above these things, every contractor and subcontractor have to deploy qualified and sufficient Environmental, health & safety (EHS) expert. Contractors should conduct environmental audit annually by independent third party. All the audit findings (Noncompliance) should be corrected (corrective and preventive action) by the contractor by their own cost and effort. Contractor should monitor all the environmental aspect as per the Environmental Monitoring Plan through independent monitoring organization. Monitoring results should be submitted to employer without any modification.

Figure 13.6-1 outlines the environmental management and monitoring implementation structure with the reporting flow during the construction phase.



Source: Preparatory Survey on Chittagong Area Coal Fired Power Plant Development Project in Bangladesh Final Report

Figure 13.6-1 Environmental Management and Monitoring Implementation Structure in the Construction Phase

In the construction monitoring related to the Unit 1/2 project, consulting meetings are held quarterly with local residents to hear their opinions.

It has been pointed out that the results of the monitoring have not been sufficiently explained to the local residents. But during the consulting meetings that have been held, CPGCBL give information with the local residents to explain matters related to the surrounding environment.

	
Matarbari Union(November 17, 2021)	Dhalghata Union(November 18, 2021)

The monitoring results are prepared as monthly reports and quarterly reports, and the contents are confirmed by the consultants that employed by CPGCBL. If there are any doubts or errors, the contractor is requested to resubmit and CPGCBL finalizes the report. CPGCBL has been submitting the quarterly report to DOE for review by DOE.

(2) Operation phase

The power plant has the responsibly for organizing Environmental Management Unit (EMU) and formulation and implementation of environmental management plan that includes mitigation measures.

The environmental management manager with specialized knowledge shall be assigned to ensure the implementation of the environmental management plan.

The person in charge of environmental management shall educate the staff about the contents of the environmental management plan before the start of operation, and regularly re-educate during operation.

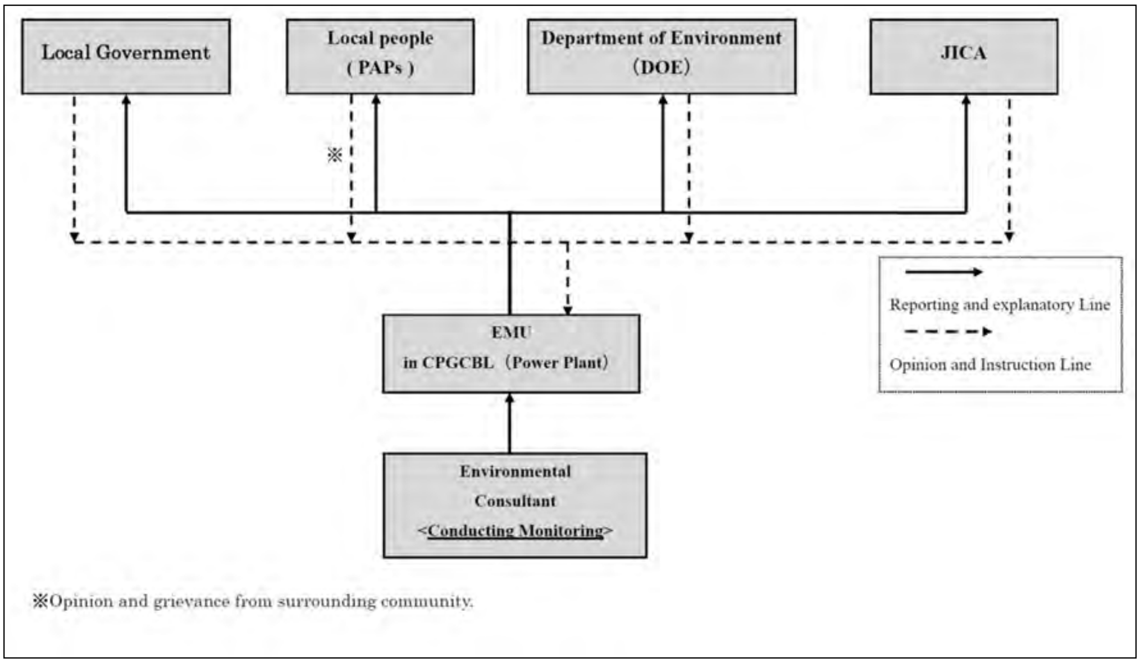
EMU shall establish grievance organization and implement necessary mitigation measures in order to respond appropriately to the opinions and complaints of local residents.

In addition, based on cooperation with the local community, EMU will actively explain mitigation measures.

The person in charge of environmental management shall report the implementation of the environmental management plan and environmental monitoring to the director of the power plant, and the director is the ultimate responsible person.

EMU manager regularly holds consulting meeting to the local community and hearing complaints continually. EMU shall report these complaints, implementation with the environmental management plan current status of environmental monitoring to related authority and JICA.

Figure 13.6-2 describes the environmental management and monitoring implementation structure with the reporting flow during the operation phase.



Source: Preparatory Survey on Chittagong Area Coal Fired Power Plant Development Project in Bangladesh Final Report

Figure 13.6-2 Environmental Management and Monitoring Implementation Structure in Operation Phase

[Concept of environmental management, and Correspondence/ handling of grievance in this project]

This project is located in a part of the site of Units 1/2 under construction.

Therefore, regarding the concept of environmental management and the Correspondence/ handling of grievance in this project (Units 3/4), basically the same procedure as for Units 1/2 will be followed as described above.

In addition to this, the valuable experience gained at Unit 1/2 will be reflected in this project (Units 3/4).

(3) Mitigation Measures

The environmental management plan during construction and operation phase is based on the same concept as Units 1/2, which is currently under construction, and it was organized, referring to "Preparatory Survey on Chittagong Area Coal Fired Power Plant Development Project in Bangladesh Final Report" (Table 13.6-1).

Table 13.6-1 Environmental Management Plan

No	Potential Impact to be Managed	Sources of Potential Impact	Standard of Impact	Objectives	Management Effort	Management Location	Period of Management	Management Institution	Cost
Construction Phase									
1	Air Quality	1) Dust resulting from construction work 2) Air pollution arising from incineration of construction materials and waste 3) Exhaust gas from construction machinery and vehicles used for mobilization of equipment	1) - 3) - Exhaust gas (NOx, SOx, PM, CO, CO2) - Ambient air quality standards (NO2, SO2, PM10, PM2.5) - IFC/WB EHS Guidelines values	1) - 3) - Prevention of air pollution in the surrounding area	1) Dust prevention - Watering access road and construction site, especially in the dry season - Using cover sheets on trucks for the transportation of soil 2) Waste management - Prohibit open burning 3) Prevention of exhaust gas emission - Periodic maintenance and management of all the construction machinery and vehicles	1),2) - Construction area such as storing and handling of construction materials/wastes 3) Access road (along residential area)	1) - 3) - During construction phase	- Implementation: Contractor/ Environmental Consultant - Supervisor: CPGCBL/ Supervision Consultant	Expenses included in contract cost by Contractor
2	Water Quality	1) Wastewater from construction area 2) Domestic wastewater of workers 3) Inappropriate disposal of waste 4) Leakage oil and chemical materials from construction activity	1)- 4) pH, BOD, TSS, Oil, Coliforms, etc. - Wastewater standards - Ambient water quality standards (Inland surface water) - Ground water quality (Drinking water quality standards) 3), 4)	1) - 4) - Prevention of water pollution in the surrounding area (against degrading water quality of surrounding waterbody and underground penetration due to inappropriate disposal/treatme nt)	1) Wastewater - Excavate channels, ditches and temporary settling pond around construction area - Install oil separator for treatment of oily wastewater - Construct silt basin 2) Domestic wastewater - Install wastewater treatment facility for workers such as septic tanks, sewage treatment plant 3) Waste management	1) - 4) - Construction area	1) - 4) - During construction phase	- Implementation: Contractor/ Environmental Consultant - Supervisor: CPGCBL/ Supervision Consultant	Expenses included in contract cost by Contractor

No	Potential Impact to be Managed	Sources of Potential Impact	Standard of Impact	Objectives	Management Effort	Management Location	Period of Management	Management Institution	Cost
			- Waste management rule		- Prohibit illegal dumping 4) Oil and chemical materials leakage - Storage of oil and chemical materials in an appropriate storage site and appropriate method to prevent permeation into ground				
3	Waste	1) Construction waste from construction work 2) Domestic waste from workers 3) Hazardous waste such as waste batteries, fluorescent lamp etc.	1) - 3) - Waste management rule	1) - 3) - Prevention of inappropriate waste disposal	1), 2) Construction and domestic waste - Conduct separate waste collection and promote recycling and reuse - Appropriate disposal of non-recyclable waste according to rules 3) Hazardous waste - Hazardous waste should be treated under the related regulations	1) - 3) - Construction area - Villages near the site	1) - 3) - During construction phase	- Implementation: Contractor/ Environmental Consultant - Supervisor: CPGCBL/ Supervision Consultant	Expenses included in contract cost by Contractor
4	Noise and Vibration	1) Noise and vibration caused by construction machinery 2) Noise caused by vehicles used for mobilization of equipment and workers	1), 2) - Noise level standards - IFC/WB EHS Guidelines values	1), 2) - Reduction of noise levels from construction activities	1) Construction machinery - Optimizing construction schedule - Performing construction work during daytime, especially piling work - Using low-noise/ low vibration equipment 2) Mobilization - Transportation of material and equipment for construction by shipping - Determine a traffic control	1), 2) - Construction area	1), 2) - During construction phase	- Implementation: Contractor/ Environmental Consultant - Supervisor: CPGCBL/ Supervision Consultant	Expenses included in contract cost by Contractor

No	Potential Impact to be Managed	Sources of Potential Impact	Standard of Impact	Objectives	Management Effort	Management Location	Period of Management	Management Institution	Cost
					plan including route-setting - Limit truck speed especially around residential areas (Access road (along residential area)				
5	Odor	- Domestic waste from workers	- Waste management rule - Ambient air quality standards (NH3, H2S)	- Prevention of generating odor	- Taking appropriate measures for handling general waste (proper/quick processing, sealed (with lid) storage) - Prohibit illegal waste disposal	- Construction area	- During construction phase	- Implementation: Contractor/ Environmental Consultant - Supervisor: CPGCBL/ Supervision Consultant	Expenses included in contract cost by Contractor.
6	Soil	1) Leakages of oil and chemical materials from construction activity 2) Inappropriate disposal of waste	1), 2) - Waste management rule	1), 2) - Prevention of soil pollution in the surrounding area	1) Leakages of oil and chemical materials - Storage of oil and chemical materials in an appropriate storage site and method to prevent permeation into the ground 2) Waste management - Prohibit illegal dumping	1), 2) - Construction area	1), 2) - During construction phase	- Implementation: Contractor/ Environmental Consultant - Supervisor: CPGCBL/ Supervision Consultant	Expenses included in contract cost by Contractor
7	Sediment	1) Run off water from construction area 2) Domestic wastewater of workers 3) Leakages of oil and chemical materials from construction activity	1) - 3) - Wastewater standards - Waste management rule	1) - 3) - Prevention of water pollution in the surrounding area	1) - 3) - Implement the same mitigation measures as those addressed in “Water quality” and “Waste”	1) - 3) - Construction area	1) - 3) - During construction phase	- Implementation: Contractor/ Environmental Consultant - Supervisor: CPGCBL/ Supervision Consultant	Expenses included in contract cost by Contractor

No	Potential Impact to be Managed	Sources of Potential Impact	Standard of Impact	Objectives	Management Effort	Management Location	Period of Management	Management Institution	Cost
8	Ecosystem, Protected Area	1) Existence of endangered species 2) Spawning of sea turtles	1), 2) - Bangladesh wild life act,1974 (Preservation) (Amendment) - JICA ESC Guidelines	1), 2) - Protection of endangered species	-Implement relevant mitigation measures to following factors while considering possible cumulative and/or compound impacts with Phase 1 1) Existence of endangered species - Prohibit disturbance, harassment, and hunting, especially of the Spoon billed Sandpiper and Fishing Cat, by workers - Replace to nearby site, if needed 2）Spawning of sea turtles - Turning off unnecessary lights during the nesting season - Using a smaller number or lower wattage of lights - Using red, yellow lights (as sea turtles are less affected by these colors) - Using low noise machinery - Planning construction activities to minimize adverse effects during the nesting season	1) Construction area 2) Construction site adjoining sand beach	1), 2) - During construction phase	- Implementation: Contractor/ Environmental Consultant - Supervisor: CPGCBL/ Supervision Consultant	Expenses included in contract cost by Contractor
		- Potential impact due to water pollution caused	- Wastewater standards	- Prevention of water pollution in order to	- Implement the same mitigation measures as those addressed in "Water	- Construction area			

No	Potential Impact to be Managed	Sources of Potential Impact	Standard of Impact	Objectives	Management Effort	Management Location	Period of Management	Management Institution	Cost
		by construction activities		reduce negative impact on marine organisms	quality”				
9	Deterioration of Local Economy such as Losses of Employment and Means of Livelihood	- Increase in employment and business opportunities	- Number of employment opportunities for local residents and number of businesses around the construction area	- Improvement of the local economy - Improvement of living standards of local residents - Consideration to local residents' feelings	- Employ local residents as much as possible - Use the services (i.e., laundry and catering services, etc.) and products offered by the local community. - Developing “Livelihood restoration program”, including job training programs to persons who want the training.	- Villages near the site	- During construction phase	- Implementation: Contractor/ Environmental Consultant - Supervisor: CPGCBL/ Supervision Consultant	Expense is included in contract cost by Contractor - Hire local residence: 1,000Tk./person -day
10	Land Use and Utilization of Local Resources	Restrictions on fishing operations due to construction work, changes in seawater draw into salt pans	Amount of landing, Amount of salt production	- Consideration to local residents' feelings	- Implement the same mitigation measures as those addressed in the “Local economy”	- Villages near the site	- During construction phase	- Implementation: Contractor/ Environmental Consultant - Supervisor: CPGCBL/ Supervision Consultant	Expenses included in contract cost by Contractor
11	Disturbance to Water Usage, Water Rights, etc.	1) Adverse impact due to water pollution 2) Usage of underground water	1) Water pollution - Same as those addressed in “Water quality” 2) Ground water - Drinking water quality standards	1) Water pollution - Same as those addressed in “Water quality” 2) Ground water - Consideration to local residents' living	1) Water pollution - Implement the same mitigation measures as those addressed in “Water quality” 2) Ground water - Monitoring of water levels and water quality at wells in residential areas	1), 2) - Construction area	1), 2) - During construction phase	- Implementation: Contractor/ Environmental Consultant - Supervisor: CPGCBL/ Supervision Consultant	Expenses included in contract cost by Contractor
12	Disturbance to	1) Increased	1) - 3)	1) - 3)	1) Marine traffic	1) Sea area near	1) - 3)	- Implementation:	Expenses

No	Potential Impact to be Managed	Sources of Potential Impact	Standard of Impact	Objectives	Management Effort	Management Location	Period of Management	Management Institution	Cost
	Existing Social Infrastructure and Services	marine traffic may disturb the existing marine traffic including fishing boats 2) Traffic jams caused by increased number of vehicles and road degradation during construction	-Increasing traffic volume around the construction site	- Mitigation of traffic jams	- Consulting with related authorities on the schedules of vessels - Determining water routes after consultation with related authorities 2), 3) Land traffic - Making appropriate vehicle schedules - Reducing the number of vehicles used by using buses - Consulting with related authorities on bus schedules	the site 2), 3) Roads near the construction area	During construction phase	Contractor/ Environmental Consultant - Supervisor: CPGCBL/ Supervision Consultant	included in contract cost by Contractor
13	Local Conflicts of Interest	- Conflicts between local residents and external workers	- Change in local customs	- Consideration of the attitudes of local residents to the project	- Employ local residents as much as possible - Promote communication between external workers and local people (e.g., join in local events)	- Villages near the site	- During construction phase	- Implementation: Contractor/ Environmental Consultant - Supervisor: CPGCBL/ Supervision Consultant	Expenses included in contract cost by Contractor
14	Gender	1) Gender among those who are to be resettled 2) Loss of salt fields, shrimp farms and fishing site for oush net	1), 2) - Living standards of gender	1), 2) - Consideration of living standards of gender	1), 2) - Developing "Livelihood restoration program", including job training programs to persons who want the training.	1), 2) - Villages near the site	1), 2) - During construction phase	- Implementation: Contractor/ Environmental Consultant - Supervisor: CPGCBL/ Supervision Consultant	Expenses to be paid by CPGCBL - Job training programs: 120,000 Tk./ 20person・20day
15	Children's Rights	- Child labor	- Child labor	- Banning child labor	- Prohibit labor contracts between subcontractor and children	- Construction area	- During construction phase	- Implementation: Contractor/ Environmental	Expenses included in contract cost by

No	Potential Impact to be Managed	Sources of Potential Impact	Standard of Impact	Objectives	Management Effort	Management Location	Period of Management	Management Institution	Cost
					- Patrolling periodically to check for any child labor			Consultant - Supervisor: CPGCBL/ Supervision Consultant	Contractor
16	Infectious Diseases such as HIV/AIDS	- Temporary influx of migrant labor during construction may increase risk of infection - COVID-19	- Sanitation for local residents	- Consideration for sanitation for local residents	- Implementation of periodic medical check-ups by temporary medical team - Education and training on health care of workers	- Construction area	- During construction phase	- Implementation: Contractor/ Environmental Consultant - Supervisor: CPGCBL/ Supervision Consultant	Expenses included in contract cost by Contractor - Medical checkups: 22,500Tk./ person (Full Medical Checkup) - Safety education and training: 75,000Tk./ 20 person
17	Work environment (including work safety)	1) Labor accidents 2) Diseases caused by air pollutants, water pollutants, and noise by construction work	1) Labor accidents - Handling heavy loads - Working at heights - Electric shocks 2) Environment pollution - Ambient air quality standards - Noise level standards	1), 2) - Prevention of labor accidents and health problems	1) Labor accidents - Prepare a manual for labor accident prevention including safety education and training - Provide workers with appropriate protective equipment, such as helmets - Install fire extinguishers in fire handling places - Inspect and ensure that any lifting devices, such as cranes, are appropriate for	1), 2) - Construction area	1), 2) - During construction phase	- Implementation: Contractor/ Environmental Consultant - Supervisor: CPGCBL/ Supervision Consultant	Expenses included in contract cost by Contractor - Protective equipment: 5,000Tk./ person

No	Potential Impact to be Managed	Sources of Potential Impact	Standard of Impact	Objectives	Management Effort	Management Location	Period of Management	Management Institution	Cost
			- Waste management rule - IFC/WB EHS Guidelines values		expected loads - Keep lifting devices well maintained and perform maintenance checks as appropriate during the construction period - Use equipment that protects against electric shocks 2) Environment pollution - Observe related standards and provide workers with appropriate equipment (PPE), such as masks, ear plugs, etc.				
18	Accidents	- Traffic accidents	1) Marine traffic 2) Land traffic	1), 2) - Traffic accidents	1) Marine traffic - Marking buoys around the construction area for marine safety - Informing vessel schedules to local fishermen, etc. 2) Land traffic - Informing bus schedules to the surrounding villages - Determining a traffic control plan - Training safe operation of vehicles	1) Sea area near the site 2) Roads near the construction area	1), 2) - During construction phase	- Implementation: Contractor/ Environmental Consultant - Supervisor: CPGCBL/ Supervision Consultant	Expenses included in contract cost by Contractor - Making buoys: 5,000Tk./ unit
19	Cross-boundary impact and climate change	- CO_2 will be produced by construction work	- Amount of CO_2 emissions	- Reduce CO_2 emissions as much as possible	- Periodic maintenance and management of all construction machinery and vehicles	- Construction area	- During construction phase	- Implementation: Contractor/ Environmental Consultant - Supervisor:	Expenses included in contract cost by Contractor

No	Potential Impact to be Managed	Sources of Potential Impact	Standard of Impact	Objectives	Management Effort	Management Location	Period of Management	Management Institution	Cost
								CPGCBL/ Supervision Consultant	
Operational Phase									
1	Air Quality	1) Exhaust gas from the stacks 2) Dust from ash disposal activity 3) Exhaust gas from vehicles used for mobilization of equipment and workers 4) Dust from coal handling activities at jetty and coal yard	1) - 4) - Exhaust gas (NOx, SOx, PM, CO, CO2) - Ambient air quality standards (NO2, SO2, PM10, PM2.5) - IFC/WB EHS Guidelines values	1), 3) - Prevention of air pollution in the surrounding area 2) Appropriate handling of ash 4) Appropriate coal handling during stock and unloading activities	1) Power plant operational activities: - To reduce PM emissions, Electrostatic Precipitator will be installed. - To reduce NOx emissions, firing system will use low combust technology, Denitration equipment (SCR) - To reduce SO2 emissions, Desulfurization equipment will be installed. - Duct will be provided with CEMS (Continuous Emission Monitoring System) with the supported infrastructure as required under the gas emission standards and IFC/WB EHS Guidelines 2) Ash handling - Shifting the fly ash and the bottom ash to the ash pond using air sealed conveyer - Watering in ash pond as required for the dry season - Re-greening especially along the boundary of the plant site, surrounding ash	1) Stack 2) Ash pond 3) Villages near the site 4) Coal stock yard	1) - 4) - During operation of power plant	- CPGCBL/ Environmental Consultant	- Flue gas treatment facilities (Expenses included in contract cost by Contractor)

No	Potential Impact to be Managed	Sources of Potential Impact	Standard of Impact	Objectives	Management Effort	Management Location	Period of Management	Management Institution	Cost
					pond with domestic plants 3) Gas emissions from vehicles - Periodic maintenance and management of vehicles 4) Coal handling - A cover will be installed for the conveyor for coal transportation to coal yard - Unloading of coal will be minimized (e.g., reduce the frequency of activity, etc.) during times of high speed winds - Spraying water in coal yard to keep the surface wet and prevent wind from blowing coal and dust - Installation of a dust control fence - Re-greening especially along boundary of plant site, surrounding coal yard with domestic plants				
2	Water Quality	1) Thermal effluents from cooling system 2) Wastewater from plant process 3) Rainwater drainage from ash pond and coal yard 4) Leakages of oil	1) - 4) Water temperature, pH, DO, SS, oil, BOD, COD, Heavy metals - Wastewater standards - Ambient water quality standards	1) - 4) - Prevention of sea water pollution	1) Thermal effluents - Thermal effluents are discharged to north side far from the intake point of cooling water to reduce the impact on surrounding area 2) Wastewater from plant process - Installation of wastewater treatment system by	1) - 4) - Power plant, especially at discharge of thermal effluents and wastewater treatment system	1) - 4) During the operation of power plant	- CPGCBL/ Environmental Consultant	- Wastewater treatment system: (Expenses included in contract cost by Contractor)

No	Potential Impact to be Managed	Sources of Potential Impact	Standard of Impact	Objectives	Management Effort	Management Location	Period of Management	Management Institution	Cost
		and chemical materials	(Sea water) - IFC/WB EHS Guidelines values - Ground water (Drinking water quality standards) 5) Waste management rule		neutralization, settling and oil separation so any wastewater produced complies with wastewater standards and IFC/WB EHS Guidelines 3) Run off water - Run off water must be collected in the pond and discharged after appropriate treatment - The bottom of the ash pond shall have an impermeable layer such as HDPE(High Density Polyethylene) sheet and clay 4) Oil and chemical materials leakage - Storage of oil and chemical materials in an appropriate tank with retaining wall and method to prevent permeation into ground (Oil spillage response plan)				
3	Waste	1) Fly ash and bottom ash 2) Sludge from wastewater treatment and waste oil from equipment, etc. 3) Sewage and	1) - 3) - Waste management rule - Environmental Conservation Rules	1) Appropriate handling of coal ash 2), 3), 4) - Management of waste, especially hazardous waste	1) Ash pond is designed with sufficient capacity for the operation of this project, and the promotion of recycling. 2), 3), 4) Waste management - Developing a waste	1) Ash pond 2), 3), 4) - Power plant	- During the operation of power plant	- CPGCBL/ Environmental Consultant	- Ash handling facilities:(Expenses included in contract cost by Contractor)

No	Potential Impact to be Managed	Sources of Potential Impact	Standard of Impact	Objectives	Management Effort	Management Location	Period of Management	Management Institution	Cost
		garbage from workers 4) Hazardous waste (waste chemicals) generated by operation		- Prevention of inappropriate waste disposal	management program consisting of reduction, reuse, and recycling of materials - Systematic collection and protected storage - Waste disposal at appropriate location - Hazardous waste shall be treated under the related regulations - Prohibition of dumping any contaminating materials - Disposal & transportation of hazardous & sewage waste by certified company				
4	Noise and vibration	1) Noise and vibration from steam turbines, generators, and pumps, etc. 2) Noise by ash disposal activity 3) Noise caused by vehicles used for mobilization of equipment and workers 4) Noise from coal handling activity at jetty and coal yard	1) - 4) - Noise level standards - IFC/WB EHS Guidelines values - DOE Guidelines values	1) - 4) - Mitigation of noise generated by the power plant	1) - 4) - Maintenance of equipment - Installation of low noise/ low vibration type equipment - Adequate basis of equipment to reduce vibration - Adequate enclosure of equipment to reduce noise	1) - 4) - Power plant	1) - 4) - During the operation of power plant	- CPGCBL/ Environmental Consultant	- Buildings housing boiler and turbine generator (Expenses included in contract cost by Contractor)
5	Odor	1) Domestic waste	1) Waste	- Prevention of	1) Taking appropriate	- Power plant	- During the	- CPGCBL/	Expenses by

No	Potential Impact to be Managed	Sources of Potential Impact	Standard of Impact	Objectives	Management Effort	Management Location	Period of Management	Management Institution	Cost
		from workers 2) Leakage from ammonia storage facilities	management rule 2) Environmental Conservation rules - Ambient air quality standards (NH_3, H_2S)	generating odors	measures for handling domestic waste - Prohibit illegal waste disposal 2) Maintenance of facilities		operation of power plant	Environmental Consultant	CPGCBL
6	Soil	1) Seepage from ash pond 2) Leakages of oil and chemical materials	1), 2) - Ground water (Drinking water quality standards) - Waste management rule	1), 2) - Prevention of soil and water pollution in the surrounding area	1) Seepage from ash pond - The bottom of the ash pond should have an impermeable layer such as HDPE(High Density Polyethylene) sheet and clay 2) Oil and chemical materials leakage - Storage of oil and chemical materials in an appropriate tank with retaining wall and method to prevent permeation into ground	1) Ash pond 2) Power plant	1), 2) - During coal unloading activity	- CPGCBL/ Environmental Consultant	Expenses by CPGCBL
7	Sediment	1) Wastewater from plant process 2) Run off water from ash disposal site and coal yard 3) Leakages of oil and chemical materials	1), 2) - Wastewater standards - IFC/WB EHS Guidelines values 3) Waste management rule	1) - 3) - Prevention of sea water pollution	1) Wastewater from plant process - Installation of wastewater treatment system by neutralization, settling and oil separation so any wastewater produced complies with wastewater standards and IFC/WB EHS Guidelines	1), 2) - Wastewater treatment system 3) Power plant	1) - 3) - During the operation of power plant	- CPGCBL/ Environmental Consultant	Expenses by CPGCBL

No	Potential Impact to be Managed	Sources of Potential Impact	Standard of Impact	Objectives	Management Effort	Management Location	Period of Management	Management Institution	Cost
					2) Run off water - Runoff water is collected in the pond and discharged/recycled after appropriate treatment. 3) Oil and chemical materials leakage - Storage of oil and chemical materials in an appropriate tank with retaining wall and method to prevent permeation into ground				
8	Ecosystem, Protected Area	1) Existence of endangered species 2) Spawning of sea turtles	1), 2) - Bangladesh wild life act, 1974 (Preservation) (Amendment) - JICA ESC Guidelines	1), 2) - Protection of endangered species	-Implement relevant mitigation measures to following factors while considering possible cumulative and/or compound impacts with operation of Phase 1 1) Existence of endangered species - Prohibit disturbance, harassment, and hunting, especially of the Spoon billed Sandpiper and Fishing Cat, by workers 2) Spawning of sea turtles - Turning off unnecessary lights during the nesting season - Using a smaller number or lower wattage of lights - Using red and yellow	1) Power plant 2) Power plant adjoining sand beach	1), 2) - During the operation of the power plant	- CPGCBL/ Environmental Consultant	Expenses by CPGCBL

No	Potential Impact to be Managed	Sources of Potential Impact	Standard of Impact	Objectives	Management Effort	Management Location	Period of Management	Management Institution	Cost
					lights (as sea turtles are less affected by these colors) - Using low noise machinery				
		- Negative impact due to air pollutants, noise, and waste management	- Emission gas standards - Ambient air quality standards - Wastewater standards - Noise level standards - Waste management rule - IFC/WB EHS Guidelines values	- Prevention of air pollution, water pollution, noise, and inappropriate waste treatment	- Implement the same mitigation measures as those addressed in "Air quality", "Water quality", "Noise", and "Waste"	- Power plant			
9	Disturbance to Poor People	- Improved road along with the power plant	- Living standards of poor people	- Access to social services	- Construction of the access road, community road, and road around the power plant boundary - These roads will be built with sufficient height that they can be used even in the rainy season	- Villages near the site	- During the operation of power plant	- CPGCBL/ Environmental Consultant	Expenses by CPGCBL
10	Deterioration of Local Economy such as Losses of Employment and Means of Livelihood	- Increase in employment and business opportunities	- Number of employment opportunities for local residents and number of businesses around the power plant	- Improvement of the local economy - Improvement of living standards of local residents - Consideration	- Employment of local residents as much as possible - Use of services (i.e., laundry and catering services, etc.) and products offered by the local community	- Villages near the site	- During the operation of power plant	- CPGCBL/ Environmental Consultant	Expenses by CPGCBL

No	Potential Impact to be Managed	Sources of Potential Impact	Standard of Impact	Objectives	Management Effort	Management Location	Period of Management	Management Institution	Cost
				of local residents' feelings					
11	Land Use and Utilization of Local Resources	- Changing traditional land use patterns and utilization of local resources	- Local residents' feelings	- Consideration of local residents' feelings	- Implement the same mitigation measures as those addressed in "Local economy"	- Villages near the site	- During the operation of power plant	- CPGCBL/ Environmental Consultant	Expenses by CPGCBL
12	Disturbance to Water Usage, Water Rights, etc.	- Adverse impact due to water pollution	- Same as those addressed in "Water quality"	- Same as those addressed in "Water quality"	- Implement the same mitigation measures as those addressed in "Water quality"	- Power plant	- During the operation of power plant	- CPGCBL/ Environmental Consultant	Expenses by CPGCBL
13	Disturbance to the Existing Social Infrastructure and Services	1) Traffic jams caused by increased vehicles 2) Improved roads along with the power plant 3) Improved social infrastructure along with the power plant	- Impact to social infrastructure and services	1) Minimization of increasing traffic volume 2) Access to social services 3) Improvement of living standards of local residents	1) Traffic volume - Minimizing traffic volume by using buses for employees 2) Access to social services - Construction of the access road, community road, and road around the power plant boundary - These roads can be used even in the rainy season. 3) Improvement of living - New service facilities, such as school and medical center, are made available to local residents, as required - Electrification of surrounding area will be examined	1), 2) - Villages near the site 3) Power plant	1) - 3) - During the operation of power plant	- CPGCBL/ Environmental Consultant	Expenses by CPGCBL
14	Misdistribution of Benefits	- It can occur among residents,	- Affected peoples'	- Consideration to affected	- Developing an employment plan that is fair	- Villages near the site	- During the operation of	- CPGCBL/ Environmental	Expenses by CPGCBL

No	Potential Impact to be Managed	Sources of Potential Impact	Standard of Impact	Objectives	Management Effort	Management Location	Period of Management	Management Institution	Cost
	and Compensation	workers, government officers and local politicians	emotions	peoples' emotions	to every affected person		power plant	Consultant	
15	Local Conflicts of Interest	- Conflict between local residents and workers	- Change in local customs	- Consideration of the attitudes of local residents to the project	- Employ local residents as much as possible - Promote communication between workers and local people (e.g., join in local events)	- Villages near the site	- During the operation of power plant	- CPGCBL/ Environmental Consultant	Expenses by CPGCBL - Hire local residence: 1,000Tk./person -day
16	Gender	- Improved road along with the power plant	- Living standards of gender	- Access to social services and markets	- Implement the same mitigation measures as those outlined in "Poor people"	- Villages near the site	- During the operation of power plant	- CPGCBL/ Environmental Consultant	Expenses by CPGCBL
17	Children's Rights	1) Child labor 2) Open the school in the power plant	1), 2) - Children's rights	1) Banning child labor 2) Open the school	1) Child labor - Prohibit labor contracts between subcontractor and children - Patrolling periodically to check for any child labor 2) Open the school - The school within the power plant site shall be open to local children - Construction of the access road, community road, and road around the power plant boundary - These roads will be built with sufficient height so that they can be used even in the rainy season	1), 2) - Power plant	1), 2) - During the operation of power plant	- CPGCBL/ Environmental Consultant	Expenses by CPGCBL
18	Work	1) Labor accidents	1) Labor	1), 2)	1) Labor accidents	1), 2)	1), 2)	- CPGCBL/	Expenses by

No	Potential Impact to be Managed	Sources of Potential Impact	Standard of Impact	Objectives	Management Effort	Management Location	Period of Management	Management Institution	Cost
	environment (including work safety)	2) Diseases caused by air pollutants, water pollutants, and noise from the operation of the power plant	accidents - Handling heavy loads - Working at heights - Electric shocks 2) Environment pollution - Ambient air quality standards - Noise level standards - Waste management rule - IFC/WB EHS Guidelines values	- Prevention measures against labor accidents and health problems	- Prepare a manual for labor accident prevention including safety education and training - Provide workers with appropriate protective equipment such as helmet - Inspect and ensure that any lifting devices, such as cranes, are appropriate for expected loads - Use equipment that protects against electric shock 3) Environment pollution - Observe related standards and provide workers with appropriate facilities	- Power plant	- During the operation of power plant	Environmental Consultant	CPGCBL - Safety education and training: 75,000Tk./ 20person - Protective equipment: 5,000Tk./ person
19	Accidents	1) Traffic accidents 2) Fire 3) Cyclones and tidal surge	1) Traffic accidents - Marine traffic - Land traffic 2) Fire 3) Cyclones and tidal surge	1) Prevention of traffic accidents 2) Prevention of fire 3) Prevent floods caused by cyclones	1) Traffic accidents - Determining water routes and setting course buoys on navigation channel for safety - Informing vessel schedules to local fishermen, etc. - Observation of traffic regulations, installation of traffic signs, and education on safe driving - Informing vicles schedules , such as bus, to the surrounding villages 2) Fire	1), 3) - Villages near the site 2) Power plant	1) - 3) - During the operation of power plant	- CPGCBL/ Environmental Consultant	Expenses by CPGCBL - Course buoys: 5,000Tk./ unit - Fire extinguisher: 60,000Tk./ set (Consist of 6 pcs)

No	Potential Impact to be Managed	Sources of Potential Impact	Standard of Impact	Objectives	Management Effort	Management Location	Period of Management	Management Institution	Cost
					- Installing fire extinguishers in fire handling places - Installing fire fighting system - Spraying water in coal yard - Developing fire fighting organization and implementing fire drills 3) Cyclones and tidal surges - Construction of embankment along navigation channels and revetment in the port to prevent floods caused by cyclones.				
20	Cross-boundary impact and climate change	- CO2 emission	- Amount of CO2 emission	- Reduce CO2 emissions per electric generate (kW)	- Use of USC of high efficiency for power generation	- Power plant	- During the operation of power plant	- CPGCBL/ Environmental Consultant	- Boiler and auxiliaries:(Expenses by CPGCBL)

Source: Study Team

13.7 Monitoring Plan

Environmental monitoring becomes as the guideline for the environmental management meter during construction and operation phase.

Referring to "Preparatory Survey on Chittagong Area Coal Fired Power Plant Development Project in Bangladesh Final Report" for Units 1/2, which is currently under construction, the environmental impact items, monitoring methods, responsible organizations, and costs for this project were organized (Table 13.7-1).

Table 13.7-1 Environmental Monitoring Plan

No	Significant Impact to be Monitored	Source of Significant Impact	Monitored Parameter	Purpose of the Monitoring	Monitoring Method: Method of Collecting and Analyzing Data	Monitoring Method: Location	Monitoring Method: Duration and Frequency	Responsible Organization	Cost
Construction Phase									
1	Air Quality	1) Dust resulting from construction work 2) Air pollution arising from incineration of construction materials and waste	1) - 3) - Exhaust gas (NOx, SOx, PM, CO, CO2) - Ambient air quality standards (NO2, SO2, PM10, PM2.5) - IFC/WB EHS Guidelines values Meteorological Condition (Temperature, Moisture, Wind)	1) - 3) - Evaluation of effect of the mitigation measures towards air pollution	1) - 3) - Collecting samples and analyzing at a lab - Measuring meteorological data	1) 2) - 3 points Residential area around the power plant	1) - 3) - Once every three months	- Implementation: Contractor/ Environmental Consultant - Supervisor: CPGCBL/ Supervision Consultant	Expenses included in contract cost by Contractor
		3) Exhaust gas from construction machinery and vehicles used for mobilization of equipment				3) - 2 points along access road (residential area)			
2	Water Quality (Soil) (Sediment)	1) Run off water from construction area 2) Domestic wastewater of workers (STP water) 3) Inappropriate disposal of waste 4) Leakages of oil and chemical materials from construction activity	1) - 4) pH, BOD, TSS, Oil, Coliforms, etc. - Wastewater standards and swage waste water standard - Ambient water quality standards (Inland surface water) - Ground water quality (Drinking water quality standards)	1) - 4) - Evaluation of effect of the mitigation measures towards water pollution	1) - 4) - Collecting samples and analyzing at a lab	1) - 4) - 1 point: Foreside of the drain outlet - 1 point: Surface water near the construction area - 1 point: Ground water from existing wells - 5 points: Sea water near the construction area	1) - 4) - Once every three months	- Implementation: Contractor/ Environmental Consultant - Supervisor: CPGCBL/ Supervision Consultant	Expenses included in contract cost by Contractor

No	Significant Impact to be Monitored	Source of Significant Impact	Monitored Parameter	Purpose of the Monitoring	Monitoring Method: Method of Collecting and Analyzing Data	Monitoring Method: Location	Monitoring Method: Duration and Frequency	Responsible Organization	Cost
3	Wastes (Odor) (Sediment)	1) Construction waste from construction work 2) Domestic waste from workers 3) Hazardous waste such as dry batteries, etc.	1) - 3) Kinds and quantity of waste, and the disposal method - Waste management rule - Ambient air quality standards (NH_3, H_2S)	1) - 3) - Evaluation of effect of the mitigation measures for waste	1) - 3) - Record of kinds and quantity of waste, and the disposal method	1) - 3) - Contractor's office	1) - 4) - Once a year	- Implementation: Contractor/ Environmental Consultant - Supervisor: CPGCBL/ Supervision Consultant	Expenses included in contract cost by Contractor
4	Noise and Vibration	1) Noise and vibration caused by construction machinery	1), 2) Noise level - Noise level standards - IFC/WB EHS Guidelines values	1), 2) - Evaluation of effect of the mitigation measures towards noise levels	1), 2) - Measurement using noise level meter	1) - 3 points: On the border of the site near the residential areas	1), 2) - Once every three months	- Implementation: Contractor/ Environmental Consultant - Supervisor: CPGCBL/ Supervision Consultant	Expenses included in contract cost by Contractor
		2) Noise caused by vehicles used for mobilization of equipment and workers				2) - 2 points along access road (residential area)			
5	Ecosystem, Protected Area (Endangered Species)	1) Existence of endangered species 2) Spawning of sea turtles	1), 2) Species, Number - Bangladesh wild life act, 1974 (Preservation) (Amendment) - JICA ESC Guidelines	Implement EMoP, liaisoning with EMoP of Phase I. 1) Evaluation of existence of endangered species 2) Evaluation of spawning of sea turtles	1), 2) - Observation	1) Endangered species - 1 point: Construction area 2) Sea turtle - 2 lines: Beach in front of the site and the sandbar	1) Endangered species - Migration bird: Once a week in migration season - Others: Twice a year in dry and	- Implementation: Contractor/ Environmental Consultant - Supervisor: CPGCBL/ Supervision Consultant	Expenses included in contract cost by Contractor - Observation: 400,000Tk./ researcher・year

No	Significant Impact to be Monitored	Source of Significant Impact	Monitored Parameter	Purpose of the Monitoring	Monitoring Method: Method of Collecting and Analyzing Data	Monitoring Method: Location	Monitoring Method: Duration and Frequency	Responsible Organization	Cost
							rainy seasons 2) Every 3 days in spawning season		
	Ecosystem, Protected Area (Marine Biota)	1) Potential impact due to the degradation of water quality caused by civil engineering work 2) Domestic wastewater of workers 3) Inappropriate disposal of solid waste	1) - 3) Species, Number - Phyto and Zoo Plankton - Benthos (Sea bottom)	1) - 3) - Evaluation of effect of the mitigation measures towards water pollution	1) - 3) - Collecting samples at the site, analyzing at a lab	1) - 3) - 5 points: Sea area in front of construction area	1) - 3) - Twice a year in dry and rainy seasons		Expenses included in contract cost by Contractor - Sampling & analyzing: 200,000Tk./ season (Simultaneous collection with "water quality")
	Ecosystem, Protected Area (Mud Flat, Fish & Nekton)	1) - 3) - Same as those addressed in "Marine Biota"	1) - 3) Species, Number, Weight - Benthos (Mud flat) - Fish and Nekton	1) - 3) - Same as those addressed in "Marine Biota"	1) - 3) - Collecting samples at the site, analyzing at a lab	1) - 3) - Benthos: 1 point (Beach in front of the site) - Fish and Necton: 1 point (Sea area in front of the site)	1) - 3) - Twice a year in dry and rainy seasons		Expense is included in contract cost by Contractor - Sampling & analyzing: 200,000Tk./ season
6	Deterioration of Local Economy such as Losses of Employment and Means of	- Increase in employment and business opportunities	- Number of employment opportunities for local residents and number of businesses around	- Improvement of the local economy - Improvement of living standards of local residents	- Information from related institutions - Interviewing residents	- Related institutions - Villages near the site	- Once a year	- Implementation: Contractor/ Environmental Consultant	Expenses included in contract cost by Contractor

No	Significant Impact to be Monitored	Source of Significant Impact	Monitored Parameter	Purpose of the Monitoring	Monitoring Method			Responsible Organization	Cost
					Method of Collecting and Analyzing Data	Location	Duration and Frequency		
	Livelihood		the construction area	- Consideration to local residents' feelings				- Supervisor: CPGCBL/ Supervision Consultant	- Interviewer: 5,500Tk./ researcher
7	Land Use and Utilization of Local Resources	- Changing the traditional land use patterns and utilization of local resources	- Same as those addressed in "Local Economy"	- Same as those addressed in "Local Economy"	- Same as those addressed in "Local Economy"	- Same as those addressed in "Local Economy"	- Same as those addressed in "Local Economy"	- Implementation: Contractor/ Environmental Consultant - Supervisor: CPGCBL/ Supervision Consultant	Expenses included in contract cost by Contractor
8	Disturbance to Water Usage, Water Rights, etc.	- Usage of underground water (See "2. Water quality)	- Pollution and usage of underground water	- Evaluation of effect of the mitigation measures towards water pollution - Consideration to local residents' living on the usage of underground water	- Implement the same mitigation measures as those addressed in "Water quality" - Ground water level	- 1 point: Existing well	- Once every three months	- Implementation: Contractor/ Environmental Consultant - Supervisor: CPGCBL/ Supervision Consultant	Expenses included in contract cost by Contractor
9	Disturbance to Existing Social Infrastructure and Services	1) Increase in the number of vessels 2) Increase in the number of cars	1), 2) - Traffic volume by construction	1), 2) - Evaluation of effect of construction schedule	1), 2) - Record of numbers of vessels and cars being used	1), 2) - Sea area and villages near the site	1), 2) - Once a year	- Implementation: Contractor/ Environmental Consultant - Supervisor: CPGCBL/ Supervision Consultant	Expenses included in contract cost by Contractor
10	Local Conflicts of Interest	- Conflict between local residents and external	- Change in local customs	- Confirmation of the attitudes of local	- Interviewing residents	- Villages near the site	- Regular monitoring	- Implementation:	Expenses included in

No	Significant Impact to be Monitored	Source of Significant Impact	Monitored Parameter	Purpose of the Monitoring	Monitoring Method: Method of Collecting and Analyzing Data	Monitoring Method: Location	Monitoring Method: Duration and Frequency	Responsible Organization	Cost
		workers		residents to the project			and reporting Once a year	Contractor/ Environmental Consultant - Supervisor: CPGCBL/ Supervision Consultant	contract cost by Contractor (Simultaneous collection with “Local economy”
11	Gender	1) Gender among those who are to be resettled 2) Loss of salt fields, shrimp farms and fishing sites for push net	1), 2) - Living standards of gender	1), 2) - Confirmation of living standards of egnder	1), 2) - Interviewing gender	1), 2) - Villages near the site	1), 2) - Once a year	- Implementation: Contractor/ Environmental Consultant - Supervisor: CPGCBL/ Supervision Consultant	Expenses included in contract cost by Contractor (Simultaneous collection with “Local economy”
12	Children’s Right	- Child labor	- Banning child labor	- Evaluation of effect of banning child labor	- Checking the labor contracts between subcontractor and workers - Patrolling construction area for child labor	- Contractor’s office - Construction area	- Once a year	- Implementation: Contractor/ Environmental Consultant - Supervisor: CPGCBL/ Supervision Consultant	Expenses included in contract cost by Contractor
13	Infectious Diseases such as HIV/AIDS	- Temporary influx of migrant labor during construction may increase risk of infection	- Health of labors	- Evaluation of sanitation for labor	- Labor health records	- Related institutions	- Once a year	- Implementation: Contractor/ Environmental Consultant - Supervisor: CPGCBL/ Supervision	Expenses included in contract cost by Contractor

No	Significant Impact to be Monitored	Source of Significant Impact	Monitored Parameter	Purpose of the Monitoring	Monitoring Method: Method of Collecting and Analyzing Data	Monitoring Method: Location	Monitoring Method: Duration and Frequency	Responsible Organization	Cost
								Consultant	
14	Work Environment (Including Work Safety)	- Labor accidents	Record of accidents - Handling heavy loads - Working at heights - Electric shock	- Evaluation of effect of the work safety plan	- Record of accidents	- Contractor’s office	- Once a year	- Implementation: Contractor/ Environmental Consultant - Supervisor: CPGCBL/ Supervision Consultant	Expenses included in contract cost by Contractor
15	Accidents	- Traffic accidents	Record of accidents - Marine traffic - Land traffic	- Evaluation of effect of traffic schedules	- Record of accidents	- Contractor’s office	- Once a year	- Implementation: Contractor/ Environmental Consultant - Supervisor: CPGCBL/ Supervision Consultant	Expenses included in contract cost by Contractor
16	Cross-boundary Impact and Climate Change	- CO_2 will be produced by construction work	- CO_2 emissions	- Efforts to reduce CO_2	- Record of machinery maintenance	- Contractor’s office	- Once a year	- Implementation: Contractor/ Environmental Consultant - Supervisor: CPGCBL/ Supervision Consultant	Expenses included in contract cost by Contractor
Operation Stage									
1	Air Quality	1) Exhaust gas from the stacks 2) Dust from ash disposal activity	1) - 4) - Exhaust gas (NOx, SOx, PM, CO, CO_2) - Ambient air quality	1) - 4) - Evaluation of effect of the mitigation measures towards air	1) Exhaust gas - CEMS (Continuous Emission	1) Stack outlet 2) - 3) - 3 points: Residential area	1) Continuous measure-ment 2) - 4)	- CPGCBL/ Environmental Consultant	- CEMS (Expenses included in contract cost

No	Significant Impact to be Monitored	Source of Significant Impact	Monitored Parameter	Purpose of the Monitoring	Monitoring Method: Method of Collecting and Analyzing Data	Monitoring Method: Location	Monitoring Method: Duration and Frequency	Responsible Organization	Cost
		3) Dust from coal handling activity at jetty and coal yard	standards (NO2, SO2, PM10, PM2.5) - IFC/WB EHS Guidelines values 2) - 4) Meteorological Condition (Temperature, Moisture, Wind)	pollution	Monitoring System) 2) - 4) - Collecting samples at the site, analyzing at a lab - Measuring the meteorological data	around the power plant	- Once every 3 months		by Contractor) - Measurement of air quality by CPGCBL
		4) Exhaust gas from vehicles used for mobilization of equipment and workers				4) - 2 points along access road (residential area)			
2	Water Quality (Soil) (Sediment)	1) Thermal effluents from cooling system 2) Wastewater from plant process 3) Rainwater drainage from ash pond and coal yard 4) Leakages of oil and chemical materials	1) - 4) Water temperature, pH, DO, SS, oil, BOD, COD, Heavy metals - Wastewater standards - Ambient water quality standards (Sea water) - IFC/WB EHS Guidelines values - Ground water (Drinking water quality standards) - Swage waste water standard	1) - 4) - Evaluation of effect of the mitigation measure towards water pollution	1) Thermal effluents - Measuring vertical sea water temperature profile with CTD meter before discharge 2) - 4) - Collecting samples at the site, analyzing at a lab - Continuous measurement using a sensor	1), 4) - 5 points: Sea area around thermal water discharge point - 1 point: Ground water from existing well 2), 3) - 2 points: Drain outlet of the wastewater treatment facility	1) Regularly before discharge 1), 4) - Once every 3 months 2), 3) - SS, Oil, BOD, Heavy metal etc.: Sampling and analyzing (as necessary) - pH: Continuous measurement	- CPGCBL/ Environmental Consultant	- Continuous sensor (Expenses included in contract cost by Contractor) - Measurement of water quality by CPGCBL
3	Waste (Odor) (Sediment)	1) Fly ash and bottom ash 2) Sludge from	1) Amount of coal ash generation and disposal	1) - 3) - Evaluation of effect of the handling of	1) Coal ash - Record of the amount of coal ash	1) - 3) - Power plant office	1) - 3) - Once a year	- CPGCBL/ Environmental Consultant	Expenses by CPGCBL

No	Significant Impact to be Monitored	Source of Significant Impact	Monitored Parameter	Purpose of the Monitoring	Monitoring Method			Responsible Organization	Cost
					Method of Collecting and Analyzing Data	Location	Duration and Frequency		
		wastewater treatment and waste oil from equipment, etc. 3) Sewage and garbage from workers	2), 3) Kinds and quantity of waste, and the disposal method - Waste management rule - Ambient air quality standards (NH_3, H_2S)	coal ash, sludge, and garbage	generation and disposal 2), 3) - Record of the amount of sludge and garbage				
4	Odor	1) Leakage from ammonia storage facilities 2) Exhaust of ammonia residue (un reacting)	1) Inspection of facilities and operation 2) Meteorological Condition (Temperature, Moisture, Wind) - Ambient air quality standards (NH_3)	- Prevention generating of odor	1) Record of inspection of facilities and operation 2) Collecting samples at the site, analyzing at a lab	1) Ammonia storage facilities 2) - 3 points: On the border of the site near the residential areas	1) Periodical inspection 2) - Once every 3 months	- CPGCBL/ Environmental Consultant	Expenses by CPGCBL - Measurement of odor by CPGCBL
5	Noise and Vibration	1) Noise and vibration from steam turbines, generators, and pumps, etc. 2) Noise from ash disposal activity 3) Noise from coal handling activity at jetty and coal yard	1) - 4) Noise level - Noise level standards - IFC/WB EHS Guidelines values	1) - 4) - Evaluation of effect of the mitigation measures towards noise levels	1) - 4) - Measurement using noise level meter	1) - 3) - 3 points: On the border of the site near the residential areas	1) - 4) - Once every 3 months	- CPGCBL/ Environmental Consultant	Expenses by CPGCBL
		4) Noise caused by vehicles used for mobilization of equipment and workers				4) - 2 points along access road (residential area)			
5	Ecosystem,	1) Existence of	1), 2)	Implement EMoP,	1), 2)	1) Endangered	1) Once a	- CPGCBL/	Expenses by

No	Significant Impact to be Monitored	Source of Significant Impact	Monitored Parameter	Purpose of the Monitoring	Monitoring Method: Method of Collecting and Analyzing Data	Monitoring Method: Location	Monitoring Method: Duration and Frequency	Responsible Organization	Cost
	Protected Area (Endangered Species)	endangered species (migration bird) 2) Spawning of sea turtles	Species, Number - Bangladesh wild life act, 1974 (Preservation) (Amendment) - JICA ESC Guidelines	liaisoning with EMoP of Phase I. 1) Evaluation of existence of endangered species (migration bird, Fishing Cat) 2) Evaluation of spawning of sea turtles	- Observation	species (migration bird) - 1 point: Ash pond 2) Sea turtles - 2 lines: Beach in front of the site and the sandbar	week in migration season 2) Every 3 days in spawning season	Environmental Consultant	CPGCBL - Observation: 200,000Tk/ researcher
	Ecosystem, Protected Area (Marine Biota)	1) Degradation of water quality caused by operation of power plant 2) Domestic wastewater of workers 3) Inappropriate disposal of solid waste	1) - 3) Species, Number - Phyto and Zoo plankton - Benthos (sea bottom)	1) - 3) - Evaluation of effect of the mitigation measure towards water pollution	1) - 3) - Collecting samples at the site, analyzing at a lab	1) - 3) - 5 points: Sea area in front of the site	1) - 3) - Twice a year in dry and rainy seasons		Expenses by CPGCBL - Sampling & Analyzing: 300,000Tk./ all sample (Simultaneous collection with “water qulity”)
	Ecosystem, Protected Area (Mud Flat, Fish & Nekton)	1) - 3) - Same as those addressed in “Marine Biota”	1) - 3) Species, Number, Weight - Benthos (mud flat) - Fish and nekton	1) - 3) - Same as those addressed in “Marine Biota”	1) - 3) - Collecting samples at the site, analyzing at a lab	1) - 3) - Benthos: 1 point (Beach in front of the site) - Fish and Necton: 1 point (Sea area in front of the site)	1) - 3) - Twice a year in dry and rainy seasons		Expenses by CPGCBL - Sampling & Analyzing: 300,000Tk./ all sample
6	Deterioration of Local Economy such as Losses of Employment and Means of	- Increase in employment and business opportunities	- Number of employment opportunities for local residents and number of businesses around	- Evaluation of increase in employment and business opportunities	- Information from related institutions - Interviewing residents	- Related institutions - Villages near the site	- Once a year	- CPGCBL/ Environmental Consultant	Expenses by CPGCBL - Interviewer: 5,500Tk./

No	Significant Impact to be Monitored	Source of Significant Impact	Monitored Parameter	Purpose of the Monitoring	Monitoring Method			Responsible Organization	Cost
					Method of Collecting and Analyzing Data	Location	Duration and Frequency		
	Livelihood		the construction area-						researcher
7	Land Use and Utilization of Local Resources	- Changing traditional land use patterns and utilization of local resources	- Local residents' feelings	- Confirmation of local residents' feelings	- Interviewing residents	- Villages near the site	- Once a year	- CPGCBL/ Environmental Consultant	Expenses by CPGCBL (Simultaneous collection with "Local economy")
8	Disturbance to the Existing Social Infrastructure and Services	1) Increase in the number of vessels 2) Increase in the number of cars	1), 2) - Traffic volume	1), 2) - Evaluation of effect of traffic schedules	1), 2) - Record of numbers of vessels and cars being used	1), 2) - Power plant office	1), 2) Continuous records	- CPGCBL/ Environmental Consultant	Expenses by CPGCBL
9	Misdistribution of Benefits and Compensation	- It can occur among residents, workers, government officers, and local politicians	- Local residents' feelings	- Confirmation of local residents' feelings	- Interviewing residents	- Villages near the site	- Once a year	- CPGCBL/ Environmental Consultant	Expenses by CPGCBL (Simultaneous collection with "Local economy"
10	Local Conflicts of Interest	- Conflict between local residents and workers	- Local residents' feelings	- Confirmation of local residents' feelings	- Interviewing residents	- Villages near the site	- Regular monitoring and reporting Once a year	- CPGCBL/ Environmental Consultant	Expenses by CPGCBL (Simultaneous collection with "Local economy"
11	Gender	1) Loss of salt fields, shrimp farms and fishing sites for push net 2) Improved road along with the power plant	1), 2) - Living standards of gender	1), 2) - Confirmation of living standards of gender	1), 2) - Interviwing gender	1), 2) - Villages near the site	1), 2) - Once a year	- CPGCBL/ Environmental Consultant	Expenses by CPGCBL (Simultaneous collection with "Local econom

No	Significant Impact to be Monitored	Source of Significant Impact	Monitored Parameter	Purpose of the Monitoring	Monitoring Method			Responsible Organization	Cost
					Method of Collecting and Analyzing Data	Location	Duration and Frequency		
12	Children's Rights	1) Child labor 2) Improved road along with the power plant	1) Child labor 2) Enrollment rate	1) Evaluation of effect of banning child labor 2) Improvement of enrollment rate	1) Child labor - Checking labor contracts between subcontractor and workers - Patrolling working area for child labor 2) Enrollment rate - Information from related institutions	1) Working area 2) Related institutions	1), 2) - Once a year	- CPGCBL/ Environmental Consultant	Expenses by CPGCBL
13	Work Environment (Including Work Safety)	- Labor accidents	Record of accidents - Handling heavy loads - Working at heights - Electric shocks	- Evaluation of effect of the work safety plan	- Record of accidents	- Power plant office	- Once a year	- CPGCBL/ Environmental Consultant	Expenses by CPGCBL
14	Accidents	1) Traffic accidents 2) Fire	1) Record of traffic accidents - Land traffic - Marine traffic 2) Fire - Record	1), 2) - Evaluation of effect of the work safety plan	1), 2) - Record of accidents and fire	1), 2) - Power plant office	- Once a year	- CPGCBL/ Environmental Consultant	Expenses by CPGCBL
15	Cross-boundary Impact and Climate Change	- CO2 emissions	- Amount of CO2 emissions	- Efforts to reduce CO2	- Calculate the CO2 emissions from fuel consumption	- Power plant office	- Once a year	- CPGCBL/ Environmental Consultant	Expenses by CPGCBL

Source: Study Team

13.8 Summary of Environmental and Social Impact Assessment Results

Table 13.8-1 shows summary of Environmental and Social Impact Assessment Results by coal-fired thermal power plant project.

Table 13.8-1 Summary of Environmental and Social Impact Assessment Results

Item			Scooping		Assessment after survey		Results
			Pre- / construction phase	Operation phase	Pre- / construction phase	Operation phase	
Pollution Control	1	Air Quality	✓	✓	B-	B-	**Construction phase:** -Impact of construction work is temporary. Scattering of dust will be suppressed by sprinkling water, and heavy machinery will be managed by regular inspections to reduce exhaust gas. **Operation phase:** -As measures to control pollutants in exhaust gas, low NOx combustion method, electrostatic precipitator, denitration facility, and desulfurization facility will be adopted. As a result, exhaust gas emission standards can be complied with. -The distribution concentration of air pollutants caused by exhaust gas will meets Bangladesh air quality standards. -The measures against dust scattering at coal storage and ash yard will be taken.
	2	Water Quality	✓	✓	B-	B-	**Construction phase:** -During the construction period, concrete wastewater and oil-contaminated wastewater will be treated by sedimentation and oil separation equipment. **Operation phase:** -The concentration of pollutants will be treated at a wastewater treatment facility to meet wastewater standards. --Both locations of cooling water intake and thermal effluent outlet are separated. In addition, hot water will rise due to thermal effluent, is only the surface layer. -The wastewater from coal storage and ash yard will be treated at the wastewater treatment facility.
	3	Soil Quality	✓	✓	B-	B-	**Construction phase:** -Oil contaminated wastewater is treated with the oil separator. -Oils and chemicals will be properly stored. **Operation phase:** -It will implement measures to curb underground infiltration in ash yard. -The area where oil and chemical substances are stored shall have the structure that does not

Item			Scooping		Assessment after survey		Results
			Pre- / construction phase	Operation phase	Pre- / construction phase	Operation phase	
							penetrate underground.
	4	Sediment	✓	✓	B-	B-	**Construction and Operation phase:** -Wastewater and waste shall be properly treated.
	5	Noise and Vibration	✓	✓	B-	B-	**Construction phase:** -Construction machinery and vehicles will be maintained and managed, and low noise / low vibration models will be used. -The noise generated by construction machinery will be attenuated but it is necessary consider countermeasure to meet noise standards of residential area. **Operation phase:** -Machines should be maintained and managed, and low noise / low vibration type should be used. -The noise generated by machinery will be attenuated and meet noise standards of residential area.
	6	Odor	✓	✓	B-	B-	**Construction and Operation phase:** -Domestic waste will be appropriately disposed or reused in accordance with related laws and regulations. **Operation phase:** -Ammonia used in the denitration facilities should be stored and used under appropriate management.
	7	Wastes	✓	✓	B-	B-	**Construction phases:** -Construction waste and domestic waste will be reused or properly disposed of in accordance with related laws and regulations. **Operation phases:** -Sludge from wastewater treatment facilities, waste oil at the time of machine inspection, and domestic waste will be reused or properly disposed of in accordance with related laws and regulations. -Coal ash will be disposed of at the ash yard on the project site and will be considered for reuse.
	8	Subsidence	✓	✓	D	D	**Construction and Operation phases:** - There is no subsidence during Units1/2 construction work. Underground water will be not used during construction work and operation.
Natural Environment	9	Protected Area	✓	✓	D	B-	**Construction and Operation phases:** Sonadia Island ECA is located around the study site (17 km away to the south)
	10	Ecosyste	✓	✓	B-	B-	**Construction phase:** No sandbar but mangrove

Item			Scooping		Assessment after survey		Results
			Pre- / construction phase	Operation phase	Pre- / construction phase	Operation phase	
		m					vegetation and sandy beach exist within the study site. Footprint of Fishing Cat (Prionailurus viverrinus) was found in the mangrove vegetation of Kohelia Channel. Fishing Cat is a Nationally Endangered species as well as Globally Endangered (IUCN Bangladesh 2015a). Upon considering the fact that construction activity of Phase I is on-going around the project site, this fact supports that relevant environmental management program and policy, established and implemented within Phase I Project, seems to be appropriate and work. It is noted that Phase II project is to be conducted within the already-developed land, so that occurrence of no further severe direct impact on surrounding area is expected. Sea turtles and birds, sea mammals such as dolphin, listed within IUCN Red List, may occur therein, so that negative impacts on rare species and/or local ecosystem, due to construction activities, would not be negligible. **Operation phase:** No sandbar but mangrove vegetation and sandy beach exist within the study site. Footprint of Fishing Cat (Prionailurus viverrinus) was found in the mangrove vegetation of Kohelia Channel. Fishing Cat is a Nationally Endangered species as well as Globally Endangered (IUCN Bangladesh 2015a). Sea turtles and birds, sea mammal such as dolphin, listed within IUCN Red List, may occur therein, so that negative impacts on rare species and/or local ecosystem, due to discharge of both wastewater (oil may be contained) and coolant water from power plant into the Kohelia Channel, and accidental kills of certain amounts of aquatic species due to intake of large amount of river water during the operation phase, would not be negligible.
Social Environ-ment	11	Resettlement	✓	-	D	D	**Pre-construction phase:** There will be no new land acquisition for Unit 3/4 project and no impact on resettlement is expected. But measures will be taken as necessary while sharing the results of the monitoring survey after resettlement for Unit 1/2 project.
	12	Poor people	✓	✓	B+	B+	**Construction phase:** The households that were forced to relocate due to the acquisition of land for Unit 1/2 project have received compensation for relocation and are living in houses provided by

Item			Scooping		Assessment after survey		Results
			Pre- / construction phase	Operation phase	Pre- / construction phase	Operation phase	
							CPGCBL. Therefore, no negative impact from the planning and construction of Unit 3/4 project is expected, and a positive impact from the creation of employment opportunities is expected. In addition, compensation was paid to the wage workers among the affected people by Unit 1/2 project, employment would be provided during the construction of the power plant, and vocational training have been provided, but there are some complaints about the actual employment situation, so it is necessary to consider employment for the affected people and low-income groups in the area during the construction of Unit 3/4. **Operation phase:** The households that were forced to relocate due to the acquisition of land for Unit 1/2 project have received compensation for relocation and are living in houses provided by the CPGCBL. Therefore, it is not expected that they will be negatively affected by Unit 3/4 operation. On the other hand, it is expected that the project will create employment opportunities and improve access to social services due to the development of infrastructure around the power plant. In addition, compensation was paid to the wage workers among the affected people by Unit 1/2 project, employment would be provided during the construction of the power plant, and vocational training have been provided, but there are some complaints about the actual employment situation, so it is necessary to consider employment for the affected people and low-income groups in the area during the construction of Unit 3/4. and low-income groups in the region will be created and access to social services will be improved.
	13	Ethnic minorities and indigenous peoples	✓	-	D	D	**Construction phase and Operation Phase:** It is confirmed that there are no ethnic minorities or indigenous peoples living in this area, and no impact is expected.
	14	Local economy such as employme	✓	✓	B+/-	B+/-	**Construction phase:** Increase of employment in Unit 3/4 project is expected. But there are complaints for employment during Unit 1/2 construction.

Item			Scooping		Assessment after survey		Results
			Pre- / construction phase	Operation phase	Pre- / construction phase	Operation phase	
		nt and livelihood means					Therefore, it is necessary to avoid the sense of dissatisfaction and unfairness among applicants by providing job training and offering easy-to-understand employment conditions according to the level of skill. In addition, there have been complaints of interference from fishermen and boat drivers in the construction of Unit 1/2 project. Therefore, it is necessary to continue to prevent the impact of the project by informing the public in advance and adjusting the water area to be used by the project proponent including the contractor. During the construction of Unit 3/4, Unit 1/2 are expected to be in operation, which is expected to have a positive impact on the local economy by increasing employment and human flow. **Operation phase:** It is predicted that there are no significant changes in the current and water temperature due to the discharge of cooling water from Unit 3/4 project. Hence, no impact on the fisheries and salt/shrimp industries is expected. It is assumed that the local economy will be positively affected by the increase in employment and human flow. But it should be considered that complaints on employment have been raised during the construction of Unit 1/2. In order to address this dissatisfaction, it is necessary to dispel the dissatisfaction and sense of unfairness among applicants by providing vocational training and presenting easy-to-understand employment conditions according to the level of skill, thereby creating an employment promotion effect.
	15	Land Use and Utilization of Local Resources	✓	✓	B-	B-	**Construction phase:** There is no change in land use and local resource use due to Unit 3/4 project. But there have been complaints about the impact of Unit 1/2 project on salt fields, shrimp farming and fisheries. In order to address those complaints, measures should be taken as necessary while sharing the monitoring of Unit 1/2 project. **Operation phase:** The is no land use change, and it is predicted that there are no significant changes in the current and water temperature due to the discharge of cooling water from Unit 3/4 project, and rainwater and domestic wastewater from the power plant will be discharged after

Item			Scooping		Assessment after survey		Results
			Pre- / construction phase	Operation phase	Pre- / construction phase	Operation phase	
							appropriate treatment. Therefore, the impact on the utilization of local resources, such as seawater for salt farming and fisheries is not significant.
	16	Water usage	✓	✓	B-	B-	**Construction phase:** Water to be used for the construction of Unit 3/4 is planned to be transported by ship from other areas and stored in tanks, so no impact on local water use is expected. In addition, rainwater and domestic wastewater from the power plant will be properly treated and discharged, so no impact on the surrounding water environment is expected. On the other hand, there is a possibility of groundwater contamination due to ground improvement works and spills of oil and hazardous substances, so groundwater monitoring should be continued. **Operation phase:** The freshwater process water to be used for Unit 3/4 operation service will be produced by seawater desalination, and the water used for daily life will be transported by ship from other areas and stored in tanks. Therefore, no impact on local water use is expected. Rainwater and domestic wastewater from the power plant will be properly treated and discharged to the seaside, and cooling water will also be discharged to the seaside, so no impact on the use of seawater for salt production in the salt fields is expected.
	17	Existing Social Infrastructure and Services	✓	✓	B-	B-/+	**Construction phase:** Construction materials for Unit 3/4 project will be transported from the sea, and in addition, once Unit 1/2 is in operation, the marine traffic related to power plant is expected to increase, requiring measures such as coordination with coastal fisheries and transportation, and the installation and dissemination of route signs. With the construction of Unit 3/4 the operation of Unit 1/2 to Traffic jams and road deterioration are expected due to the increase in commuting vehicles for both Unit 3/4 construction and Unit 1/2 operation. In addition, it is desirable for the project proponent to coordinate and promote consultations with LGED, Union Chairmen and residents on measures for road repair and maintenance. **Operation phase:** Raw materials, including coal and necessary

Item			Scooping		Assessment after survey		Results
			Pre- / construction phase	Operation phase	Pre- / construction phase	Operation phase	
							materials for the operation will be transported from the sea for the time being, which is expected to increase vessel navigation. Therefore, it is necessary to take measures such as coordination between coastal fisheries and transportation boat navigation, and installation and dissemination of route signs. As it is expected that the number of commuting vehicles to the power plant will increase, causing traffic congestion and road deterioration. Therefore, it is necessary to take comprehensive measures such as shared ride commuting, staggered commuting, and assignment of traffic control staffs for the power plant personnel. In addition, it is assumed that the project will have an impact on social services and easy access to markets throughout the year by improving and paving the surrounding roads and opening up and sharing the available facilities of the power plant to the residents.
	18	Social institutions such as social infrastructure and local decision-making institutions	✓	✓	B-	B-	**Construction phase and Operation phase:** Unit 3/4 project is not expected to have any impact on social organizations such as social capital and local decision-making bodies. However, in addition to the potential impact on existing social infrastructure and social services mentioned in the previous section, it is desirable to share local issues and coordinate measures as necessary. Since an initiative is already functioning under the coordination of the Prime Minister's Office, in which authorities and administrations involved in the development of the project in the Maheshkhali-Matarbari region share information and make adjustments as necessary, it is assumed that this initiative function will be effective for each project.
	19	Misdistribution of benefits and compensation	✓	✓	B-	B-	**Construction phase:** As there is no land acquisition in Unit 3/4 project, no misdistribution of benefits and compensation is not expected. However, the impact of the construction work on existing social infrastructure and social services, and the possibility that the disparity between the residents affected by Unit 1/2 project and those who were not compensated will become apparent, as well as the possibility that dissatisfaction with the misdistribution of benefits and compensation will increase due to the addition of problems such as inundation.

Item			Scooping		Assessment after survey		Results
			Pre- / construction phase	Operation phase	Pre- / construction phase	Operation phase	
							As a member of this society, the project proponent will be expected to contribute to the improvement of local social infrastructure and social services, as well as to the resolution of problems, in cooperation with social authorities, and to contribute to local communities through CSR activities. Although the new Real Estate Acquisition and Expropriation Law was enacted in 2017, it is confirmed that the Unit 1/2 project will be implemented based on the system in place at the time of the procedure, and the compensation is based on the JICA ESC Guidelines, so no inequity is observed. **Operation phase:** As there is no land acquisition in Unit 3/4 project, no misdistribution of benefits and compensation is not expected. However, the impact of the construction work on existing social infrastructure and social services, and the possibility that the disparity between the residents affected by Unit 1/2 project and those who were not compensated will become apparent, as well as the possibility that dissatisfaction with the misdistribution of benefits and compensation will increase due to the addition of problems such as inundation. As a member of business society, the project proponent will be expected to contribute to the improvement of local social infrastructure and social services, as well as to the resolution of problems, in cooperation with social authorities, and to contribute to local communities through CSR activities. Although the new Real Estate Acquisition and Expropriation Law was enacted in 2017, it is confirmed that the Unit 1/2 project will be implemented based on the system in place at the time of the procedure, and the compensation is based on the JICA ESC Guidelines, so no inequity is observed.
	20	Local conflicts of interest	✓	✓	B+	B+	**Construction phase:** There is little dissatisfaction with the compensation due to Unit 1/2 project, and the DC office, the project proponent, NGOs, and consultants are working together to complete the compensation for Unit 1/2 project, and no axis of conflict is recognized. Since there is a high expectation for employment in this area, it is necessary to take

Item			Scooping		Assessment after survey		Results
			Pre- / construction phase	Operation phase	Pre- / construction phase	Operation phase	
							into consideration that not only can a positive impact be assumed as an increase in employment opportunities related to the construction of the Unit 3/4 project, but it can also be a source of conflict of interest within the region. It is desirable for the project operator and EPC contractor to work together to explain the project to the local community, devise vocational training programs that also take literacy into consideration, and secure the actual number of employees. In addition, the project should be prepared in consideration of the consistency with the employment for the for Unit 1/2 operation. **Operation phase:** There are high expectations for employment in this region. For this reason, it is desirable to not only assume a positive impact as an increase in employment opportunities related to the operation of Units 3/4, but also to give consideration to the fact that it may be a factor that creates conflicts of interest within the region, and to promote explanations to the region, devise vocational training that takes into account the improvement of literacy, and secure the number of actual employees.
	21	Cultural heritage	✓	✓	D	D	**Construction phase and Operation phase:** There are no nationally or regionally designated cultural heritage sites within a 15 km radius from the project site, and there are no cultural heritage properties at the settlement, village, or union level around the project site, and no impact is expected by Unit 3/4 project.
	22	Landscape	-	-	D	D	**Construction phase and Operation phase:** There is no picturesque scenery existing on or around the site.
	23	Gender	✓	✓	B+	B+	**Construction phase:** The gender consideration in the construction of Unit 3/4 is expected to be the employment of women in construction-related activities. However, considering the low literacy rate and lack of experience of women in this area, as well as the cultural and religious roles of women, it is desirable to provide employment opportunities that include a vocational training component. It is also desirable to develop an employment plan that includes vocational training that takes into account the family structure and income of the women, considering that the improvement

Item			Scooping		Assessment after survey		Results
			Pre- / construction phase	Operation phase	Pre- / construction phase	Operation phase	
							of livelihoods is also important as a gender consideration, given the role of women in this area. **Operation phase:** The gender consideration in Units 3/4 operation is expected to be the employment of women in power plant related activities. However, considering the low literacy rate and lack of experience of women in this area, as well as the cultural and religious roles of women, it is desirable to provide employment opportunities that include a vocational training component. It is also desirable to develop an employment plan that includes vocational training that takes into account the family structure and income of the women, considering that the improvement of livelihoods is also important as a gender consideration, given the role of women in this area..
	24	Children's Rights	✓	✓	B-	B+	**Construction phase:** No children were found to be working in the construction of Unit 1/2, and the same monitoring should be conducted in the construction of Unit 3/4 project. In addition, in order to protect children's health and ensure their school attendance, it is desirable to conduct activities to contribute to the development of social infrastructure and improvement of social services, considering the importance of improving livelihoods and ensuring safe routes to school. **Operation phase:** The construction and paving of the surrounding roads may facilitate year-round access to social services and markets, which is assumed to have a positive impact on ensuring children's health and school attendance.
	25	Infectious diseases such as HIV/AIDS	✓	-	B-	D	**Construction phase:** There is a possibility of the risk that the infectious diseases such as HIV/AIDS will be introduced with migration of workers for Unit 3/4 construction. In the construction of Unit 1/2 awareness-raising, education, and training related to HIV/AIDS have been implemented, and have had a certain effect. Therefore, it is desirable to implement similar activities and monitoring during the construction of Unit 3/4.

Item			Scooping		Assessment after survey		Results
			Pre- / construction phase	Operation phase	Pre- / construction phase	Operation phase	
	26	Work environment (including work safety)	✓	✓	B-	B-	**Construction phase:** In the construction of Unit 1/2 project, considerations have been given to the hygiene, safety and environment of the working environment and monitoring, such as sanitary equipment in the worker's dormitory, waste management, deployment of personal protective equipment, and deployment of fire extinguishers. The effect on the safety of the working environment has been confirmed. It is desirable to carry out similar activities and monitoring during the construction of Unit 3/4 project. On the other hand, during the construction of Unit 1/2 project, two fatal accidents, a traffic accident of construction-related vehicles, and a marine accident of construction-related vessels occurred. In order to prevent the occurrence of these accidents, it is necessary to carry out training, education and enlightenment using posters and videos in detail. **Operation phase:** In order to prevent occupational accidents among power plant staff, it is necessary to establish a person in charge of EHS management and guidelines, and to take measures such as training program and creating posters and video materials for awareness-raising.
other	27	Accidents	✓	✓	B-	B-	**Construction phase:** There is a possibility of traffic accidents on land and at sea during the construction of Unit 3/4 project. Therefore, it is desirable to promote not only safety education for construction workers and distribution of educational materials such as posters and videos, but also, to the extent possible, implementation of measures to prevent traffic accidents on surrounding roads, installation of signs at sea, and placement of educational posters on traffic safety at jetty and port. **Operation phase:** Since traffic accidents are expected to occur on land and at sea among the power plant personnel, it is desirable to promote safety education and training program to the personnel concerned, and distribution of educational materials such as posters and videos. Furthermore, along with this, it is desirable to

Item			Scooping		Assessment after survey		Results
			Pre- / construction phase	Operation phase	Pre- / construction phase	Operation phase	
							implement measures to prevent traffic accidents on surrounding roads, install signs at sea, and place posters to raise awareness of traffic safety at jetty or port, to the extent possible.
	28	Cross-boundary Impact and Climate Change	✓	✓	B-	A-	**Construction phase:** -All construction machines and vehicles will be managed and regular maintenance will be carried out. **Operation phase:** -CO2 is generated by the operation of the power plant. The power plant will adopt ultra-supercritical technology (USC). Compared to conventional thermal power plants in Bangladesh, as the amount of CO2 generated, 2,571,327 t-CO2 / y can be suppressed.

Note: '✓' is attached to items that are expected to be affected by the project or that cannot be determined at the scoping stage before / during construction and during operation. '-' is attached to items for which no impact is expected.in the scoping stage.
A+/-: Significant positive/negative impact is expected.
B+/-: Positive/negative impact is expected to some extent.
C+/-: Extent of positive/negative impact is unknown. (Further examination is needed, and the impact may be clarified as the study progresses.)
D: No impact is expected.
Source: Study Team

13.9 Stakeholder meeting and others

Stakeholder meetings for two phases were held by CPGCBL for this project at Dhaka and at the project site in Matarbari.
First phase is explain about scoping method for this project. Second phase is to explain for environment and social impact assessment.

13.9.1 Stakeholder Meeting in first phase

(1) Minute of meeting for NGO
The first stakeholder meeting was held in Dhaka on 27th February 2021, outlined below in accordance with JICA ESC Guidelines.
Regarding notification and application to join for the meeting, CPGCBL dealt with through Website, and sent invitation letters to the related governmental organizations and NGO.
Refer to Appendix 13.9 for screen shot of Website, invitation letter, meeting attendance list, pictures of the meeting and presentation material.

Chairperson: Md. Nurul Alam, Additional Secretary (Planning), Power Division
Date & Time: 3:00 pm on 27th February 2021
Venue: Bijay Hall (Level-15), Bidyut Bhaban, 1, Abdul Gani Road, Dhaka.

S/No.	Questions/Opinions/Recommendations	Provided Answers
1	A) Since Matarbari project is located very near to Air Force danger area VGD-2 where	A-D) Regarding any matters in order to impose any restrictions on the flight /

S/No.	Questions/Opinions/Recommendations	Provided Answers
	bombardment of training aircraft is done, has this issue been considered in the project planning/ development? B) Also Matarbari Power Project is located at a very important training operation zone VGR-20 of Air Force where maximum altitude for training aircraft is about 22,000 feet. Will the emission of flue gases from proposed coal fired power plant cause any restrictions on the flight/movement? And has there been any detailed study conducted on this prohibition? C) The stack height of Matarbari Power Plant is 275 m (902 feet). So, will there any restriction be imposed on the low altitude like 600-1000 feet flight movement? D) Considering the above facts, if there is any necessity of imposing restrictions or prohibitions while implementing this project, it is necessary to discuss with Civil Aviation Authority of Bangladesh and Bangladesh Air Force.	movement, the necessary steps will be taken after official discussion with Bangladesh Civil Aviation Authority and Bangladesh Air Force.
2	A) There are many rare species of wildlife/sandpiper/flora and fauna around Sonadia Island. Whether the Matarbari port connected channel will be included in the Environmental and Social Impact Assessment (ESIA) of the Matarbari power project? Besides, will there be any study of the impact on marine biodiversity because of the movements of mother vessels through Matarbari channel? B) Whether greenery/afforestation will be implemented to keep the balance of the environment due to emission of CO_2 from the power plant? If ‘Yes’, then these initiatives of greenery should not be limited to the project area rather it can be extended to the various conserved forests around the project area which will help to mitigate the adverse effects on the environment.	A) The survey activities is being conducted as per the TOR- approved by Department of Environment (DOE). The effects on flora and fauna (marine, river and terrestrial) are also covered in the ESIA study. Furthermore, impacts on marine biodiversity is being monitored every three months under the implementation of first phase of Matarbari Project. B) Green belt activities will be implemented under this project.
3	A) Due to the construction of sediment mitigation dyke to maintain the navigability of Kutubdia Channel has been reduced. Prime Minister’s Office instructed to perform regular dredging to maintain navigability of the area. Therefore, if any further extension of sediment mitigation dyke or dredging is required then the Navy needs to be involved. If the Hydrology Specialist Officer of the Navy is included in the survey, the survey can be done in a better way.	A) Decreasing of Kutubdia Channel navigability has been discussed in various meetings including the fast-track meeting held at the Honorable Prime Minister’s Office and a study report has been submitted by Navy. The feasibility study for the second phase (Units 3 and 4) of the Matarbari project is being conducting by JICA. CPGCBL has already been requested to JICA to include the impact of the project on water flow and water temperature of the Kutubdia Channel including potential solution of sedimentation

S/No.	Questions/Opinions/Recommendations	Provided Answers
	B) The Navy and the Coast Guard are the responsible parties for providing security to ships arriving at the Matarbari project area including Maheshkhali LNG Terminal. For this reason, he requested to provide temporary barracks or accommodation in the Matarbari project area for naval staff.	of the project site in this Feasibility Study report. The Navy will be involved in any subsequent activities to address the results of the study and solution for reduction of navigability of the channel. If dredging is required to maintain the navigability, any further decision will be made upon consulting with the Navy to determine the responsibility for this activity. B) Regarding the allocation of temporary accommodation of Navy staff, CPGCBL has already discussed with the Chittagong Port Authority.
4	Whether the adequacy of Power Evacuation System for this project has been taken into consideration?	The existing power evacuation system is adequate for this Project. However, the issue can be confirmed through Grid Study under the scope of Feasibility Study of the project.
5	What will be the amount of water required for the project (Cooling/ Drinking/ Industrial Water)? What will be the source of the water? Will there be any impact on the drinking water demand of the local people? Are all these factors considered in Environmental and Social Impact Assessment (ESIA)?	Polished Sea Water will be used by some treatment process of this project. No Ground Water will be used here. As a result, there will be no problem of drinking water of the local people. In addition, the used water temperature will be kept below the standard as per the guidelines of the DoE before discharging it to the environment. Water will be purified through oil water separator. Additionally, each water discharge point will be monitored through central monitoring system to ensure the quality of discharged water.
6	Is there any plan for dredging of the Kohelia Channel which has been filled due to land acquisition of the project? Has the approval of BIWTA been obtained for the construction of this project?	Only the acquired land for the Matarbari Power Project has been filled in. Kohelia Channel was not filled out. BIWTA authorities could inspect Matarbari project area, necessary cooperation will be provided on behalf of CPGCBL.
7	A1) Matarbari project is a reflection of the development of our country, hence it is quite significant. However, it is discussed here, which countries are generating how much electricity from coal but it is necessary to discuss which countries are reducing generation from coal and filling the power deficit from other resources. Because Honorable Prime Minister has promised that Bangladesh will become a country of 0% Carbon Emissions by 2050. But according to the presented information, about 32% of the total power will be generated from coal in 2041, On August 28, 2020, the Honorable State Minister for Power, Energy and Mineral Resources informed that no other coal-based	A1) Bangladesh is voluntarily committed to emit 5% less CO2 than that the amount which will be emitted in 2030 (in case of the continuation of the current trend). However, with advanced technology and financial support CO2 emissions can be reduced up to 15%. Amongst the current technologies of power generation from coal, Ultra Super Critical is the one which emits the least amount of CO2 and it will be used in the Matarbari project. Next PSMP will be reflected including the directives from Honorable Prime Minister, State Minister and Global commitments.

S/No.	Questions/Opinions/Recommendations	Provided Answers
	power project will be implemented except the ongoing five projects. It conflicts with the discussion.	
	A2) There are 11 recognized national parks and sanctuaries within 25 km radius of this project. That should be considered for implementation of the project.	A2) The impact assessment on national parks and sanctuaries will be included in the studies.
	B) 3rd generation fighter jets of Air Force will create vibration in tourist capital Cox's Bazar.	B) We accept as an opinion.
	C) Simulation of $PM_{2.5}$ and mercury (Hg) pollution impacts on human body are not included in the ESIA Study of on-going Matarbari project (1st phase). $PM_{2.5}$ and mercury (Hg) are extremely harmful for human being. Since $PM_{2.5}$ and mercury (Hg) are emitted from coal-based power plants, it is necessary to assess the impacts in ESIA study for both phase of the power project. Also need to assess what kind of impact of Hg will have on water body, fish resources and human body.	C) Since the beginning of the 1st phase of Matarbari project, concentration of mercury (Hg) is monitoring in soil, water and air at the project area in every 3 months. The monitoring results are found within the limit set by the DoE. The ongoing feasibility study will predict the levels of PM2.5 and mercury (Hg) emitted from the 1st and 2nd phase projects.
	D) Vulnerability Study must have been completed due to climate risk as the power plant is situated in the coastal area. In a US-based study in 2019 shown that inundation projection in coastal areas have been changed. Considering the differences between the two studies, he recommended for taking necessary measures.	D) The difference between the two studies will be considered to include in the assessment study.
	E) When earth filling work started in Matarbari Phase I project, waterlogging (inundation) was created in Matarbari area for a long time. Locals have complained that there is still logging in some places.	E) Untimely rainfall resulting from climate change caused waterlogging in the project area. The problem has already been expeditiously eliminated by digging of channel.
	F) A press conference was held in Dhaka after BAPA visited the Kohelia Channel. Later BAPA came to know that a director of the DoE, Chittagong had OSD due to his submission of a report on the veracity of the Kohelia Channel filling.	F) We accept as an opinion.
	G) RHD is constructing a road by filling part of the Kohelia Channel. Also temporary road guide wall is being constructed which will be removed after the completion of works. The government has been directed by the Supreme Court to strengthen the River Commission. Besides, all the rivers of our	G) Note; See the answer of 6.

S/No.	Questions/Opinions/Recommendations	Provided Answers
	country have been declared as Living Entity. The State Acquisition and Tenancy Act 1950, Port Rule 1966 and the High Court's Verdict 2009, have provided instructions on defining a river and determining the size of a river. Furthermore, the channel connected to the river and the riverbank are parts of the river. It is not our intention to obstruct this road construction work. However, unless the road is properly constructed, we will complain. H) Many mitigation measures are being taken in this project and some expenses are being spent from the climate fund. It is not ethically correct. I) Groundwater quality cannot be maintained by cutting down the hills and forests in Maheshkhali area. As Maheshkhali is the only hilly island of Bangladesh and flat lands are being made by cutting down the hills & forests, the required environmental study should be comprehensive, science-based, transparent, inclusive, and meaningful. The United Nations has directed to conduct a strategic environmental assessment for the south-west region which is being implemented by the government. So, a strategic environmental assessment needs to be done for the south-east region presently. It would not be appropriate to build a power plant without assessing it. J) We want to point that the forest area of "Hasser char" is being deforested to fill the project area. K) The fishermen of the villages around the project area used to make a living by fishing. But fishing is currently being prevented by the Coast Guard. Fishermen and their families are protest against it.	H) No money is being spent on this project from the climate fund. The project is being fully funded by JICA and the Government of Bangladesh. I) Hill cutting issue is not directly related to this project. J) 18.5 m (depth), 250 m (width), 14.3 km (length) has excavated for port-connected channel. The filling of the project area is being done using the dredged sand. Therefore, there is no need to bring sand from "Hasser char". K) The Navy and the Coast Guard are working to ensure the safety of ships arriving at the project area. And no fishing boat cannot get close around the foreign ships. Besides, the government has also banned the use of several types of nets. If illegal nets are found, Fisheries Officer and Navy will control in accordance with Fisheries Act. The issue will be discussed in detail with the people engaged in these livelihoods at the Stakeholder meeting that is to be held in Matarbari area.
8	In process of screening in Feasibility Study / ESIA, it is determined whether the project will be implemented or not. The mitigation of various effects of the project is taken into	These issues are included in the Coal Procurement Plan. In case of Payra coal fired power plant, coal is being brought by determining the specific calorific value, Ash

S/No.	Questions/Opinions/Recommendations	Provided Answers
	consideration. One of the most important steps in this mitigation measure is to determine what fuel will be used in the project. In case of the choosing coal, hazardous content such as sulfur, Hg will adversely affect the environment and increase the cost of the project. Please inform that any policy/ system developed for monitoring coal quality?	Content, Sulfur content and other criteria. Almost same policy will be taken over Rampal and Matarbari Power Plant project. The type of coal which have serious impacts on environment will not be imported. Besides, international policies will be followed in case of coal import.

Source: Study Team

(2) Minute of meeting for local residents

The second stakeholder meeting was held in Matarbari on 7th June 2021, outlined below in accordance with JICA ESC Guidelines.

Due to the spread of Covid-19 in Bangladesh including CPGCBL, time was taken about three months after the stakeholder discussions in Dhaka on February 27, 2021.

Regarding notification and application to join for the meeting, CPGCBL asked to post on the bulletin board and at the room of Dhalghata Union Parishad, Matarbari Union Parishad, and sent invitation letters to the related governmental organizations and NGO to be able to join in person or by online.

CPGCBL asked Matarbari and Dhalghata chairmen to invite local residents.

Under Covid-19 crisis, since some local residents may difficultly join, separately, CPGCBL also prepared the opportunities of Focus Group Discussion.

Refer to Appendix 13.9 for invitation letter, pictures of the meeting.

Chairperson: Md. Mahfuzur Rahman, Upazila Nirbahi Officer (UNO), Maheshkhali, Cox's Bazar

Date & Time: 3:00pm on 7th June 2021

Venue: Matarbari Site Office, CPGCBL

S/No.	Questions/Opinions/Recommendations	Provided Answers
1	A) CPGCBL was requested to give immediately all compensation for affected persons of land acquisition in 1st Phase of the Matarbari Project. Moreover, CPGCBL was requested to complete the rehabilitation works as soon as possible.	A) CPGCBL couldn't pay compensation to some of the PAP's due to lack of necessary documents and copy of cheque from DC Office, Cox's Bazar. About 95% compensation has already been paid to the PAP's. CPGCBL will pay the remaining compensation based on their submission of necessary documents.
	B) All kinds of supports will be provided for Matarbari development works. CPGCBL shall pay the attention not to deprive their lawful rights.	B) Note; See the answer of clause 1 (A)
	C) BDT 220,000 was given as One Time Assistance (OTA) to each of 1000 No. of Project Affected Persons (PAP's) for 1414 Acres of Land acquisition and 2000 No. of PAP's for 1200 Acres of Land acquisition. CPGCBL has decided to only pay owners of the 1200 acres land acquisition and shall give OTA (BDT 220,000) to all of the co-sharers.	C) Regarding 1414 acres and 1200 acres of land acquisition, these land means Matarbari 2*600 MW USC CFPP and Bangladesh-Singapore 700 MW USC CFPP respectively. Currently, around 95% of compensation has been completed for Matarbari 2*600 MW USC CFPP. Regarding development of Bangladesh-Singapore 700 MW USC CFPP is not relevant to today's meeting.
	D) Many of salt farmers, salt transporters, fishermen and excavation labors have not included in the PAP's list yet. CPGCBL shall include these people in the PAP's list for compensation as soon as possible.	D) List of the PAP's for Land acquisition has been prepared by conducting field survey later on in 2016 by Joint Verification Team (JVT) that were composed of Power Division with the representatives of CPGCBL, DC Office, Cox Bazar, local Chairman and NGO. And JVT finalized the list of the PAP's. After verifying by JVT, the list has been finalized. Currently, about 95%

S/No.	Questions/Opinions/Recommendations	Provided Answers
		compensation has already been paid to the PAP's. Regarding remained compensation, CPGCBL is taking effort to solve as soon as possible.
	E) CPGCBL should be continually keeping in mind the demands of the local people and considering the overall development of the country. CPGCBL should conduct fully cooperation and support for people of Matarbari.	E) These issues will be considered in near future.
2	A) The people of the country are eagerly waiting for the implementation of the Matarbari power project. But people of Matarbari, Dhalghata are much sacrificing. CPGCBL should provide many people with, shelter to refugees, creating business opportunities and so on. PAP's for land acquisition have not yet received compensation, should be paid their dues as soon as possible. Some of the people are creating unwanted obstacles in getting compensation to the real victims by filing various harassment cases. CPGCBL shall encourage people to withdraw these harassing cases. CPGCBL is required to held the public hearing to quickly resolve the disturbing complaints filed against some PAP's who could not receive their compensation due to these complaints.	A) Note; See the answer of clause 1 (A)
	B) Commentator thanks that CPGCBL is providing employment of many labors from Matarbari and Dhalghata Union and will provide opportunities for employing more laborers from this area. But people are probably being deprived this opportunity due to syndicates and middlemen. CPGCBL authorities will consider this issue. Till now, no employment opportunities were created for the educated unemployed young people of Matarbari and Dhalghata in this project. Commentator want to know whether CPGCBL have any employment opportunities or not. People of Dhalghata are the victims of discrimination in the employment of laborers during the construction of the project and in case of trading as well. Commentator requests that the people of Matarbari and Dhalghata union will be prioritized equally in case of laborer recruitment and business.	B) CPGCBL is hiring about 2,000 skilled and unskilled people from Matarbari and Dhalghata areas as construction workers. At present, some engineers have been appointed following the government rules and regulations for supervising the activities of EPC contractors. Some educated people will be needed before the power plant is commissioned in 2023. Some local educated youths can be employed. In addition, an agreement/ contract will be signed with the EPC contractor to ensure employment of local people as skilled/unskilled workers in the second phase of the project.
	C) Due to the filling up of the Kohelia Channel, fishermen are unable to catch fish and are living inhumane lives. Due to implementation of project, the affected persons are generated. CPGCBL shall consider to provide alternative livelihoods to a few categories of people including fishermen and salt farmers.	C) Note; See the answer of clause 1 (A)
	D) CPGCBL shall take measures for the quick drainage	D) CPGCBL will take to solve the current water-logging

S/No.	Questions/Opinions/Recommendations	Provided Answers
	of water from the Matarbari area. E) CPGCBL shall promptly repair roads, culverts and embankments of Matarbari and Dhalghata union basis under coordination with other affiliated government departments. F) Commenter requested for resuming the construction of long-awaited technical college in Maheshkhali area and completing the construction work of the technical college. G) CPGCBL shall provide the relief assistance to the local people including poor people of Matarbari and Dhalghata Unions during the lockdown due to Covid-19 last year.	problems. E) Under CSR activities for Matarbari project by EPC contractor, a few small roads were repaired in the Matarbari area including the community road along the project boundary. However, it is not possible for CPGCBL to take any action regarding construction/ repair of local road because this is under the purview of another department of the government. F) Scope for construction of Technical Training Center has been included in RDPP to create skilled manpower within Maheshkhali area. All necessary steps for the construction of this center will be taken once the RDPP is approved. G) CPGCBL distributed the relief assistance among the poor people of local area on 19 June 2021 is in process.
3	A) Commenter wanted to know the selection process of stakeholders for this meeting. B) The Matarbari project is a part of the massive development plans of the Honorable Prime Minister for Bangladesh's economic growth. The government has created special economic zones, a new legal framework and new divisions to follow up these development activities. But, commenter expressed doubts whether the way in which the current development projects are progressing were a part of the dream of Honorable Prime Minister or not. C) Noticeably increase of land seizing in industrialized areas and coastal area is going on. Furthermore, the land acquisition and compensation processes are not going on properly and the Honorable prime minister is also aware of this matter. The Honorable Prime Minister has always said that acquiring farming land for industrialization is prohibited. Country's 70% of the salt production comes from Maheshkhali area. The chairman of Dhalghata has also raised the issues regarding compensation, rehabilitation and the grief of salt farmers. D) Commenter had raised some issues in the previous stakeholders meeting held at Dhaka regarding this project. The country's people along with Maheshkhali people are hopeful about this project. However, people of Matarbari and Moheshkhali are not aware about the	A) CPGCBL announced it to the related people that had interests in this project consulting with consultants referring to JICA ESC Guidelines. As a result, all local and district level government offices, NGO's, UP Chairmen of Matarbari and Dhalghata, teachers, PAP's including different categories of local people joined. B) The project work will be finished within the time schedule mentioned in the contract agreement. C), DC office, Cox's Bazar had provided all compensation money for land acquisition for PAP's in accordance with Land Acquisition and Resettlement Action Plan (LARAP) as per the land acquisition policies. D) The matter has been discussed in the first stakeholder's meeting which was held at Dhaka in February, 2021. The consultants have already been instructed to incorporate the assessment of the possible pollution that might cause from $PM_{2.5}$ and Hg.

S/No.	Questions/Opinions/Recommendations	Provided Answers
	emission from this coal-based power plant. The disabled child may born from the pregnant mothers due to this emission. Policymakers of Bangladesh are aware about this matter and relevant assessment is required. CPGCBL did not conduct the mercury (Hg) pollution modelling in the survey of first phase of the project. Whereas, 630,000 mothers in USA gives birth while taking this risk of Mercury (Hg) pollution. $PM_{2.5}$ and Hg are extremely harmful for the human body. In this regard, commenter requested again to conduct the modelling of $PM_{2.5}$ and Hg considering cumulative impact of phase 1 & 2.	Since Matarbari is a disaster-prone area, necessary steps have been taken to incorporate the Disaster Management Plan in the survey. These issues will be mentioned in the final report.
	E) Commenter's concerns about filling of Kohelia Channel is not being taken seriously. And the generated waste or solid waste is dumping in the Kohelia Channel through pipe during the construction activities of the projects. Due to this activities, commenter's doubts on the commitment given by CPGCBL will be expanded.	E) The issue of filling about Kohelia Channel has been discussed in the first stakeholder's meeting at Dhaka in February, 2021. No solid waste of the project is being disposed in the river. And the site have purification facilities like sedimentation pond. After treatment and quality check, the wastewater is discharged. In addition, waste treatment/ discharge process is monitored by Department of environment.
	F) The greater economy has become static due to the current pandemic situation. 40,000 MW Power Generation demand seems unacceptable. The reassessment of power demand is necessary. Commentator has already requested to Power Cell and Government Policymakers regarding this topic.	F) The issue is not under jurisdiction of CPGCBL.
	G) How many Megawatts of electricity is generated from coal? And there is no discussion about which countries have announced to stop electricity production from coal or which countries have committed to stop using coal. Regarding the coal use, China has stopped more than 1,000 coal mines since 2018 as well as closed the under-construction coal-based power plants near Beijing. Main objective of the stakeholders meeting is to produce based on true, correct information so that policymakers and the general people can get the right information.	G) The issue is not under jurisdiction of CPGCBL.
	H) Currently, there are many heavy industrial activities are going on along with power development projects in Moheshkhali. Commenter asked whether any load bearing capacities for heavy industries in Maheshkhali have been assessed or not? Hill in Maheshkhali had been destroyed/ settle down in 2010. Dauki Tectonic Fault going through Maheshkhali can be the reason behind it. In this regard, whether any strategic environmental assessment has been conducted or not? Regarding Safe for construction of heavy industries in Maheshkhali, the projects must be sustainable like that of Japan.	H) The issue has been discussed in the first stakeholders meeting held at Dhaka in February 2021.
	I) According to the order by Bangladesh's court, the river	I) The initiative to implement the project has been taken

S/No.	Questions/Opinions/Recommendations	Provided Answers
	is living entity. River filling is not permissible by taking the clearance from department of environment. Development of coal-based power plant had been necessary due to the low price of coal and inadequacy of other fuels, but the project now is unnecessary. Because it is possible to generate electricity from alternative sources due to the technological advancement and various research. J) How much reduction of CO_2 is possible by using ultra-super critical technology? It was not mentioned about how much CO_2 will be emitted through this coal-based power plant. CO_2 emission in Maheshkhali and Matarbari area will be 20 times higher than Japan's highest air pollution limit. It is unacceptable. K) There was no impact assessment carried out for construction of 2km channel for ship transportation. Nobody knows the reason why "Zhaoban" fell during Yaas cyclone, and trees in "Haasher Chor" are breaking apart. Commenter thanks CPGCBL is working for the growth of Bangladesh and CPGCBL's efforts and wants to provide any kind of co-operation. If the problems or weaknesses are not addressed properly, the project will not be sustainable and not yield good results in the long run. Therefore, CPGCBL shall take necessary measures to resolve these issues. Japanese companies is implementing this project, but on the other hands, as global commitment, they do not to invest coal-based power plants or the related any technological advancements support. This project will being implemented for the next 25-30 years. But it will become obsolete in 5-7 years. Who will take over the responsibility afterwards? It is necessary to be addressed about these problems such as preservation of bio-diversity, long-term environmental impact and so on.	as a part of the Fuel Diversification Plan of the Power System Master Plan (PSMP) which was approved by the government. J) 1200MW coal-based power plant with sub-critical technology emits 72.3 lac tons of CO_2 every year. On the other hand, the ultra-super critical technology is discharged 66.6 lac tons/year of CO_2 for generating same energy. Therefore, it emits 5.66 lac tons less CO_2 per year. K) Necessary mitigation measures will be taken to keep the probable pollution rate in allowable limit through this ongoing survey.
4	A) CPGCBL have been working tirelessly for the development of the project as well as overall development of the country. CO2 concentration is rising in the air, temperature will increase. As for effect of green belt, trees consume CO2 in air. Will any measurement device be installed for monitoring and controlled the emission level within the allowable limit? B) There are any impact on the biodiversity due to the discharge of coal during coal handling. What kind of impact will have on Water Quality? Will there be any measures to assess the impact on the reproduction of Fish / Aquatic Elements in particular? What kinds of measure will be taken to assess the overall Environmental Impact/ Climatic Changes in and	A) State-of-the-art technology for monitoring and measurement of emissions (CO_2, SO_x, NO_x, etc.) will be installed. Relevant information will be available in the CPGCBL website in for public. B) After unloading from the ship, it will be handled via covered conveyor to storage at stock yard. The coal will not be visible anywhere up to use at boiler. In this case, there is no possibility of adverse impact on water quality and any aquatic or terrestrial fauna.

S/No.	Questions/Opinions/Recommendations	Provided Answers
	around the project area?	
5	A) Main problem is waterlogging in Matarbari area. About 10-15 Nos of villages are flooded during monsoon results from rainfall. The people have been suffering from this waterlogging problem from the last 4-5 years. Although both the chairman of Matarbari and the CPGCBL were inspected the area, no actions were taken to drain out the water. CPGCBL shall take immediate actions for drain out the water before the upcoming monsoon season. B) The embankment on north side of Matarbari has already disappeared. The embankment on west side is also disappearing on the verge due to the change of current direction due to excavation for channel in sea. The shifting of sand for the channel excavation is occurring. Hundreds of families in west part of Matarbari, Sheikh Para and Jele Para have been evicted in last year. In addition, more than 100-200 families have been displaced due to cyclone Yaas. The government has promised to build a sustainable embankment to protect the remaining houses on the west side of the embankment. In addition, it is necessary to repair the embankment temporarily by Geo-tex bags or any other means. C) Before the implementation of this project, the general public of Matarbari was assured to be employed semi-educated, skilled and unskilled laborer. At present, the number of unemployed people in Matarbari area is about 15,000 and about 80% of the population in Matarbari are living under the poverty line. It is hoped to employ adequately in order to eliminate the unemployed people in Matarbari. D) About the main road from Maheshkhali to Matarbari which most of the goods of the project are transported, Currently condition is dilapidated condition, and to be repaired is necessary.	A) Necessary actions will be taken to solve the current problem. B) The government has taken a plan to build a Super Dike in this area under Bangladesh Water Development Board. C) Note; See the answer of clause 2 (B) D) Note; See the answer of clause 2 (E)
6	A) Total 690.67 sq km area is under jurisdiction of CoxDA. Mouza of Maheshkhali like Sonadia, Pahar Thakurtala, Putibila, Gorokghata and Amidordia (total 17.67 sq km) is also under jurisdiction of CoxDA. According to CoxDA's building construction rule, it is required to get approval from CoxDA for establishment of any structures. B) How about the disaster management plan of the project?	A) According to the mention of the representative of CoxDA, Matarbari, Mouza is not under jurisdiction. Nevertheless, the project will be implemented by maintaining proper coordination with CoxDA. B) It was replied that the Disaster Management Plan will be included in the ongoing survey.
7	A) The higher authorities had promised to install a vocational school/ college to train up the people who will lose the income opportunity in the public consultation meeting on the beginning of construction of this project. Whether would this promise be realized or not?	A) Note; See the answer of clause 2 (F)

S/No.	Questions/Opinions/Recommendations	Provided Answers
	B) It was promised in the same meeting that the project construction will be started for providing compensation in 21 No. of categories including businessmen/ skilled-unskilled labors etc. How many categories of people have been compensated till now?	B) Note; See the answer of clause 1 (B)
	C) Whether will the local people get the employment opportunity in transparent and impartial way or not?	C) Note; See the answer of clause 1 (B)

Source: Study Team

13.9.2 Stakeholder Meeting in second phase

Bangladesh was locked down from July 1st to 14th in 2021, and from July 23rd to August 10th in 2021 as the measure to prevent the spread of Covid-19, and preparations for Stakeholder meeting for second phase were started after the lockdown.

The method of notification was the same as the previous meetings.

Refer to Appendix 13.9 for screen shot of Website, invitation letter, meeting attendance list, pictures of the meeting and presentation material.

(1) Minute of meeting by online

Chairperson: Md. Nurul Alam, Additional Secretary (Planning), Power Division
Date & Time: 3:00pm on 31 August, 2021
Location: Online

S/No.	Questions/Opinions/Requests	Provided Answers
1	A) No mentionable effects will be occur as the project area has a distance of 17kms from Sonadia island. In case of any impact happening, he praises the initiative to conduct monitoring every 3 month's interval. He also said that he had conducted surveys by independent scientist on the cumulative impact of all proposed projects at Matarbari. Air pollution before the 10 coal-based projects were excluded. The results of the survey showed that the air pollution that will occur in the Matarbari area will be 20 times more than Japan's air quality standard. He wanted to know from CPCGBL about the methodology that is applied to calculate the mentioned emission amount in the presentation. He also wanted to know from the CPCGBL if the final EIA report will be published in the website.	A) CPCGCBL's Managing Director informs that the methodology of each Air Dispersion Modelling will be separately mentioned in the final EIA and it will be published in the website, once it's finalized. The Mercury modelling is done through a consultancy company which are engaged by JICA and the details of modelling will be included in the final EIA report. Beside that the results obtained from the EIA report shows that the air quality result is within the limits of all applicable approved local and international air quality standards.
	B) He expresses doubts about the goal of producing 40,000 MW by 2030 as stated by PSMP. In this matter, he also says that the export industry and other industries are facing major losses due to the COVID-19 pandemic. Bangladeshi govt. is also rectifying their PSMP and he provides his opinion that electricity production will be less than 40,000 MW by 2030.	B) CPGCBL's Managing Director informs that according to the PSMP's final rectification (PSMP-2016 revisit), the goal of producing 40,000MW by 2030 and another rectification activity is ongoing. It is possible to provide information in this regards, when that amendment will be completed.
	C) He questions JICA, what is the reason behind the Japanese government funding the Matarbari project despite of stopping funding of coal-based projects across the world?	C) CPCBGL's Managing Director informs that the entire infrastructure (land acquisition, land development etc.) of the project has been done for the 4 units and JICA has financed the first project keeping in view the financing of the second project.

S/No.	Questions/Opinions/Requests	Provided Answers
		It is informed to the meeting that the amount that is invested in Matarbari for the construction of units 1& 2, to make it economically viable and to keep the cost of power generation at a tolerable level it is necessary to build unit 3&4.
	D) He also mentions that 70% of the countries salt comes from Matarbari. The construction of the electricity center will affect the salt extraction process. He wanted to know if the government had any alternative plans to meet the salt demands.	D) There is no need to acquire any new land for the construction of the presented power plant. as a result, the salt extraction process will not be hampered due to the of the project.
	E) He expresses doubts that Matarbari power plant, economic zone, deep sea-port, and other development activities are linked to the erosion of the world's largest sea-beach, Cox's Bazaar. He also wanted to know if the government has done any strategic environmental assessment about the environmental effect caused by the development activities in the area. As an example, he sheds light on the strategic environment assessment in the Sundarbans. He expressed concerns that the project will not be sustainable if mitigation measures aren't taken after conducting any assessments.	E) An analysis of the suitability of different alternatives review of the project shows that the project has nothing to do with beach erosion. According to the project preparatory survey conducted by the study team appointed by JICA, project construction in this area is safe. In addition, all applicable Mitigation Measure of Preparatory Survey and EIA will accepted.
	F) He applauded the government for taking the initiative of re-excavation of the Kohelia Channel for the greater good of the country.	F) ---
	G) He called upon the CPCGBL to maintain transparency to follow the international and Bangladesh environmental laws. He also requested the CPCGBL to include BAPA in the meetings with environment department and to make the EIA report open to all.	G) The final EIA report will be published on CPGCBL's website after approved by the Department of Environment, which will be open to all.
	H) He expressed concern if the investment for including new technology will make the project a profitable one or not.	H) CPCGBL's Managing Director informs that Selective Catalytic Reduction (SCR) will be used through new technology in the project, which will increase the total expense of the project by 2%. The project will remain profitable despite the expense increase. In addition, new technologies will play an important role in protecting the environment, which cannot measure economically.
2	A) He wanted to know if the project includes anything about the necessity of water in the future due to the use of ultra-super critical technology in the project's EIA report or if there's any information on how much water is necessary.	A) CPCGBL's Managing Director informs that the matter has been included in the EIA report and the project will require 50m3/sec water.
	B) He also mentioned that the Public Health and Planning Center is working on a water supply master plan in the Matarbari area Moheshkhali-Matarbari under the authority of Integrated Infrastructure Development Initiative (MIDI). He sheds light on the issue about the steps that will be taken to meet the water demands of the power plant in that regard.	B) CPCGBL's Managing Director informs that seawater will be purified via a water treatment plan to meet the water needs of the project and there will be arrangements for rainwater harvesting. The pure water will also be used to meet the household needs and providing drinking water. Note that there is no plan to use groundwater in the project.
3	A) The following subjects can be included to environmental monitoring to make the project	A) CPCGBL's Deputy Manager(EST) informs that the presented matters have already be included to our

S/No.	Questions/Opinions/Requests	Provided Answers
	foolproof: _Aquatic Life in the project area _Agricultural soil _Health, Safety, and Environment of surrounded people B) Other than that, Sonadia island can also be included under 24/7 monitoring due to the flow of north-south wind. (Although, the island is 17km away from the project)	environment management plan and environment-based observation plan. B) The meeting has been informed, due to the distance of 17 km from the project area to Sonadia island, there will be no significant impact. There are also plans to monitor every three months.
4	A) According to decision 3(a) of the first stakeholder's meeting of CPCGBL, the hydrographic survey of the Kutubdia Channel under the authority of Bangladesh Navy and Chittagong Port is operational. In this regard, he thanks the electricity department. He states that the Kutudbia Channel is actually very important; other than that, the power department and Bangladesh Navy uses this channel for various important work. The wind and tidal direction causes the channel and its surrounding areas to experience sedimentation/sedimentation siltration which causes rapid changes in the parameter. Observing this change through the survey or constantly dredging it if the channel loses navigability will be difficult and expensive. According to paragraph 2.6 of the decision taken during the meeting at the Prime Minister's Office on October, 2019, a remodeling survey of this channel will allow identifying problems relevant to the channel and solving them in future easier. B) He also mentions that Bangladesh Navy and Coast Guard are conducting security operations to provide protection to the Maheshkhali LNG Terminal as well as Matarbari electricity project and artificial basin. Currently, there are 8 people in this team who patrol's these areas on a speedboat. It's worth mentioning that the currently deployed coast guard team is stationed at Kohelia Channel and has to go to the artificial basin which requires them to travel 20-22km which is more than 10 nautical miles. Another is obstacle is the Kohelia Channel not being suitable for movement during ebb. If the project area requires emergency support then, it will be difficult to provide it due to navigability limitations. On the other hand, going to the artificial basin is also difficult if the weather is perilous. We also have a team at Pekua river, which is almost 6 nautical miles away from the project area. He also informs that, the activities to increase the width of the channel by 100m according to decision 3(b) of the first stakeholders meeting is still ongoing. After it is complete, a decision will be reached on the matter or residency after a discussion between Bangladesh Navy, Chittagong Port, and CPCGBL. He requests CPCGBL to take necessary steps for the construction of temporary barracks and housing for the Navy staff to provide constant protection, considering the time constraints of increasing the width of the channel and providing	A) CPCGBL, Bangladesh Navy, and Chittagong Port will start planning for a remodeling survey once the currently ongoing Kutubdia Channel hydrographic survey is complete. B) Project Director of CPCGBL has already discussed with coast guard about residency. In that discussion, it was decided to determine the place of residence of the members of the Coast Guard. And it has been decided to move the platoon that is currently in the Kohelia Channel, shifted inside to the channel.

S/No.	Questions/Opinions/Requests	Provided Answers
	emergency support.	

Source: Study Team

(2) Minute of meeting for local residents

Chairperson: Md. Nurul Alam, Additional Secretary (Planning), Power Division

Date & Time: 10:00am on 31 August, 2021

Location: Matarbari and Online

S/No.	Questions/Opinions/Requests	Provided Answers
1	A) She says that, the FGD and other sources of the power plant will be produced oily and chemical wastewater. She wanted to know if there is a separate wastewater treatment or ETP will be used for different types of effluent or there will be a one ETP in this case. B) She praised the CPGCBL for their initiative to establish the Sewage Treatment Plant (STP). C) She also mentions that a lot of dust has been created from the different tasks of the first phase of construction. She wanted to know about the control measures for dust during the second phase of the construction work.	A) The treatment of effluent (Oily & FGD wastewater) generated from different sources have been included in the EIA study report. B)--- C) The matter of controlling dust has been included in the EIA report.
2	A) He complains that there's not enough opportunity for the people of Matarbari and Dhalghata to work in the ongoing implemented project. He mentions that the people of Matarbari helping a lot in the implementation of the project and hopes for more opportunities of works and trades in relevance to the projects activities in that regard. B) He also mentions, that the fishermen in the adjoining watershed and beyond are facing difficulties in fishing, with their nets. C) Due to the construction works of the project, the villagers are often faces difficulties in transportation. Oftentimes, it's not easy to communicate with the control room. The movement of heavy vehicles due to work involving the project is causing the roads to be in terrible conditions while also creating a lot of dust and dirt. He mentions that the process of spraying water to minimize the creation of dust in this regard is irregular. He attracts the overall attention of the CPGCBL on this matter. D) Conducting the piling work at the mid night that causes problems in children's sleep.	A) In the ongoing project, 2010 local laborers employed in its different activities. The local people will be employed in the 2nd phase, on the basis of skill and work opportunities. B) The adjoining water border of the project is monitored for the sake of the safety of foreign citizens and various obstacles have been imposed. All obstacles will be removed once the activities of the project is over. C) The reformation and construction of roads are being conducted under Corporate Social Responsibility (CSR) and will remain continuous. Necessary instructions will be given to the contractor organizations to ensure regular water spraying to control the generation of dust. D) Necessary instructions will be given to the contractor organizations not to conduct piling activities at the mid night.
3	In his speech, he informs the meeting that the Cox's Bazaar Development Authority is conducting the execution of the masterplan is ongoing as per Building Construction Act (1952). He expresses his opinion that it's important for any project implementation to align with the Cox's Bazaar Development Authority in this	The Managing Director of CPGCBL informs the meeting participants that the implantation of the Matarbari ultra-super critical coal-based power plant, phase-2 project under CPGCBL will be conducted in coordination with the Cox's Bazaar Development authorities He also mentioned that once the COVID-19 situation

S/No.	Questions/Opinions/Requests	Provided Answers
	regard. He hopes that CPGCBL will work unitedly with the Cox's Bazaar Development Authority in the 2nd phase construction of the project. He applauded the CPGCBL for organizing a stakeholder's meeting for the second time. He briefly informs that if necessary, another meeting can be arranged with everyone's presence at the Deputy Commissioner's conference room.	improves, in future the meeting will be arrange in attendance with all.
4.	He informed everyone that the 123/33 KV Grid sub-station under CPGCBL's project provides electricity to Matarbari, Pekua, and Chokoria. Since construction of fencing and embankment work is ongoing in the adjoining areas of the sub-station, electricity is being providing to the mentioned Upazila via underground cable currently. Sometimes the underground cable gets damaged and electricity supply gets temporarily obstructed due to the landfilling of the construction of Embankment and Fencing work. He informed everyone that Bangladesh Rural Electricity Association had solved the issue by providing uninterrupted electricity through arranging overhead line. In these circumstances, he expects complete help and cooperation from CPGCBL in providing uninterrupted electricity supply from the KV Grid sub-station constructed under their project to Matarbari, Pekua, and Chokoria via overhead line.	The Managing Director of CPGCBL says that uninterrupted electricity will be supplied from the 132/33 KV Grid sub-station and all forms of cooperation will be provided to complete the activities of overhead lines once the Embankment and Fencing and other landfilling activities are completed in the adjoining areas.
5	He attracted the attention of the CPGCBL in the prevalence of middlemen in the employment of laborers and the poor condition of the roads. Furthermore, he demands for creation of more employment and the construction of roads, culverts, and mosques.	The Managing Director of CPGCBL informs that the mentioned subjects will be taken into consideration when planning for the Corporate Social Responsibility (CSR)
6	He says that he is hopeful for employment in the project after taking computer training from CPGCBL. He requests the CPGCBL for providing training on subjects relevant to the project's work.	The Managing Director of CPGCBL says that the training is not just for employment but also to become self-dependent. CPGCBL is always ready to train the family members of the affected. He requested the Chairman to provide a list of trainees on the basis of qualifications and need in this matter.
7	He expresses his thanks to CPGCBL for organizing the stakeholder's meeting. He requested for alternative employment opportunities for all the fishermen who lost their livelihood due to the implementation of the project. He emphasized on the importance of being attentive of preventing any negative impacts on the biodiversity and fisheries of the Kohelia Channel. He expressed his conviction to work together for the implementation of the Blue (Sunil) Economy initiative which was accepted under the leadership of the honorable Prime Minister Sheikh Hasina after the sea victory. He requested for the inclusion of the Upazila Fisheries Officer of Moheshkhali in future meetings due to most registered fishermen being from Moheshkhali.	The Managing Director of CPGCBL says that the future meetings will include the Upazila Fisheries Officer of Moheshkhali.
8	A) The chairmen of Dholghata and Matarbari are ready to provide any kind of assistance to the CPGCBL to mitigate the complications arising from the remaining 4.2% EP (Effected Party) of the rehabilitation activities	A) Although the case matter is not under the jurisdiction of the CPGCBL, to resolving the case all forms of assistance will be provided from CPGCBL.

S/No.	Questions/Opinions/Requests	Provided Answers
	who are unable to receive compensation money due to various issues like land related dispute, cases etc.	
	B) He wanted to know when the excavation of the Kohelia Channel will exactly happen.	B) The excavation of the Kohelia Channel is not under the jurisdiction of CPGCBL. Therefore, CPGCBL will request Bangladesh Water Development Board for the quick completion of the excavation of the Kohelia Channel.
	C) He called for a quick completion of the work related to the access road and wanted to know the probable dates of completion of work. Although Sumitomo Corporation has rented 10 vehicles from CPGCBL, only 4 of them are allotted for the conveyance of the locals, of which only 2 are in working condition. He requested for providing at least 6 operational vehicles.	C) Quickly finishing the activities of the access road is under the jurisdiction of the Road & Highway Directorate. The Road & Highway Directorate will be requested to quickly complete the access road activities on behalf of the CPGCBL. Other than that, the contractor organizations will be provided with instructions for the reformation of roads and arranging transportation.
	D) He drawn the attention of the CPGCBL on the possibility of including fishermen in the list of beneficiaries.	D) All affected by the project are finalized through the socioeconomic survey and the JVT committee formed by the ministry and the MIDI committee form for the development of Matarbari and Moheshkhali on a local level.
	E) He attracted the attention to CPGCBL on the influence of local middlemen in the selection for employment of laborers and requested to reveal the salary chart and vacancy information of contractor organizations to the masses.	E) The contractor organizations will be informed in this matter.
	F) He requested for employing them after providing them with training according to the type of work and position of the project.	F) The Managing Director of CPGCBL says that the training is not just for employment but also for self-dependence. CPGCBL is always ready to provide training to the family members of those affected by the project. He requested the Chairman to provide a list of interest trainees on the basis of qualifications and need on this matter.
	G) He wanted to know when the Matarbari ultra-super critical coal-based power project (1st phase) will go into production.	G) According to the present speed of construction, the Matarbari ultra-super critical coal-based power project (1st Phase) will be able to produce electricity by 2024 unless the COVID-19 situation deteriorates.
	H) He wanted the immediate implementation of Township Facilities so that both CPGCBL and the local people can receive improved facilities.	H) There is a planning to complete Township Facilities work quickly. The engagement of consultant is under process for this work.
	I) He requested for the quick completion of the work of Matarbari and Dhalghata union's access road.	I) ---
9	A) The local people are constantly cooperating for the implementation of the project and will help more but he demanded that their needs to be fulfilled.	A) After start of the power plant, part of the revenue profit will be used for the development of Matarbari and Dholghata under Corporate Social Responsibility (CSR). A committee will be formed on this matter according to the format given by the government and in coordination with the local administration.

S/No.	Questions/Opinions/Requests	Provided Answers
	B) He also demanded for most laborers to be employed from Matarbari-Dholghata in the project implementation activities. C) He hoped for the help of contractor organizations affiliated with the CPGCB in the landfilling of the proposed technical school to create a skilled workforce. D) He thanked the CPGCBL for providing compensation to 1000 laborers. E) He expressed his hope that part of the profit share of revenues that will come after the implementation of the project will be used in improving the living standards of the residents of Matarbari and Dhalghata. F). He also remains hopeful that Matarbari and Dhalghata will develop in the same style as Singapore after the implementation of the project. G). He requested for the employment of others after the local laborers of Matarbari and Dhalghata in the proposed deep sea port construction.	B) The matter of employing local people (based on qualification and skill) will receive priority in case of the 2nd phase. C) There's a proposal of establishing a technical school in the DPP of the ongoing Matarbari 2*600 Megawatt ultra-super critical coal-based power project (first phase). Once it is approved, the necessary activities to establish the proposed technical school will start immediately. D-G) The matter of employing laborers in the construction of the deep-sea port is under the authority of Chattogram Port Authority (CPA). The matter will be informed to the CPA authority on behalf of CPGCBL. He thanked the chairman of Matarbari Union Council for speaking in interest of the local people and the country.

Source: Study Team

13.9.3 Focus Group Discussion (FGD) and Mixed Group Discussion (MGD)

To identify the current socio-economic situation of non-compensated people of different occupational groups, random FGDs have been conducted in Matarbari union and Dhalghata union in June and July as the scoping stage, and in September as the impact assessment stage.

For selection of the focus group it is considered occupational pattern base on nature and scope of work of the area. Base occupational pattern it is considered for FGD of different occupational group of people whose livelihood is impacted directly or indirectly due to the implementation of the projects. Different groups like;

(i) Fisherman & people was engaged with fishing related business, (ii) Shrimp workers and people related to this business, (iii) Salt farmer and relevant business people, (iv) Daily labor, (v) Farmers (Agriculture), (vi) Woman with children, (vii) CNG & Auto rickshaw driver only in Matarbari

MGD was held for to cover the people who could not access to the stake holder meeting.

Table 13.9-1 FGD & MGD in Matarbari area (scoping stage)

SL	Occupation	Date Time	No. of participant	Location	GPS
01.1	Fisherman & people engaged with fishing related business	15/02/2021 11:30	16	Shirar Dail	N 21^0 43' 7.9" E 91^0 52' 35.7"
02.1	Shrimp workers and people related to this business	16/02/2021 14:30	22	Bangla Bazar	N 21^0 43' 5.92" E 91^0 53'2.53"
03.1	Salt farmer and relevant business people	16/02/2021 11:00	16	Shirar Dail	N 21^0 43' 2.6" E 91^0 52' 34.4"
04.1	Daily labor	17/02/2021 12:30	17	Puran Bazar	N 21^0 40' 7.05" E 91^0 51' 45.25"
05.1	Farmers (Agriculture)	19/02/2021 13:30	18	Mog Dail Bazea	N 21^0 43' 7.45" E 91^0 53' 4.87"
06.1	Woman with children	22/02/2021	16	Mager Dail	N 21^0 43' 6.8"

		15:00			E 91⁰ 53' 1.78"
07.1	Mixed Group	02/03/2021 10:00	26	Shirar Dail	N 21⁰ 42' 50.45" E 91⁰ 52' 34.0"
08.1	CNG & Auto rickshaw Driver	01/03/2021 15:00	15	Natun Bazer	N 21⁰ 43' 50.7" E 91⁰ 53' 49.5"

Source: Study Team

Table 13.9-2 FGD & MGD in Dhalghata area (scoping stage)

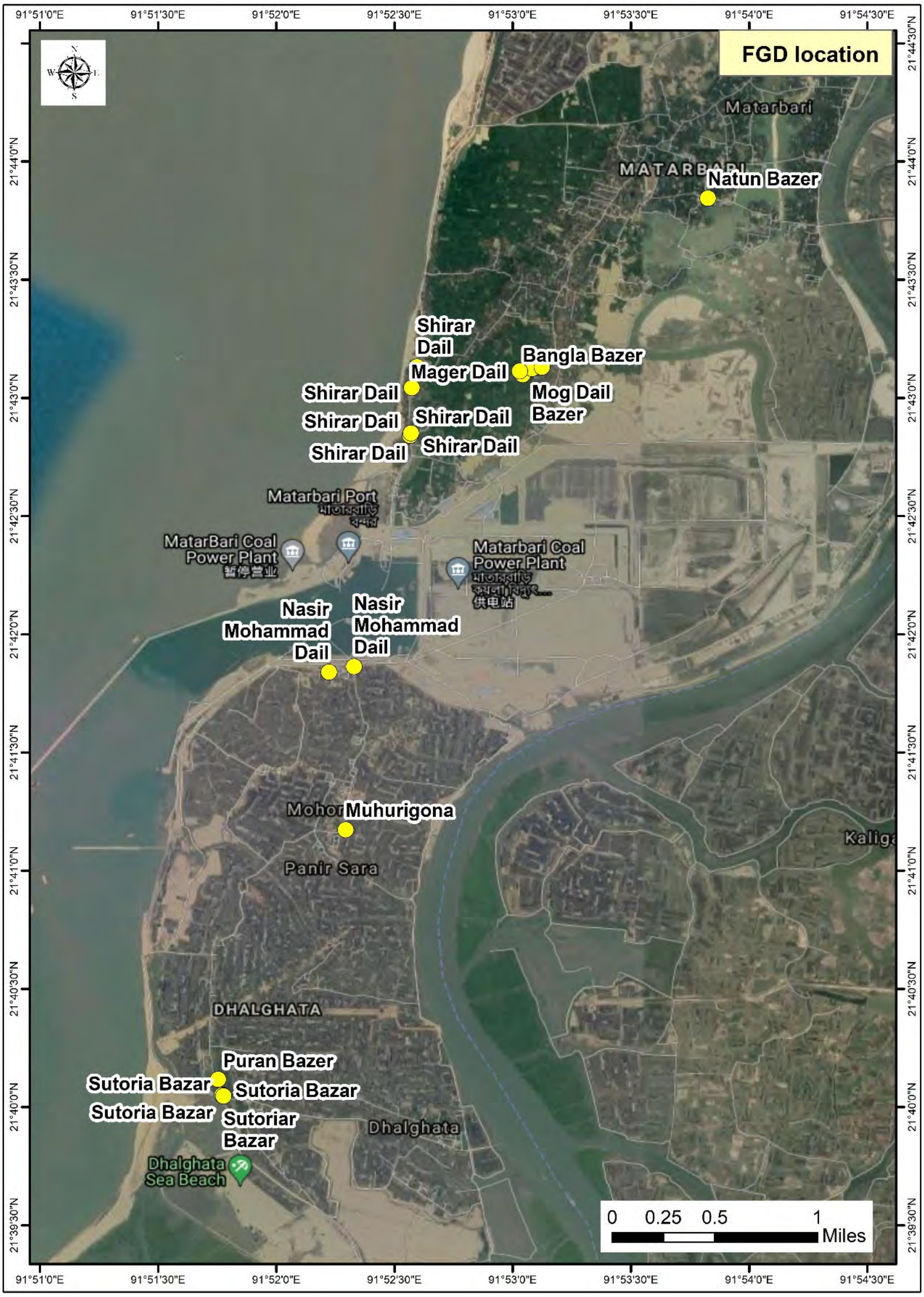
SL	Occupation	Date Time	No. of participant	Location	GPS
09.1	Fisherman & Fishing boat Driver	31/03/2021 10:00	17	Sutoria Bazar	N 21^0 40' 03.05" E 91^0 51' 46.3"
10.1	Fishing Boat Owner	31/03/2021 12:30	28	Sutoria Bazar	N 21^0 40' 03.05" E 91^0 51' 46.3"
11.1	Shrimp worker	30/03/2021 14:40	06	Muhurigona	N 21^0 41' 10.4" E 91^0 52' 17.6"
12.1	Salt worker & Salt broker	30/03/2021 11:30	09	Nasir Mohammad Dail	N 21^0 41' 51.80" E 91^0 52' 19.7"
13.1	Daily Labor	02/04/2021 13:00	13	Sutoria Bazar	N 21^0 40' 03.05" E 91^0 51' 46.3"
14.1	Woman with Children	01/04/2021 11:00	13	Nasir Mohammad Dail	N 21^0 41' 50.4" E 91^0 52' 13.4"
15.1	Mixed Group	02/04/2021 15:30	29	Sutoriar Bazar	N21^0 40'02.8" E 91^0 51' 46.6"

Source: Study Team

Table 13.9-3 FGD in inundation area in Matarbari area

SL	Occupation	Date Time	No. of participant	Location	GPS
16	Boat driver and Fisherman	08-06-2021 16.00	11	Shirar Dail	N 21^0 42' 51.1" E 91^0 52' 34.2"
17	Shrimp firm Owner	07-06-2021 12.30	03	Shirar Dail	N 21^0 42' 51.1" E 91^0 52' 34.2"
18	Salt firm Owner	07-06-2021 10.00	03	Shirar Dail	N 21^0 42' 51.1" E 91^0 52' 34.2"
19	Salt & Shrimp firm workers	07-06-2021 15.30	07	Mog Dail Bazar	N 21^0 43' 07.8" E 91^0 53' 07.4"
20	Aquaculture owners	08-06-2021 11.00	12	Shirar Dail	N 21^0 42' 51.1" E 91^0 52' 34.2"
21	aquaculture workers	08-06-2021 13.00	03	Shirar Dail	N 21^0 42' 51.1" E 91^0 52' 34.2"

Source: Study Team



Source: Study Team

Figure 13.9-1 Location of FGD and MGD in Matarbari area and Dhalghata area (scoping stage and inundation area in Matarbari area)

Table 13.9-4 FGD & MGD in Matarbari area (impact assessment stage)

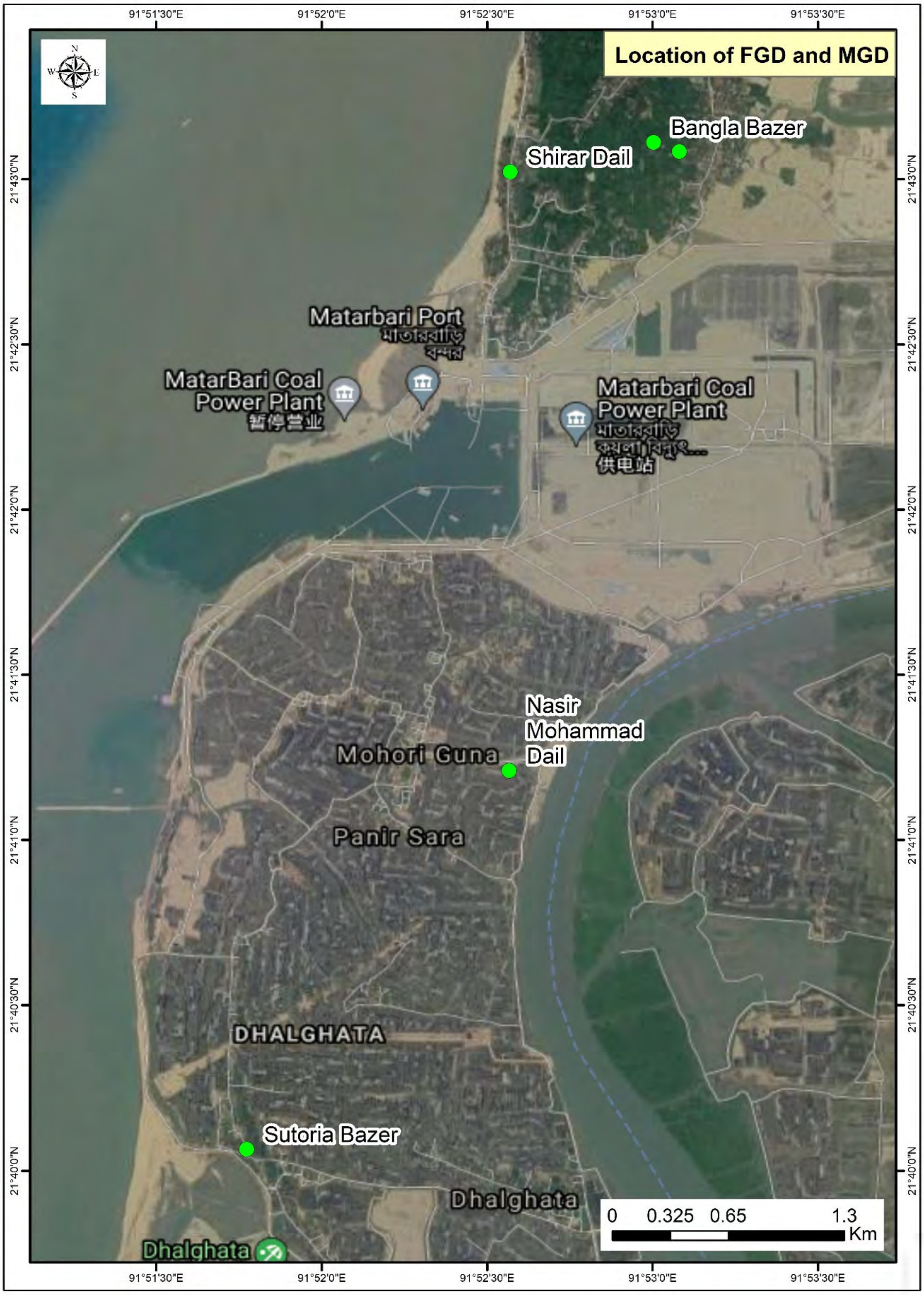
SL	Occupation	Date Time	No. of participant	Location	GPS
01.2	Fisherman & people engaged with fishing related business	01/09/2021 12:30	12	Shirar Dail	N 210 43' 1.3" E 910 52' 34.2"
02.2	Shrimp workers and people related to this business	01/09/2021 16:00	17	Bangla Bazar	N 210 43' 05.0" E 910 53' 4.87"
03.2	Salt farmer and relevant business people	01/09/2021 17:00	12	Bangla Bazar	N 210 43' 05.0" E 910 53' 4.87"
04.2	Daily labor	01/09/2021 14:00	12	Shirar Dail	N 210 43' 1.3" E 910 52' 34.2"
05.2	Farmers (Agriculture)	01/09/2021 18:00	10	Bangla Bazar	N 210 43' 05.0" E 910 53' 4.87"
06.2	Woman with children	01/09/2021 15:00	11	Bangla Bazar	N 210 43' 06.7" E 910 53' 00.2"
07.2	Mixed Group	01/09/2021 10:00	29	Shirar Dail	N 210 43' 1.3" E 910 52' 34.2"
08.2	CNG & Auto rickshaw Driver	01/09/2021 8:00	11	Natun Bazer	N 210 43' 05.0" E 910 53' 00.3"

Source: Study Team

Table 13.9-5 FGD & MGD in Dhalghata area (impact assessment stage)

SL	Occupation	Date Time	No. of participant	Location	GPS
09.2	Fisherman & Fishing boat Driver	02/09/2021 11:00	17	Sutoria Bazar	N210 40'03.9" E 910 51' 46.4"
10.2	Fishing Boat Owner	02/09/2021 12:30	28	Sutoria Bazar	N210 40'03.9" E 910 51' 46.4"
11.2	Shrimp worker	02/09/2021 17:00	06	Nasir Mohammad Dail	N 210 41' 12.6" E 910 52' 34.0"
12.2	Salt worker & Salt broker	02/09/2021 18:00	09	Nasir Mohammad Dail	N 210 41' 12.6" E 910 52' 34.0"
13.2	Daily Labor	02/09/2021 14:30	13	Sutoria Bazar	N210 40'03.9" E 910 51' 46.4"
14.2	Woman with Children	02/09/2021 16:00	13	Nasir Mohammad Dail	N 210 41' 12.6" E 910 52' 34.0"
15.2	Mixed Group	02/09/2021 9:00	29	Sutoriar Bazar	N210 40'03.9" E 910 51' 46.4"

Source: Study Team



Source: Study Team

Figure 13.9-2 Location of FGD and MGD in Matarbari area and Dhalghata area (impact assessment stage)

(1) Outline of opinions in the scoping stage

The opinions in FGDs and MGD are shown in Table 13.9-6, Table 13.9-7 and Table 13.9-8.

Table 13.9-6 The opinions in FGDs and MGD for the scoping stage in Matarbari area

SL	Occupation	Opinions & Expectation
01	Fisherman & People engaged with fishing related business	**Opinions:** - Nowadays the fishermen are getting less fish in compare to before 2013. - There is some restriction of fishing from the Coast Guard and Navy around the coal power projects. The fisherman cannot put their fishing net around the project area. - Sometimes Coast Guard and Navy seized the fishing net, if the fisherman does fishing very close to project site. - Income of fisherman and boat driver are very low nowadays. - The people who are engage is fishing business they are also struggling due less amount fish catching. - Fishing boat owners are also having financial loss due less amount fishing. - Some fisherman and fishing boat drivers are change their occupation for survival. - Some fisherman and boat driver are temporal unemployed or less employment. - Some of fishing related businessman diversify their business area for their existence. **Expectation:** - To get work/job from the project during its construction and operation. - To get some financial assistance or interest free loan for fishing related business people to migrate other business.
02	Shrimp workers and people related to this business	**Opinions:** - Due to land acquisition for coal power, the shrimp production land has been reduced in Matarbari area. Normally the people who involve in Shrimp production taking land lease from land owner and use the workers for shrimp production. The leasing cost has been raised in Matarbari area. So that the shrimp production cost is increase in Matarbari area. - Daily wages of Shrimp production worker are less compare to market condition. - Few of the shrimp production worker already change their occupation but majority of them mentioned it is not possible for them to change the occupation because they working in this area quite long time and this is the only skilled they have. - Due to water logging, there is less salt and shrimp production in the surrounding area of the project which affects the livelihood of shrimp and salt workers and related people. **Expectation:** - To resolve the inundation problem near to projects area. - To get work/job from the project during its construction and operation on priority basis. - To get some financial assistance or interest free loan for shrimp related business people who are interested to migrate other business.

SL	Occupation	Opinions & Expectation
03	Salt farmer and relevant business people	**Opinions:** - Salt and Shrimp is produce in same land. During the dry season salt is cultivated and in the same land shrimp production is done in the rainy season. - Due to land acquisition for coal power, the salt production land has been reduced in Matarbari area. The leasing cost has been raised in Matarbari area. So that the salt cultivation cost is increase in Matarbari area. - Daily wages of Salt production worker are less compare to market condition. - Few of the salt cultivation workers already change their occupation but majority of them mentioned it is not possible for them to change the occupation because they working in this area quite long time and this is the only skilled they have. - Surrounding the project's area, there is an insufficient flow of tidal water (which is containing salt) in the salt pad at the salt cultivation period/session. The insufficient tidal water was also due to project activities like water blockage in Rangakhali khal (main Chanel). Salt farmers use saltwater to the salt pad through pumping from nearby water. Salt production costs have been increased due to this reason also. **Expectation:** - To get work/job from the project during its construction and operation on priority basis. - To get some financial assistance or interest free loan for salt broker people to migrate other business.
04	Daily labor	**Opinions:** - Due to land acquisition for coal power, the salt production land has been reduced in Matarbari area. The leasing cost has been raised in Matarbari area. So that the salt cultivation cost is increase in Matarbari area. - Daily wages of salt production daily labor are less compare to market condition. - It is quite difficult to live for low-income people in Living in the Matarbari area. **Expectation:** - To get work/job from the project during its construction and operation on priority basis.
05	Farmers(Agriculture)	**Opinions:** - Daily wages of farmers are less compare to market condition if work for others. Lots of workers available in the Matarbari. - Due to inundation problems in some area only one crops can produce in a year which lead the worker less job. **Expectation:** - To get work/job from the project during its construction and operation on priority basis. - Resolve inundation problems in the affected area.
06	Woman with children	**Opinions:** - Due to local culture, women are very conservative and they are not interested to work in outside. The women are contributing to household income which is balanced with multiple household responsibilities including child care which releases other

SL	Occupation	Opinions & Expectation
		household members particularly their husband to work in the outside areas. As a responsible members of the family, some of them mentioned that they often remained stressed to run the family due to less income. - A few women complained that they feel, sometimes, difficulty to send the children to school. **Expectation:** - Looking for assurance of their husband work.
07	CNG & Auto rickshaw Driver	**Opinions:** - Road condition is very bad. Due bad road condition, some accidents happen - It also increases the maintenance cost of the Auto rickshaw and CNG operation. - Due to narrow road and bad condition create traffic congestion. **Expectation:** - Good road condition should be maintained by coal power.
08	Mixed Group	**Opinions:** - The coal power plant project brings some change in the social structure. In future, the Matarbari area will be develop. But few group of occupation people like; fisherman, boat driver, salt worker, salt broker, shrimp worker, people related to people have some problem of work. Some of lost their work and some are change the profession. - Water drainage and water logging is a major problem in Matarbari. At some part of Matarbari, a lot of house goes underwater in rainy session. - People working in shrimp production and salt cultivation as daily labor over aged like; over 50 years old is quite difficult to get work as a daily labor in another area because of their lack of adaptability and over-aged. Due to their longtime engagement, they are comfortable with shrimp production and salt cultivation. The over-aged labor groups are vulnerable. Some of they are unemployed for some time or have fewer employment opportunities. - It is less paid working as a daily labor in shrimp production and salt cultivation in comparison to job present market condition. - Due to the transportation of heavy vehicle for coal power projects construction are destroying the existing road. Moreover, there is a huge traffic jam in the morning and evening in Matarbari main entry road. - Most of sluice gate are block due the construction sand which create inundation problem of some are of Matarbari. - Children’s in the inundation are sometime unable to reach in school. Children’s of inundation area suffering different types of water borne diseases. **Expectation:** - To get work/job from the project during its construction and operation, CPGCBL/Contractor will take initiative to give the job for local people on a priority basis based on their skill. - All job advertisements should be opened to all and it will remain on the main gate of the project office.

SL	Occupation	Opinions & Expectation
		- A new revised list on affected occupational category for compensation. - As an indirectly affected people, they are expecting some extra support from the project like financial, capacity enhancement training, etc. - The water logging issue needs to solve as soon as possible. - Road maintenance needs to done at a regular interval.

Source: Study Team

Table 13.9-7 The opinions in FGDs and MGD for the scoping stage in Dhalghata area

SL	Occupation	Opinions & Expectation
01	Fisherman & Fishing boat Driver	**Opinions:** - The fisherman cannot put their fishing net around 1-2 kilometers of the project area where the main fishing ground is located. Moreover, most fishermen in this area do fishing with a small fishing boat up to 4-5 km from the shoreline. Due to this obstruction, they are catching fewer fish nowadays. This will economically affect the boat owner, boat driver, fishing labor, and people related to the fishing business. - Sometimes Coast Guard and Navy seized the fishing net if the fisherman does fishing very close to project site. - Some fisherman and fishing boat drivers are change their occupation for surveille. **Expectation:** - To get some financial assistance or interest free loan for fishing related business people to migrate other business.
02	Fishing Boat Owner	**Opinions:** - Fishing Boat owner are also having financial loss due less amount fishing. - Some of boat owner diversify their business area for their existence. **Expectation:** - To get some financial assistance or interest free loan for fishing related business people to migrate other business.
03	Shrimp workers	**Opinions:** - Daily wages of Shrimp production worker are less compare to market condition. **Expectation:** - To get work/job from the project during its construction and operation on priority basis.
04	Salt worker & Salt broker	**Opinions:** - Salt and Shrimp is produce in same land. During the dry season salt is cultivated and in the same land shrimp production is done in the rainy season. - Daily wages of salt production worker are less compare to market condition. **Expectation:** - To get work/job from the project during its construction and operation on priority basis. - To get some financial assistance or interest free loan for salt broker people to migrate other business.

SL	Occupation	Opinions & Expectation
05	Daily labor	**Opinions:** - Daily wages of salt cultivation and shrimp production daily labor are less compare to market condition. **Expectation:** - To get work/job from the project during its construction and operation on priority basis.
06	Woman with children	**Opinions:** - Due to local culture, women are very conservative and they are not interested to work in outside. The women are contributing to household income which is balanced with multiple household responsibilities including child care which releases other household members particularly their husband to work in the outside areas. As a responsible members of the family, some of them mentioned that they often remained stressed to run the family due to less income. - A few women complained that they feel, sometimes, difficulty to send the children to school. **Expectation:** - To get some financial support for their family from coal power authority.
07	Mixed Group	**Opinions:** - Some people is not got work in coal power because in many case new recruitment is controlled by broker or middle man. Moreover, the people of Matarbari get to high priority in employment issue inside coal power. - People working in shrimp production and salt cultivation as daily labor over aged like; over 50 years old is quite difficult to get work as a daily labor in another area because of their lack of adaptability and over-aged. Due to their longtime engagement, they are comfortable with shrimp production and salt cultivation. The over-aged labor groups are vulnerable. Some of they are unemployed for some time or have fewer employment opportunities. - It is less paid working as a daily labor in shrimp production and salt cultivation in comparison to job present market condition. - The fisherman cannot put their fishing net around 1-2 kilometers of the project area where the main fishing ground is located. Moreover, most fishermen in this area do fishing with a small fishing boat up to 4-5 km from the shoreline. Due to this obstruction, they are catching fewer fish nowadays. This will economically affect the boat owner, boat driver, fishing labor, and people related to the fishing business. **Expectation:** - To get work/job from the project during its construction and operation, CPGCBL/Contractor will take initiative to give the job for local people on a priority basis based on their skill. - As an indirectly affected people, they are expecting some extra support from the project like financial, capacity enhancement training, etc. - Arrangement especially in the night time for movement through projects.

Source: Study Team

Table 13.9-8 The opinions in FGDs of inundation area (Matarbari)

SL	Occupation	Opinions/Complaints & Expectation
16	Boat driver and Fisherman	**Opinions/Complaints:** - The traffic condition has been changed because some big boats come to the project area. Moreover, there is a moment restriction around project site which limit the fishing boat movement. - There is no Ghat/ landing station around the Matarbari and Dhalghata area. - Not enough work to survive - Low income **Expectation:** - Build a landing station by responsible department like BIWTA - Free movement fishing boat around the project area for fishing. - To get financial assistance from the coal power projects - To get job/work from the projects
17 & 18	Salt & Shrimp firm Owner	**Opinions/Complaints:** - Due to water logging, salt cultivation and shrimp production is very difficult because sweet water and salt water are mixed together and stay inside the field around 4-5 months which effect their production. - Most of the houses are flooded in inundated area which is also destroying their daily life. **Expectation:** - Build a sufficient sluice gate to drain out the water.
19	Salt & Shrimp firm workers	**Opinions/Complaints:** - Less work, - Difficult to survive - Some time they get sick **Expectation:** - Build a sufficient sluice gate to drain out the water. - To get financial assistance from the coal power projects - To get job/work from the projects
20	Aquaculture owners	**Opinions/Complaints:** - Due to water logging, fish production is very difficult because sweet water and salt water are mixed together and stay inside the field around 4-5 months which effect their production. - Most of the case fish get disease which give them huge financial damage. - Less fish production - Most of the houses are flooded in inundated area which is also destroying their daily life. **Expectation:** - Build a sufficient sluice gate to drain out the water. - To get financial assistance from the coal power projects
21	Aquaculture workers	**Opinions/Complaints:** - Most of the case fish get disease which give them huge financial damage that also lead to less secured job of workers. - Less fish production means has low payment of work - Most of the houses are flooded in inundated area which is also destroying their daily life.

SL	Occupation	Opinions/Complaints & Expectation
		- All the workers are suffering different types of skin diseases. **Expectation:** - Build a sufficient sluice gate to drain out the water. - To get financial assistance from the coal power projects - To get job/work from the projects

Source: Study Team

(2) Outline of opinions in the impact assessment stage

The opinions in FGDs and MGD are shown in Table 13.9-9 and Table 13.9-10.

Table 13.9-9 The opinions in FGDs and MGD for the impact assessment stage in Matarbari area

SL	Occupation	Opinions & Expectation
01	Fisherman & People engaged with fishing related business	**Opinions:** - The fishier man can catch more fish before the start of construction project - Due security restriction the fisherman unable put their fishing net near by the project area. Moreover, sometime fishing net is sized by coast guard and Navy - Due to less fishing fisherman and boat driver are not adequate earning for their living. - The fishing boat owner struggling with their investment due less amount fish catching and fishing related businessman diversify their business area who are capable. **Expectation:** - To get work during phase-2 (Unit 3 &4) construction and operation on priority based on skill. - To incorporate more affected fisherman and fishing related people as occupational category for receiving financial assistance.
02	Shrimp workers and people related to this business	**Opinions:** - Low wages of shrimp production worker are compare to market condition. - Water logging hampered salt and shrimp production in some area beside project that impose some stress to the livelihood of shrimp and salt workers and related people. - The shrimp production cost is increase in Matarbari area due to increase leasing cost of the land. **Expectation:** - Inundation problem near to projects area need to solve ASAP. - To get work/job or business opportunity the project during phase-2 construction and operation on priority basis. - Revise the list to incorporate more affected shrimp worker and shrimp related business people as occupational category for receiving financial assistance.
03	Salt farmer and relevant business people	**Opinions:** - Salt cultivation cost is increase in Matarbari area due to high leasing value of the land that impacts the slat production cost. - Getting low wedge as a salt cultivation worker. - Few of the salt cultivation workers already change their occupation but majority of them mentioned it is not possible

SL	Occupation	Opinions & Expectation
		for them to change the occupation because they working in this area quite long time and this is the only skilled they have. **Expectation:** - To get work/job from the project during its construction and operation on priority basis. - To incorporate more affected salt worker and brokers as occupational category for receiving financial assistance.
04	Daily labor	**Opinions:** - Working as daily in salt cultivation and shrimp production is not lucrative due to low wedge. - Due to coal power construction and socioeconomically changes in Matarbari area there is increase in the job opportunity a daily labor in Matarbari area. **Expectation:** - During phase-2 construction get work as a local labor at project site on priority basis. - To incorporate more labor in the existing compensation providing list as an occupational category for receiving financial assistance.
05	Farmers(Agriculture)	**Opinions:** - Due to sufficient no workers available in the locality reduce daily wedge of the farmers. - Farmers is not get not profit from their own land after doing the agriculture product in the inundation area. **Expectation:** - To get work/job construction of phase-2 on priority basis. - To incorporate more farmers in the existing compensation providing list as an occupational category for receiving financial assistance. - All the blocked sluice gate need to clear as soon as possible.
06	Woman with children	**Opinions:** - Women are supporting the household activity are not engage in outside work. Due to single sources of income most time they financial stress - Economical difficulty some time prevent children not to go to school. **Expectation:** - Expecting some sort of financial support from coal power authority.
07	CNG & Auto rickshaw Driver	**Opinions:** - Accidents happen due to bad road condition. - Traffic congestion to heavy traffic, narrow road and bad road condition. **Expectation:** - Good road condition - Regular maintenance through coal power - Solve the water logging problem
08	Mixed Group	**Opinions:**

SL	Occupation	Opinions & Expectation
		- Occupation people like; fisherman, boat driver, salt worker, salt broker, shrimp worker, people related to people have some problem of work. Some of the occupational people are displaced from their profession due to ongoing project activities. - Some of people complain they are deprived to get financial support even though they are real victims. - Some people is not got work in coal power because in many case new recruitment is controlled by broker or middle man. - Some part of Matarbari, a lot of house goes underwater in rainy session due blocked of drainage network and sluice gate. - Low payment existed for the daily labor in shrimp production and salt cultivation in comparison to present market condition. - Due to the transportation of heavy vehicle for coal power projects construction are destroying the existing road. Moreover, there is a huge traffic jam in the morning and evening in Matarbari main entry road. - Most of sluice gate are block due the construction sand which create inundation problem of some are of Matarbari. - Limited presence of children's in the school inundation area. - Children's are affected by different types of water borne diseases. **Expectation:** - To get priority on work during phase-2 construction work as well as operation of the plant based on their skill and education. - Develop a new revised list on affected occupational category for compensation. - More affected occupational people need to provide capacity enhancement training as per present market demand. - Job advertisements should be post on main gate and keep opened to all locals. - Water logging issue needs to solve by coal power as soon as possible. - Need regular road maintenance and improve the road drainage facilities.

Source: Study Team

Table 13.9-10 The opinions in FGDs and MGD for the impact assessment stage in Dhalghata area

SL	Occupation	Opinions/Complaints & Expectation
01	Fisherman & Fishing boat Driver	**Opinions/Complaints:** - Sometimes fisherman get harassed by Coast Guard and Navy for fishing close to project site. - Due to reduction of fishing area less fishes are catch by fisherman in projects surrounding. - Income of fisherman and boat driver are very low nowadays. **Expectation:**

SL	Occupation	Opinions/Complaints & Expectation
		- To add more fisherman and fishing related people as occupational category for receiving financial assistance as an affected.
02	Fishing Boat Owner	**Opinions/Complaints:** - Due adequate of fishing, investment of boat owner is in threat. - Few boat owner trying diversify their business area for their existence even which not easy. **Expectation:** - To migrate other business or sustain in this business, boat owners are seeking some financial assistance or interest free loan.
03	Shrimp workers	**Opinions/Complaints:** - Few of the shrimp production worker already change their occupation but majority of them mentioned it is not possible for them to change the occupation they do not have other skill. **Expectation:** - Looking for work in Phase-2 construction and on priority basis. - Incorporate more affected shrimp worker and shrimp related business people for financial support program.
04	Salt worker & Salt broker	**Opinions/Complaints:** - Due to land acquisition for coal power, the salt production land has been reduced in Matarbari area. The leasing cost has been raised also in Dhalghata area. So that the salt cultivation cost is increase in Dhalghata area. - Moreover, dust from the coal power construction area sometime degrade the salt quality near by the project area **Expectation:** - Get priority on work for phase-2 construction work. - To get priority of small supply /business during the phase-2 construction work and project operation. - Revise the affected list and add more affected salt worker and brokers for financial assistance.
05	Daily labor	**Opinions/Complaints:** - Daily labor wages of salt cultivation and shrimp production low because less profitability salt and shrimp business. - Not enough work in Dhalghata area **Expectation:** - To get priority to work as construction labor for phase-2 construction. - Under the financial assistance program, incorporate more labor.
06	Woman with children	**Opinions/Complaints:** - Due to financial pressure, sometimes facing difficulty to send the children at school. **Expectation:**

SL	Occupation	Opinions/Complaints & Expectation
		- Provide some financial support to the school going children's as an education assistance of affected occupations parents.
07	Mixed Group	**Opinions/Complaints:** - Some of people complain they are deprived to get financial support as an occupational category even their occupation has affected. They requested to make a revise list of affected occupational persons - Matarbari people got more employment in the phase one construction work and moreover new recruitment is controlled by broker or middle man. - Daily labor wedge in shrimp production and salt cultivation is minimum compare to others work. - People of Dhalgha have to cross coal power projects if they want to go out of Dhalghta because Dhalghata union have only one road for entry and exist. Now a day people of Dhalghata are facing lots problem passing through the projects due inadequate vehicle (provided contractor) support, unnecessary harassment by security arrangement especially in the night time. **Expectation:** - Looking for work and little business on a priority basis, based on their skill. - All job advertisements should be opened to all and it will remain posted in common access location project site. - A new revised list on affected occupational category for compensation. - To get some training as per market demand - More vehicle has to provide passing the projects. - Remove unnecessary harassment by security arrangement especially in the night time for movement through projects.

Source: Study Team

13.10 Study of the schedule for obtaining permits and approvals related to environment (Appendix 13.10)

A timeline for the preparation and implementation is summarized in Table below.

Table 13.10-1 (Pre-/Post-) Implementation Schedule

Step	Action	Responsibility	Timing	Remark
1	Decision of "Exception from IEE (Initial Environmental Examination) and Approval of Terms of Reference (TOR) for Environmental Impact Assessment (EIA))"	DOE→ CPGCBL	17 January, 2017	DOE/Clearance /5709/2017-45 (please see Appendix)
2	Decision of "Approval of Terms of Reference (TOR) for Environmental Impact Assessment (EIA))"	DOE→ CPGCBL	28 February, 2021	DOE/Clearance /5709/2017-49 (please see Appendix)
3	Submission of "EIA report about the development of Units 3/4"	CPGCBL→ DOE	August, 2021	
4	The evaluation for EIA report	DOE	From September to November, 2021	
5	Target date of EIA Approval	DOE→ CPGCBL	November, 2021	

Source: Study Team

13.11 Others

13.11.1 Check List

JICA's Environmental Checklist for the power plant, which consist of the main check items, evaluation (Yes/No) and confirmation of environmental issues (reasons and mitigation measures) is described in Table 13.11-1.

Table 13.11-1 Environmental Checklist (Thermal Power Plant)

Category	Environmental Item	Main Check Items	Yes: Y No: N	Confirmation of Environmental Considerations (Reasons, Mitigation Measures)
1 Permits and Explanation	(1) EIA and Environmental Permits	(a) Have EIA reports already been officially prepared? (b) Have EIA reports been approved by authorities of the host country's government? (c)-1 Have EIA reports been unconditionally approved? (c)-2 If conditions are imposed on the approval of EIA reports, are the conditions satisfied? (d) In addition to the above approvals, have other required environmental permits been obtained from the appropriate regulatory authorities of the host country's government?	(a) Y (b) (c) N (d) N	(a) - Draft EIA reports have been prepared for CPGCBL by the Study Team. (b)(c) - CPGCBL has officially submitted the EIA report to the Department of Environment of Bangladesh, and the EIA report has not yet been approved by the Bangladesh DOE. (d) - Required environmental permits other than the EIA reports have not been requested from the appropriate regulatory authorities of Bangladesh.
	(2) Explanation to the Local Stakeholders	(a)-1 Have contents of the project and the potential impacts been adequately explained to the local stakeholders based on appropriate procedures, including information disclosure? (a)-2 Has approval been obtained from the local stakeholders? (b) Have comments from the stakeholders (such as local residents) been reflected to the project design?	(a) Y (b) Y	(a) [Stakeholder Meeting for the scoping stage] - CPGCBL has held stakeholder meetings (SHM) with the support of the Study Team and SGS. SHM for the scoping stage of the Feasibility Study was held at Bijay Hall in Dhakaon on February 27, 2021.And second SHM was held on June 7, 2021 at Matarbari Site Office, CPGCBL. Local government officers, community leaders, NGO and local affected residents, etc were joined in SHMs. Notification was conducted through online from CPGCBL' website or distributing the invitation letter, or informing to the related persons through union chairmen. At the meeting, power-point presentation with full explanation of the project was given to the participants in their local language, to allow the audience to fully understand the project and to contribute valuable comments. However, since two SHM were held under Covid-19 crisis, CPGCBL with cooperation of Study Team and SGS held group focus meeting and mixed group meetings in Matarbari and Dhalghata and also collected opinions form villagers. [Stakeholder Meeting for explanation of EIA] - CPGCBL has held stakeholder meetings (SHM) with the support of the JICA Study Team and SGS. SHM for explanation of EIA of the Feasibility Study was held on August 31, 2021 by Online and at Matarbari Site Office, CPGCBL. Local government officers, community leaders, NGO and local affected residents, etc

Category	Environmental Item	Main Check Items	Yes: Y No: N	Confirmation of Environmental Considerations (Reasons, Mitigation Measures)
				were joined in SHMs. Notification was conducted through online from CPGCBL' website or distributing the invitation letter, or informing to the related persons through union chairmen. At the meeting, power-point presentation with full explanation of the project was given to the participants in their local language, to allow the audience to fully understand the project and to contribute valuable comments. (b) - Regarding the comments from the stakeholders, CPGCBL and Study Team shall consider and will reflect about necessary pointing out opinions in future plan and the project design.
	(3) Examination of Alternatives	(a) Have alternative plans of the project been examined with social and environmental considerations?	(a) Y	(a) - Alternative plans of the project were examined in regard to zero option and renewable power and other fuel for the power plant site. Environmental and social issues were adequately taken into account in considering the alternative plans of the project.
2 Pollution Control	(1) Air Quality	(a)-1 Do air pollutants, such as sulfur oxides (SOx), nitrogen oxides (NOx), and soot and dust emitted by the power plant operations comply with the country's emission standards? (a)-2 Is there a possibility that air pollutants emitted from the project will cause areas that do not comply with the country's ambient air quality standards? (a)-3 Are any mitigating measures taken? (b)-1 In the case of coal-fired power plants, is there a possibility that fugitive dust from the coal piles, coal handling facilities, and dust from the coal ash disposal sites will cause air pollution? (b)-2 Are adequate measures taken to prevent air pollution?	(a)-1 Y (a)-2 N (a)-3 Y (b)-1 Y (b)-2 Y	(a)-1,2,3 - SOx, NOx and Particle Matter will be generated by the operation of the power plant. A flue gas desulphurization system using lime, an electrostatic precipitator, and low-NOx burning method and SCR (Selective Catalytic Reduction) for removal of NOx will be used during this project, and exhaust concentrations will be kept below Bangladesh's emission standards and the spirit of IFC/WB EHS Guidelines. - Using AERMOD (US EPA diffusion model) etc., prediction of annual averages, a 24-hour and 1-hour value was calculated according to the time scale in conformity with the environmental standards of Bangladesh and the IFC/WB EHS Guidelines. As results, air pollutants emitted from the project will comply with Bangladesh's ambient air quality standards. (b)-1 - Coal handling and storage activities and ash handling disposal activities will result in the dispersion of dust particulates due to wind gusts. When wind speed exceeds about 6m/s, dust on the ground may be lifted up. (b)-2 - However, the occurrence ratio of wind speed exceeding 6m/s around the project site is very low. And coal storage yard and transportation of coal will be installed on the conveyor not to touch ambient air, and coal storage and ash pond will be kept wet on

Category	Environmental Item	Main Check Items	Yes: Y No: N	Confirmation of Environmental Considerations (Reasons, Mitigation Measures)
				the surface.
	(2) Water Quality	(a)-1 Do effluents including thermal effluents from the power plant comply with the country's effluent standards? (a)-2 Is there a possibility that effluents from the project will cause areas that do not comply with the country's ambient water quality standards or cause any significant temperature rise in the receiving waters? (b) In the case of coal-fired power plants, do leachates from the coal piles and coal ash disposal sites comply with the country's effluent standards? (c) Are adequate measures taken to prevent contamination of surface water, soil, groundwater, and seawater by the effluents?	(a)-1 Y (a)-2 N (b)Y (c) Y	(a)-1,2 - The temperature of thermal effluent will be discharged within ΔT 7ºC compared to the water temperature of the intake water and will be less than 40ºC. Therefore the temperature of the thermal effluent is within the discharge water regulation (40ºC). - Simulation of thermal effluent diffusion was conducted under the operation all of units (from No.1 until No.4). Since the discharge point is located near sea bottom, water temperature will rise more than 3 ºC will be occurred in the mixing zone by sea and thermal effluent. However, this zone will be limited within about 200m radius. And Regarding surface layer of sea, water temperature raised about 1 ºC will be predicted to be occurred about 1.5km to north and south along coast as matching sea current movement. Regarding in the mixing zone, aquatic biota may be affected due to raised water temperature. But regarding thermal effluent diffused at the surface layer, Nekton can avoid the sea area if it exceeds a suitable water temperature, therefore impact to Nekton is limited. Since thermal effluent is diffused in surface layer except in mixing zone, impact to flora such as seaweed is limited. - Wastewater from each facility will be collected in wastewater treatment system. The wastewater treatment system, which will consist of neutralization, coagulating sedimentation, and a filtration and oil separator, will manage and treat wastewater appropriately to comply with water quality in accordance with Bangladesh regulations and IFC/WB EHS Guidelines. Therefore, the impact on water quality is considered to be insignificant because the impact intensity is low and the coverage area is limited. (b), (c) - Leakage from the bottom of the ash pond will be prevented using an impermeable layer, such as high density polyethylene (HDPE) sheet or silt layer. - Wastewater will be managed and treated appropriately by neutralization and sedimentation to comply with water quality in accordance with Bangladesh regulations and IFC/WB EHS Guidelines. - Heavy metal ingredients contained in the coal ash and wastewater from the ash disposal site will be monitored and analyzed as a precaution.
	(3) Wastes	(a) Are wastes, (such as waste oils, and waste chemical agents), coal ash, and by-product gypsum from flue gas desulfurization generated by the power plant operations properly treated and	(a) Y	- To separate waste collection, recycling and reuse of waste will be promoted and non-recyclable waste will be disposed at appropriate sites, according to the related regulations. - Hazardous waste will be treated under the related regulations.

Category	Environmental Item	Main Check Items	Yes: Y No: N	Confirmation of Environmental Considerations (Reasons, Mitigation Measures)
		disposed of in accordance with the country's regulations?		- Fly ash and bottom ash are not categorized as hazardous materials by Bangladesh regulations. Ash disposal pond including Units 1/2 has prepared in the project site. CPGCBL considers to recycle/reuse fly ash and bottom ash for construction materials such as cement, aggregate and so on in future. Gypsum generated from desulphurization facility will also be recycled.
	(4) Noise and Vibration	(a) Do noise and vibrations comply with the country's standards?	(a) Y	<Noise> - According to the result of simulation, the predicted noise level generated by power plant operation is 14～48dB(A)dB (A) at the boundary of the project site and 26～38 dB (A) at the nearest residence. The predicted noise levels satisfy noise level standards for Bangladesh. In addition, as mitigation measures, equipment maintenance will be conducted and low noise equipment and adequate enclosures will be installed. <Vibration> - Since vibration is expected to be caused by plant operation, maintenance of equipment will be conducted.
	(5) Subsidence	(a) In the case of extraction of a large volume of groundwater, is there a possibility that the extraction of groundwater will cause subsidence?	(a) N	(a) - Ground water will not be used during the operation phase.
	(6) Odor	(a)-1 Are there any odor? (a)-2 Are adequate odor control measures taken?	(a) Y	(a) - In case domestic waste from the workers' camp is not appropriately treated, foul odors may start emanating from rotten waste. Workers shall separate and collect garbage, and illegal waste disposal will be prohibited. Appropriate disposal of waste and sewage treatment equipment for human waste (septic tank) will be installed. - Since ammonia is used in the denitration equipment, the storage of ammonia shall be adequately carried out.
3 Natural Environment	(1) Protected Areas	(a)-1 Is the project site located in protected areas designated by the country's laws or international treaties and conventions? (a)-2 Is there a possibility that the project will affect the protected areas?	(a)-1 N (a)-2 N	(a) - The project site is not located in any protected areas. - Sonadia ECA, which has been designated as Ecological Critical Area pursuant to the Environmental Protection Law of Bangladesh, is located 17km south of the proposed project site. - Air quality, water quality and noise levels during both construction and operation phases will meet environmental standards, and the impacts will not reach Sonadia ECA. Construction of Phase I (project site of Phase II is next to that of Phase I) and its environmental management/monitoring activities have been implemented already. Based on its monitoring results, it is found that the regional environment around the

Category	Environmental Item	Main Check Items	Yes: Y No: N	Confirmation of Environmental Considerations (Reasons, Mitigation Measures)
				project site (Sonadia ECA included) is well managed and no severe negative impact of Phase I construction is observed, yet.
	(2) Ecosystem	(a) Does the project site encompass primeval forests, tropical rain forests, ecologically valuable habitats (e.g., coral reefs, mangroves, or tidal flats)? (b) Does the project site encompass the protected habitats of endangered species designated by the country's laws or international treaties and conventions? (c) If significant ecological impacts are anticipated, are adequate protection measures taken to reduce the impacts on the ecosystem? (d)-1 Is there a possibility that the amount of water (e.g., surface water, groundwater) used by the project will adversely affect aquatic environments, such as rivers? (d)-2 Are adequate measures taken to reduce the impacts on aquatic environments, such as aquatic organisms? (e) Is there a possibility that discharge of thermal effluents, intake of a large volume of cooling water or discharge of leachates will adversely affect the ecosystem of surrounding water areas?	(a) N (b) Y (c) Y (d)-1 N (d)-2 Y (e) N	(a) - The project site is already reclaimed land. Its surrounding area consists of land used for salt farms and other purposes, with no primeval forests or tropical rain forests. A sandy beach is located in front of the proposed project site. There are several mangrove vegetation and tidal flats along Kohelia Channel near the project site. (b) - It is highly likely that four species of IUCN precious sea turtles spawn on the sea coast, and a detailed survey and management/monitoring should be continued while establishing integrity with those of Phase I. As mentioned above, construction of Phase I has been already started, it is noted that footprints of Fishing Cat (*Prionailurus Viverrinus*), Nationally Endangered species as well as Globally Endangered (IUCN Bangladesh 2015a), was found in the mangroves of Kohelia Channel near the project site within the dry-season ecosystem survey of Phase II feasibility study. - For the purpose of protecting the Spoon billed Sandpiper, construction workers will be instructed to strictly comply with hunting and capturing restrictions as prescribed by law. Light and noise of nighttime construction may have adverse effects on the sea turtles. (c) - Night construction activity in the spawning season should be avoided as much as possible, and should be conducted under minimum light. - Lighting color that does not affect spawning (e.g., red or yellow) will be selected. - Low-noise equipment shall also be installed. - The careful monitoring of spawning status as well as nearby mangrove vegetation is necessary. As mentioned above, several footprints of Fishing Cat (Prionailurus Viverrinus), Nationally Endangered species as well as Globally Endangered, was found in the mangroves of Kohelia Channel near the project site within the dry-season ecosystem survey of the feasibility study of Phase II. This may mean that relevant environmental management activities (on-going) of Phase I works well so far. (d) - This project does not intake surface water or ground water. (e) - The water intake and discharge of cooling water used in the power plant will be carried

Category	Environmental Item	Main Check Items	Yes: Y No: N	Confirmation of Environmental Considerations (Reasons, Mitigation Measures)
				out at a flow rate much lower than the current in the surrounding ocean, and the water flow in the surrounding sea will not be affected. - In addition, smaller fish in the sea area have sufficient swimming ability in comparison to the flow rate of water intake, and they are not likely to be affected as a consequence. - The diffusion area of thermal effluents with increased temperature of 2 ºC or higher is limited to a certain surface layer and fish can easily bypass the area.
4 Social Environment	(1) Resettlement	(a)-1 Is involuntary resettlement caused by project implementation? (a)-2 If involuntary resettlement occurs, will efforts made to minimize the impacts caused by the resettlement? (b) Is adequate explanation on compensation and resettlement assistance given to the affected people prior to resettlement? (c) Is the resettlement plan, including compensation with full replacement costs, restoration of livelihoods and living standards developed based on socioeconomic studies on resettlement? (d) Will compensation be paid prior to the resettlement? (e) Are the compensation guidelines set forth in the document? (f) Does the resettlement plan pay particular attention to vulnerable groups or people, including women, children, the elderly, people below the poverty line, ethnic minorities, and indigenous peoples? (g) Are agreements with the affected people obtained prior to resettlement? (h)-1 Is the organizational framework established to properly implement resettlement? (h)-2 Are the capacity and budget secured to implement the plan? (i) Are any plans developed to monitor the impacts	(a)-1 N (b) N/A (c) N/A (d) N/A (e) N/A (f) N/A (g) N/A (h)-1 N/A (h)-2 N/A (i) N/A	Land acquisition is not required in this phase.

Category	Environmental Item	Main Check Items	Yes: Y No: N	Confirmation of Environmental Considerations (Reasons, Mitigation Measures)
		of resettlement? (j) Will a grievance redress mechanism be set up?	(j) N/A	
	(2) Living and Livelihood	(a)-1 Is there a possibility that the project will adversely affect the living conditions of the inhabitants? (a)-2 Are adequate measures being considered to reduce the impacts, if necessary? (b)-1 Is sufficient infrastructure (e.g., hospitals, schools, and roads) available for the project`s implementation? (b)-2 If the existing infrastructure is insufficient, have any plans been developed to construct new infrastructure or improve the existing infrastructure? (c) Is there a possibility that large vehicle traffic for transportation of materials, such as raw materials and products, will impact traffic in the surrounding areas, impede the movement of inhabitants, and any cause risks to pedestrians? (d)-1 Is there a possibility that diseases, including infectious diseases, such as HIV, being transmitted due to the immigration of workers associated with the project? (d)-2 Are adequate considerations given to public health, if necessary? (e) Is there a possibility that the amount of water used (e.g., surface water, groundwater) and the discharge of thermal effluents by the project will adversely affect existing water uses and uses of	(a)-1 Y (a)-2 Y (b)-1 Y (b)-2 N/Y (c) N/Y (d)-1 Y (d)-2 Y (e) N/Y	(a)-1 - Increase of road traffic will affect transportation business, and degradation of road condition will affect transportation business as well. - Increase of marine traffic will affect fisheries and coastal transportation business. (a)-2 - Shared minivans for commuting are provided, and time-shift commuting is recommended to reduce traffic. - The proponent has been cooperated in the repairment of roads. (b)-1 - There are sufficient infrastructure, mosques, hospitals and schools available for project implementation, in addition, the proponent assists renovation of schools and mosuqes. (b)-2 - Although the infrastructure is sufficient above mentioned, the proponent is planning to establish a township with condominium, mosque, school, stadium, market and so on, next to the power plant for the purpose of promotion of local socio-economic conditions. (c) - Initially, all materials and products will be transported by ships and directly unloaded at the port next to the power plant. - After completion of high-grade access road to the site, some materials and products will be transported through the road. (d)-1 - As a part of risk management, the possibility that diseases, including infectious diseases is precautioned. (d)-2 - Training programs aiming to protection of public health and working health d¥for mangers and works are planned and implemented regularly. (e) - Surface water or groundwater is not used for the project. - Fresh water for domestic use is transported form outside and stored in tanks, and fresh water for plant is produced by desalination plant.

Category	Environmental Item	Main Check Items	Yes: Y No: N	Confirmation of Environmental Considerations (Reasons, Mitigation Measures)
		water areas (especially fishery)?		-It is predicted that the seawater temperature rising is within 1 degree Celsius, and dispersion area is restricted in narrow area near the effluent. - Accordingly, no adverse impact on environment and users of water area, such as fisherman and salt firm is predicted.
	(3) Heritage	(a)-1 Is there a possibility that the project will damage the local archeological, historical, cultural, and religious heritage of the area? (a)-2 Are adequate measures being considered to protect these sites in accordance with the country's laws?	(a)-1 N (a)-2 N/A	(a)-1 There is no local archeological, historical, cultural, and religious heritage within 15 kilometer radius form the project site.
	(4) Landscape	(a)-1 Is there a possibility that the project will adversely affect the local landscape? (a)-2 Are necessary measures taken?	(a)-1 N (a)-2 N/A	(a)-1 There is no local scenery landscape within 15 kilometer radius from the project site.
	(5) Ethnic Minorities and Indigenous Peoples	(a) Are considerations given to reduce impacts on the culture and lifestyle of ethnic minorities and indigenous peoples? (b) Are all of the rights of ethnic minorities and indigenous peoples in relation to land and resources respected?	(a) N (b) N/A	(a) There are no ethnic minorities and indigenous peoples.
	(6) Working Conditions	(a) Is the project proponent not violating any laws and ordinances associated with the working conditions of the country which the project proponent should observe in the project? (b) Are tangible safety considerations in place for individuals involved in the project, such as the installation of safety equipment which prevents industrial accidents, and management of hazardous materials? (c) Are intangible measures being planned and implemented for individuals involved in the project, such as the establishment of a safety and health program, and safety training (including traffic safety and public health) for workers etc.? (d) Are appropriate measures taken to ensure that	(a) Y (b) Y (c) Y (d) Y	(a) Project proponent complies all laws and ordinances associated working conditions of the government of Bangladesh. (b) - All workers in the site are provided PPEs (Personal Protection Equipment). - Hazardous materials are adequately managed within locked warehuses or shelves, and hazardous wastes are stored in the managed, and transported and treated by the registered waste treatment company. (c) - Safety, health and environment management system is established, and training programs for each level of staff, such as managers, workers are planned and implemented. (d)

Category	Environmental Item	Main Check Items	Yes: Y No: N	Confirmation of Environmental Considerations (Reasons, Mitigation Measures)
		security guards involved in the project do not violate the safety of other individuals involved, or local residents?		- The restricted requirement for security guard employment is defined, and specific training program is provided.
5 Others	(1) Impacts during Construction	(a) Are adequate measures considered to reduce adverse impacts during construction (e.g., noise, vibrations, turbid water, dust, exhaust gases, and wastes)? (b) If construction activities adversely affect the natural environment (ecosystem), are adequate measures considered to reduce the impacts? (c) If construction activities adversely affect the social environment, are adequate measures considered to reduce the impacts?	(a) Y (b) Y (c) Y	(a) <Noise and Vibration> - Noise levels generated by construction machinery will meet noise level standards at the nearest residential area. In addition, the predicted noise level in residential areas (day time) can be complied with Bangladesh standards and IFC/WB EHS Guidelines values. As prevention measures against noise from construction work, night construction will not be carried out as much as possible. Construction machinery and vehicles will be regularly maintained. Low-noise/ low-vibration machinery will be used. <Water Quality> - Turbid water, such as rainwater runoff, will be treated with precipitation processes. - Wastewater containing oil will be treated with oil-water separator. <Air Quality> - Prevention measures for dust dispersion will be taken by spraying water. - Maintenance of machinery will be conducted regularly, resulting in reducing exhaust gas emissions. <Waste> - Construction waste and general waste will be re-used, recycled or disposed following relevant laws and regulations. (b) The site for Units 3/4 has been already developed including ash yard and the port/jetty during construction work of Units1/2. Serious impact onshore will be not assumed by this reason. However, since construction will be carried out in sea area for the discharge channel of thermal effluent, it is necessary to correspondent such as night-time lighting, lowering noise levels, monitoring survey as mitigation measures at sea area in front of the project site. (c) - The employment of local people will be promoted for increased employment opportunities for various subcontract work resulting from the power plant construction activity. - Local people will be employed to the maximum extent possible, and foreign workers will be taught to respect local customs in order to facilitate good relationships with local

Category	Environmental Item	Main Check Items	Yes: Y No: N	Confirmation of Environmental Considerations (Reasons, Mitigation Measures)
				people. Lodgings of project workers will be equipped with sufficient living facilities keeping order that workers remain at the project site as much as possible. - Labor contracts between the construction industry and children shall be prohibited. Regular patrols to check for child workers will be conducted. - Pre-employment and periodic medical check-ups will be conducted for workers. - In regard to vessels, water routes shall be determined after consultation with the related authorities. Marking buoys will be set around the construction area for marine safety. The schedule of vessels shall be announced to fishermen, etc. - In regard to vehicles, bus use will be promoted to reduce increasing the number of vehicles on the roads.
	(2) Accident Prevention Measures	(a) In the case of coal-fired power plants, are adequate measures planned to prevent spontaneous combustion at the coal piles (e.g., sprinkler systems)?	(a) Y	(a) - Fire prevention measures shall be conducted including regular watering of the coal storage site, installation of fire protection equipment and organization of fire-fighting team and fire-fighting training.
	(3) Monitoring	(a) Will the proponent develop and implement a monitoring program for items that are considered to have potential environmental impacts? (b) What are the items, methods and frequencies of the monitoring program? (c) Does the proponent establish an adequate monitoring framework (organization, personnel, equipment, and adequate budget to sustain the monitoring framework)? (d) Are any regulatory requirements pertaining to the monitoring report system identified, such as the format and frequency of reports from the proponent to the regulatory authorities?	(a) Y (b) Y (c) Y (d)Y	(a) - Environmental Monitoring Plan will be prepared to provide guidelines for Environmental Management Plan during the construction and operation phases of the Coal-fired Power Plant. - The environmental components that will be monitored are those that will be positively or negatively affected, or expected to be affected, by the construction activities and power plant operation. (b) - Refer to Chapter 13.11.2 (c) - Environmental management administrator of CPGCBL shall report on the details and implementation status of the environmental monitoring plan. (d) - CPGCBL will report the monitoring report at quarterly basis to DOE.
6 Note	Reference to Checklist of Other Sectors	(a) Where necessary, pertinent items described in the Power Transmission and Distribution Lines checklist should also be checked (e.g., projects including installation of electric transmission lines and/or electric distribution facilities). (b) Where necessary, pertinent items described in	(a) N (b) N	---

Category	Environmental Item	Main Check Items	Yes: Y No: N	Confirmation of Environmental Considerations (Reasons, Mitigation Measures)
		the Ports and Harbor checklist should also be checked (e.g., projects including construction of port and harbor facilities).		
	Note on Using Environmental Checklist	(a) If necessary, the impacts to transboundary or global issues should be confirmed (e.g., the project includes factors that may cause problems, such as transboundary waste treatment, acid rain, destruction of the ozone layer, and global warming).	(a) Y	(a) - Ultra supercritical (USC) technology will be adopted at the power plant, producing approximately 2,623 thousand tons/year less CO2 than a sub-critical coal-fired power plant.

Source: Study Team

13.11.2 Monitoring Form

Items that require monitoring shall be decided on according to the sector and nature of the project, with reference to the following list of items.

[Construction phase]
(1) Air quality
(1-1) Ambient air quality

Sample Location	Date	PM10 (μg/m^3)	PM2.5 (μg/m^3)	SO2 (μg/m^3)	NO2 (μg/m^3)
Project site boundary near Matarbali Village					
Project site boundary near in Dhalghata Village					
Ambient Air Quality Standards		SPM；200 (8hr) PM10: 150 (24hr) PM10: 50 (year)	PM2.5: 65 (24hr) PM2.5: 15 (year)	365 (24hr) 80 (year)	100 (year)
IFC EHS Guidelines 2007		PM10: 150 (24hr) PM10: 70 (year)	PM2.5: 75 (24hr) PM2.5: 30 (year)	500 (10min) 125 (24hr)	200 (1hr) 40 (year)

Source: Study Team

(1-2) Inspection of exhaust gas of generator and construction heavy equipment/vehicle
[Analysis of Generator Flue Gas Emission Test Results]
[Each company name]

Sl. No.	Description of Monitoring Sources	Location of Sources	Parameters	Emission Test Results
1			SO_x (mg/Nm^3)	
			NO_x (mg/Nm^3)	
			CO (mg/Nm^3)	
			CO_2 (%)	
2			SO_x (mg/Nm^3)	
			NO_x (mg/Nm^3)	
			CO (mg/Nm^3)	
			CO_2 (%)	

Source: Study Team

[Analysis of Vehicular Emission Test Results]
[Each company name]

SL No	Description of Monitoring Sources		Vehicular Emission Test Results		
	Type of Construction Equipment/ Vehicle	Equipment/ Vehicle ID	HC (g/KW-h)	NO_x (g/KW-h)	CO (g/KW-h)
1					
2					

Source: Study Team

(1-3) Odor
Date: (Parameter: ppm)

Location	NH3	H2S	Remarks
Project site boundary near Matarbali Village			
Project site boundary near in Dhalghata Village			
Bangladesh Standard (according to the	1-5	0.02 - 0.2	

amendment of ECR'97)			

Source: Study Team

(2) Water quality
(2-1) Discharge location
Date:

Parameter	Unit	Result	Wastewater discharge standards			IFCWB EHS Guidelines	Remarks (Measurements method)
			Inland surface water	Public sewer	Irrigated land		
Temperature	ºC		-	-	-		
pH	-		6-9	6-9	6-9		
BOD	mg/L		50	250	100		
COD	mg/L		200	400	400		
TSS	mg/L		150	500	200	50	
Oil & grease	mg/L		10	20	10	10	
As	mg/L		0.2	0.05	0.2	0.5	
Cd	mg/L		0.05	0.5	0.5	0.1	
T-Cr	mg/L		0.5	1.0	1.0	0.5	
Cu	mg/L		0.5	3.0	3.0	0.5	
Fe	mg/L		2	2	2	1	
Pd	mg/L		0.1	1.0	0.1	0.5	
Hg	mg/L		0.01	0.01	0.01	0.005	
Total fecal coliform	MPN/100mL		-	-	-		

Source: Study Team

(2-2) Surface water (Kohelia Channel)
Date:

Parameter	Unit	Upper stream	Middle stream	Down stream	Bangladesh Standard
Temperature	(^{0}C)				NYS
Salinity	(ppt)				NYS
pH	(---)				6.5 – 8.5
DO	(mg/L)				≥ 5
BOD	(mg/L)				≤ 6
COD	(mg/L)				NYS
TSS	(mg/L)				NYS
Turbidity	(NTU)				NYS
Nitrate	(mg/L)				NYS
Oil & Grease	(mg/L)				NYS
Total Phosphorus	(mg/L)				NYS
Fecal Coliform	(MPN/ 100 ml)				≤ 5000

Sampling Point	Latitude (North)	Longitude (East)
RW-1	21° 41' 37.37"N	91° 53' 12.5"E
RW-2	21° 41' 43.93"N	91° 53' 47.61"E
RW-3	21° 42' 09.68"N	91° 54' 32.25"E

Source: Study Team

(2-3) Ground water

Date:

Test Parameters	Unit	Project site	Drinking water quality standards	WHO guideline
Temperature	°C		20-30	-
pH	-		6.5-8.5	-
DO	mg/L		6	-
Turbidity	NYU		10	-
Electrical Conductivity(in-situ)	μs/cm		-	-
Odor	-		Odorless	-
Color	Pt-Co		15	-
Suspended particulate matters	mg/L		10	-
Total dissolived solids	mg/L		1000	1000
Oil & Grease	mg/L		0.01	-
BOD5 20 oC	mg/L		0.2	-
COD	mg/L		4	-
Chloride	mg/L		150-600	-
Hardness (as CaCO3)	mg/L		200-500	-
Chlorine (residual)	mg/L		0.2	-
Cyanide	mg/L		0.1	-
Ammonia (NH3)	mg/L		0.5	-
Chromium (hexavalent)	mg/L		0.05	-
Nitrate	mg/L		10	3
Nitrite	mg/L		Less than 1	-
Phenolic compounds	mg/L		0.002	-
Sulfate	mg/L		400	-
Sulfide	mg/L		0	-
Nitrogen (Total)	mg/L		1	-
Phosphorus	mg/L		0	-
Phosphate	mg/L		6	-
Coliform (fecal)	MPN/ 100 ml		0	-
Coliform (total)	MPN/ 100 ml		0	-
Silver	ppm		0.02	-
Aluminum	ppm		0.2	0.2
Arsenic	ppm		0.05	0.01
Boron	ppm		1	0.5
Barium	ppm		0.01	0.7
Calcium	ppm		75	-

Test Parameters	Unit	Project site	Drinking water quality standards	WHO guideline
Cadmium	ppm		0.005	0.003
Chromium (total)	ppm		0.05	0.05
Copper	ppm		1	-
Iron	ppm		0.3	-
Mercury	ppm		0.001	0.006
Magnesium	ppm		30-35	-
Manganese	ppm		0.1	0.4
Sodium	ppm		200	-
Nickel	ppm		0.1	0.07
Lead	ppm		0.05	0.01
Selenium	ppm		0.01	-
Zinc	ppm		5	-

Source: Study Team

(2-4) Seawater quality

Date:

Parameter	Unit	SP-1			SP-2			SP-3		
		Surface	Middle	Bottom	Surface	Middle	Bottom	Surface	Middle	Bottom
Depth	m									
Temperature	oC									
Salinity	-									
pH	-									
DO	mg/L									
BOD	mg/L									
COD	mg/L									
Oil & Grease	mg/L									
SS	mg/L									
T-Cr	mg/L									
Cu	mg/L									
Fe	mg/L									
Zn	mg/L									
Pb	mg/L									
Cd	mg/L									
Hg	mg/L									
As	mg/L									

Parameter	Unit	SP-4			SP-5			Average		
		Surface	Middle	Bottom	Surface	Middle	Bottom	Surface	Middle	Bottom
Depth	m									
Temperature	oC									
Salinity	-									
pH	-									
DO	mg/L									
BOD	mg/L									
COD	mg/L									
Oil & Grease	mg/L									
SS	mg/L									
T-Cr	mg/L									
Cu	mg/L									
Fe	mg/L									
Zn	mg/L									
Pb	mg/L									

Parameter	Unit	SP-4			SP-5			Average		
		Surface	Middle	Bottom	Surface	Middle	Bottom	Surface	Middle	Bottom
Cd	mg/L									
Hg	mg/L									
As	mg/L									

Map of Sea and Kohelia Channel Water Quality Monitoring Locatios

Sampling Point	Latitude (North)	Longitude (East)
SW 1	21°43'15.75"N	91°51'46.25"E
SW 2	21°41'49.44"N	91°51'36.50"E
SW 3	21°40'48.88"N	91°50'42.39"E
SW 4	21°39'6.37"N	91°50'3.33"E
SW 5	21°37'22.52"N	91°49'28.16"E
SW 6	21°35'1.30"N	91°48'55.28"E

Source: Study team

(2-5) Sediment

Date:

Parameter	Unit	Results		Remarks
		Dragging area	Reference location	
Hg	mg/kg			
Cd	mg/kg			
Pb	mg/kg			
As	mg/kg			
Cu	mg/kg			
Zn	mg/kg			
Fe	mg/kg			
T-Cr	mg/kg			

Source: Study Team

(3) Noise

Date:

(Unit: dBA)

Survey phase	Results		Standards for Noise				
	Day (6:00-21:00)	Night (21:00-6:00)	A	B	C	D	E
Project site boundary near Matarbali Village			Day: 45 Night:35	Day: 50 Night:40	Day: 60 Night:50	Day: 70 Night:60	Day: 70 Night:70
Project site boundary near in Dhalghata Village							

Notes: Category of areas is as below.

A: Silent zone
B: Residential area
C: Mixed area (mainly residential area, and also simultaneously used for commercial and industrial purposes)
D: Commercial area
E: Industrial area

Reference: IFC/WB EHS Guidelines

Receptor	Day 07:00-22:00	Night 22:00-07:00
Residential, institutional, educational area	55	45
Industrial, commercial area	70	70

Source: Study Team

(4) Ecosystem

(4-1) Rare species

a. Birds

(Migratory bird)

Date (Time)	Total No. of individuals	Species Name and No. of individuals

Source: Study Team

(Others)

Date:

Scientific name	Local name	English name	Total No. of individuals	Conservation Status		Remarks
				IUCN	Local	

Source: Study Team

It is noted that the coherency of survey results of environmental monitoring activities (Phase 1 and Phase 2) such as the fish catch survey, are very important for reliable monitoring implementation as well as creation of EMoP-related database. Before conducting the fish catch survey, the survey team and its relevant supervising units shall check the coherency of survey methods such as survey points, tidal conditions, the type of fish gears to be used, the hauling time and others, based on survey results of Phase I conducted so far. Also, survey results shall be scrutinized after the survey immediately in order to check if there are unusual survey results therein. Based on those on-site review results, it is also important to decide the necessity of additional surveys in order to make this EMoP activities reliable and meaningful.

b. Sea turtle

Date (Time)	Total No. of individuals (Location)		Species Name and No. of individuals
	Line-1	Line-2	
	Long. N Lati. E	Long. N Lati. E	Length of the lines(Line-1; m,Line-2; m)
	Long. N Lati. E	Long. N Lati. E	Length of the lines(Line-1; m,Line-2; m)
	Long. N Lati. E	Long. N Lati. E	Length of the lines(Line-1; m,Line-2; m)

Source: Study Team

c. Phytoplankton

Date:

(Unit: cells/L)

Species		SP.1			SP.2			SP.3		
		Surface	Middle	Bottom	Surface	Middle	Bottom	Surface	Middle	Bottom
Depth (m)		0.5			0.5			0.5		
1										
2										
·										
·										
No. of species										
Total										

Species		SP.4			SP.5			Average		
		Surface	Middle	Bottom	Surface	Middle	Bottom	Surface	Middle	Bottom
Depth (m)		0.5			0.5			-	-	-
1										
2										
·										
·										
No. of species										
Total										

Source: Study Team

d. Zooplankton

Date:

(Unit: Individual/m3)

Species		SP.1		SP.2		SP.3	
		0 <- 5	5 <- B+1	0 <- 5	5 <- B+1	0 <- 5	5 <- B+1
1							
2							
·							
·							
No. of species							
Total							

Species		SP.4		SP.5		Average	
		0 <- 5	5 <- B+1	0 <- 5	5 <- B+1	0 <- 5	5 <- B+1
1							
2							
·							
·							
No. of species							
Total							

Source: Study Team

e. Benthos

Date:

(Unit: Individual/m2)

Species		SP-1	SP-2	SP-3	SP-4	SP-5	Total
1							
2							
·							
Total							

Source: Study Team

f. Sandy beach creatures

Date:

(Unit: Individual/m2)

Species		Result
1		
2		
·		
·		
Number of species		
Total		

Source: Study Team

g. Necton

Date:

(Unit: Individuals/haul, g/haul)

Species		Result	
		No. of individuals	weight
1			
2			
·			
·			
Number of species			
Total			

Source: Study Team

(5) Waste

[Each company name]

NO.	Waste Type (Sample)	Amount in certain duration (m3/ton)	Disposal method	Entrusted company
1	Food Waste (Organic Waste)			
2	Construction/ Recycable Waste (Wood, scraps, etc)			
3	Combustible Waste (Plastic, Can, Bottle, etc)			
4	Hazardous Waste (Oil Waste, Paint Tin, and other hazardous material)			
5				

Note; Regarding the entrusted company, the copy of certificate must be prepared in this report.

Source: Study Team

(6) Social environment

(6-1) Periodical stakeholder meeting/group discussion

NO.	Target Stakeholder	Venue (Location)	Date	No of Participant Attended	
				Male	Female
1					
2					

NO.	Commentator (If any, Information about Commentator)	Opinion/Advise	Correspondence/Response	Remark
1				
2				

Source: Study Team

(6-2) Grievance

[Local residents]

NO.	Commentator (including occupation)	Opinion	Date	Information about Commentator		Correspondence
				Sex	Age	
1						
2						

[Worker]

NO.	Commentator (Organization name and other information)	Opinion	Date	Correspondence
1				
2				

Source: Study Team

(6-3) Labor environment and accident

When (Date/time)	Where (Location)	Who (Organization/company name)	What (Accident type)	Why (Cause)	How (Correspondence)

Source: Study Team

(6-3) CO2 emission

Table 1 [In case of using combustion fuel]

Construction plan /each phase	Heavy equipment, Truck, Vehicle and so on	Fuel	Rated Output	Fuel consumption rate per one hour	Fuel consumption per one hour	Total Quantity	Average operation time per day	Average operation rate	Total fuel consumption	CO2 intensity by fuel type	CO2 emission
			(a)	(b)	(c)=(a)x(b)	(d)	(e)	(f)	(g)=(c)x(d) x(e)x(f)x(g)	(h)	(i)=(g)x(h)/1000
			(kWh)	(L/kWh)	(L/h)	(Quantity･day)	(h)		(L)	(kgCO2/L)	(ton-CO2)
Land reclamation for power block	Backhoe	Light oil									
	Compressor	Light oil									
	?????										
?????											
Total											

Table 2 [In case of using Electricity]

Construction plan /each phase	Heavy equipment, Truck, Vehicle and so on	Energy	Rated Output	Total Quantity	Average operation time per day	Total fuel consumption	CO2 intensity by Electricity	CO2 emmision
			(a)	(b)	(c)	(d)=(a)x(b)x©	(h)	(i)=(g)x(h)/1000
			(kWh)	(Quantity･day)	(h)	(kWh)	(kgCO2/L)	(ton-CO2)
Land reclamation for power block	Floodlight	Electricity						
	?????							
?????								
Total								????

Source: Study Team

[Operation phase]

(1) Air quality

(1-1) CEMS (Continuous Emission Monitoring System)

Parameter	Unit	Period exceeding the standard	Emission gas standards	IFC/WB EHS Guidelines (Thermal Power Plants; 2008)	IFC/WB EHS Guidelines (Thermal Power Plants; 2017draft)	Remarks
SO2	mg/Nm3		-	850	200	
NOX	mg/Nm3		600	510	200	
PM10	mg/Nm3		500	50	25	

Notes: Dry Gas, Excess O2 Content is 6%
Source: Study Team

(1-2) Ambient air quality
Please see [Construction phase] (1) Air quality (1-1) Ambient air quality

(1-3) Odor
Date:

Location	NH3 (ppm)	Remarks
Ammonia tank		
Denitration facility		
Bangladesh Standard (according to the amendment of ECR'97)	1-5	

Source: Study Team

(2) Water quality

(2-1) Discharge location
Please see [Construction phase] (2) Water quality (2-1) Discharge location

(2-3) Sediment (Dredging area)
Please see [Construction phase] (2) Water quality (2-5) Sediment

(2-4) Ground water
Please see [Construction phase] (2) Water quality (2-3) Ground water

(3) Noise
Please see [Construction phase] (3) Noise

(4) Ecosystem
Please see [Construction phase] (4) ecosystem

(5) Waste
Please see [Construction phase] (4) Waste

(6) Social environment

(6-1) Periodical stakeholder meeting/group discussion
Please see [Construction phase] (6-1) Periodical stakeholder meeting/group discussion

(6-2) Grievance
Please see [Construction phase] (6-2) Grievance

(6-3) Labor environment and accident
Please see [Construction phase] (6-3) Labor environment and accident

(7) Fuel (coal / petroleum)

a. Fuel procurement record
b. Fuel management record including incident such as leakage, fire and so on

(8) CO2 emission

Item	Unit	Value	Remarks
Amount of electricity generated by the project in a year or certain period	MWh/y or certain period		
Power generation efficiency of this project	%		
Higher heating value, HHV	kJ/kg		
Lower heating value, LHV	kJ/kg		
Carbon content in fuel, C%	weight%		
Conversion factor of calorie to Joule	J/cal	4.1868	1cal=4.1868J
Net caloric value of the fuel used for power generation	TJ/t		
Specific fuel consumption of this project	t/MWh		
CO_2 emission coefficient of the fuel used for power generation	t-CO2/TJ		Note-1)
Conversion factor of electric energy to thermal energy	TJ/MWh	0.0036	
CO_2 emission coefficient of electricity generation(In case of this project)	t-CO_2/MWh		Note-2)
CO_2 emission based on this project	t-CO_2/y or certain period		

Remarks:

1) CO_2 emission coefficient of the fuel=(C%/100)/LHV x (44.01/12.011) x10^6
2) CO_2 emission coefficient ={CO_2 emission coefficient of the fuel/(Power generation efficiency/100)}x 0.0036

Source: Study Team

Chapter 14 Project Cost

14.1 EPC Contract Price for Units 1/2 Project

[Confidential Information]

14.2 Construction cost index for coal-fired USC power plant by Ministry of the Environment in Japan

[Confidential Information]

14.3 Project Costs

14.3.1 Basic Calculation Method

[Confidential Information]

14.3.2 Estimation of the Project Costs

[Confidential Information]

Chapter 15 Project Evaluation

15.1 Economic and Financial Analyses

15.1.1 Framework of the Analyses

[Confidential Information]

15.1.2 Internal Rate of Return (IRR)

[Confidential Information]

15.1.3 Difference between Economic Analysis and Financial Analysis

[Confidential Information]

15.1.4 Common Parameters for Economic Analysis and Financial Analysis

[Confidential Information]

15.1.5 Economic Analysis

[Confidential Information]

15.1.6 Financial Analysis

[Confidential Information]

15.2 Project Financial Management Analysis

15.2.1 Project Profitability Analysis

[Confidential Information]

15.2.2 Generation Cost Analysis

[Confidential Information]

15.3 Estimation of Levelized Generation Cost

[Confidential Information]

15.4 Qualitative Impacts of the Project

The qualitative impacts of this project can be summarized into the following four features.

(1) Contribution to Secure Power Supply Capacity

It has been predicted that the power demand will be increasing by 8 % to 12 % annually near future. According to "Table 2.3-1 The trends in annual maximum peak demand records and the comparison to Two master Plans," the maximum peak demand in the fiscal year of 2020/21 was 13,352 MW. If demand increase rate is 8 %, 1,068 MW will be added on 2020/21 peak demand next year. If demand increase rate is 12 %, 1,602 MW will be added on 2020/21 peak demand next year. In this way, it is necessary to increase power supply capacity annually by the supply capacity equivalent to this project or more supply capacity. This project will contribute to increased power supply capacity once the project is completed by adding 1,200 MW to the power system.

(2) Contribution to Modern Power Supply System necessary to Improve Power Supply Reliability

Bangladesh economy has been developing rapidly over the past years, and labor-intensive garment industry has been contributing to the rapid economic development. Recently ICT industry working for Asian markets including Japan has also started rapid development. Over the past few years, Bangladesh largely attained 100 % household electrification rate. Considering these circumstances, it is necessary to note that the chief purpose of developing power industry in Bangladesh should shift from securing enough power supply in terms of quantity to improving power supply reliability in terms of quality, while the industry is keeping enough quantity of power supply. However, because of the past experience in acute power shortage, many private diesel-power generations and old generating facilities are still supplying electricity. Many of these generating facilities use natural gas. Telephones are still used for the power system operation, and demand and supply management. Remote control system has not yet been introduced in Bangladesh power system. Because the power demand is increasing rapidly, the number of power plants and substations is also increasing rapidly, which make the present power system operation, and demand and supply management much more difficult. Considering this situation, it is urgently necessary to modernize the present operation and management system by introducing remote control system. The initial method to control demand and supply is governor free operation. If governor free operation is not enough to control demand and supply, National Control Center will instruct relevant power stations. However, the problem is that the power stations cannot control their output including governor free operation, because of insufficient maintenance, aging facilities, insufficient gas supply and IPP contract agreement, which make system operation, and demand and supply management more difficult. In order to improve power supply reliability, it is essential to modernize operation, and demand and supply management.

This project uses coal fuel, which would make fuel supply stable for power generation, and would diversify primary energy supply. This project would contribute to more flexible demand supply management through Flex-USC technology. In future, this power station can be equipped with remote control, and would be able to take the initiative to modernize the present power supply system.

(3) Contribution to Renewable Energy Deployment

In Bangladesh, photovoltaic would be the major technology to increase renewable energy. Photovoltaic does not generate electricity during night, and reduces generation during cloudy or rainy days. In order to increase renewable energy, mainly photovoltaic, it is necessary to have complementary power source. This project will be one of best complementary power sources with the equipment of Fast Cut Back, low load operation as low as possible, and rapid load changing rate as high as possible, subject to stable plant operation, which would contribute to many introductions of renewable energy.

(4) Contribution to Future Reduction of CO_2

In future, it would be possible to renovate the power station to be equipped with mixed combustion of ammonia or biomass. Then, it would be possible to contribute to reduced CO_2 emissions.

15.5 Appraisal Indicators

The target values of indicators to appraise the performance of this project in 2 years after the construction completion of this project are defined as follows.

Appraisal Indicators	Unit	Target Values	Notes
Operation Indicators			
1. Maximum Output	MW	1,200	1 unit 600 MW x 2 units (Output at Generation End)
2. Plant Load Factor	%	80	After starting the operation of this thermal power station, this power station is anticipated to dispatch electricity for base load for coming years. Except for regular maintenance period, usually 1.5 month in a year, Flex-USC coal fired thermal power station with the latest technology continuously will generate electricity at its
3. Generated Electricity at Generation End	GWh/year	8,410	

Appraisal Indicators	Unit	Target Values	Notes
			rated capacity (1,200 MW: 600MW x 2 units) in normal conditions. The plant utilization factor of this mode of operation can be calculated as follows: Plant Utilization Factor = 1,200 x 24 x (365 - 45) ÷ 1,200 x 24 x 365 x 100 = 87.67 % However, some output changes such as black out, output adjustment and load reduction for adjusting equipment in the power plant may occur; 80 % of plant utilization factor is suggested for the indicator. Generated electricity at the plant utilization factor of 80%, can be calculated as follows: Generated Electricity at Generation End = 1,200 x 24 x 365 x 80% = 8,409,600 MWh = 8,410 GWh
4. Thermal Efficiency at Generator End	%	41.1	The thermal efficiency of this project has been estimated as 41.1 % according to the heat balance of total thermal power generation system including boiler efficiency and turbine efficiency. Based on this thermal efficiency, the design of relevant equipment and facilities, and economic and financial analysis have been carried out. The thermal efficiency for an appraisal indicator has to be calculated in terms of the operation of thermal power station. It is possible to calculate the thermal efficiency using the data of coal heat content and coal consumption as is shown below: (a) Conversion of electric energy (kWh) to heat energy (kcal) 1 kW = 1,000 Joule/sec. (Physical Constant) 1 kWh = 1kW × 1hour = 1kW × 60 sec. × 60 min. = 1,000 Joule × 60 sec. × 60 min. = 3,600,000 Joule 1 kcal = 4,185.5 Joule (Physical Constant) 1 kWh = 3,600,000 Joule ÷ 4,185.50 = 860.11 kcal/kWh (b) Heat energy necessary to generate 1 kWh of electricity (Called Heat Rate) If HR stands for heat rate, and THE stands for thermal efficiency, HR = 860.11 ÷ THE (c) Coal consumption to generate 1 kWh electricity If CC stands for coal consumption to generate 1 kWh of electricity, and HC stands for heat content of coal, CC can be calculated as follows: CC = HR ÷ HC then, HR = CC × HC = 860.11 ÷ THE Therefore, THE can be calculated as is shown below: THE = 860.11 ÷ (CC × HC) During the post-evaluation period, it is possible to calculated thermal efficiency if the amount of coal

Appraisal Indicators	Unit	Target Values	Notes
			consumption and heat content of coal can be known.
5. Plant Availability Ratio	%	85.21	Plant load factor is calculated by dividing electricity actually generated for one year by total generation for one year without stopping and reducing its rated generation capacity (1,200 MW). On the other hand, plant availability ratio compares the days the plant is ready or on operation, and the days of one year, 365. Plant factor includes reduced operation required for demand and supply management, and stopped operation because of system blackout. However, plant availability ratio is not influenced by system operation. In this science, plant availability ratio can reflect the actual situation of maintenance more than plant factor. Plant availability ratio has been estimated based on base load operation and presumed days of regular maintenance, accidents and breakdown. The regular maintenance was presumed 45 days a year, and the accidents and breakdown were presumed 9 days a year. Based on these presumptions, the plant availability ratio is calculated as follows: Plant Availability Ratio = （365 – 45 – 9） ÷ 365 × 100 = 85.21 %
6. Power Station Own Use	%	6.5	The value of 6.5 % has been assumed for plant own use in order to study equipment design, and economic and financial analysis. The plant own use is the difference between output at generation end and sent out electricity at sending end. It would be possible to confirm the value of plant own use using plant operation records.
7. Outage Hours	Hours/years	1,314	This plant is assumed to dispatch electricity for base load; then, annual outage hours can be estimated as follows: ① Regular maintenance: Less than 1,096 hours (about 45 days) ② Outage caused by technical accidents: Less than 218 hours (about 9 days) ③ Total Less than 1,314 hours (about 54 days) Please be noted that the outage caused by human mistakes has been assumed zero.
Effect Indicators			
1. Sent Out Electricity at Sending End	GWh/year	7,863	Sent out electricity at sending end can be calculated by deducting the plant own use (6.5 % of generated electricity at generation end) from the generated electricity at generation end. The following is the calculation process: Generated electricity at generation end = 1,200 x 24 x 365 x 80% = 8,409,600 MWh = 8,410 GWh Sent out electricity at sending end = Generated

Appraisal Indicators	Unit	Target Values	Notes
			electricity at generation end × （1 – 6.5 %） = 7,863 GWh
2. CO_2 Emissions	Thousand ton / year	7,316.7	Table 13.7-6 in Chapter 13 shows estimated amount of CO_2 emissions to generate unit MWh of electricity. The estimated amount of CO_2 emissions is 0.870 t-CO_2 including the emissions from desulfurization equipment. As annual generated electricity at generation end is estimated as 8,410 GWh, the annual CO_2 emissions can be calculated as follows: 0.870 t-CO_2/MWh × 8,410 GWh = 7,316.7 Thousand ton
3. NOx Emissions	Thousand ton / year	5.2	According to the study in Chapter 13, the volume of combustion gas effluence to generate electricity for one hour is estimated at 2,228,822 Nm^3, and NOx contents in unit Nm^3 is estimated at 170 mg. Accordingly, annual effluence of NOx for 2 units can be calculated as follows: 62mg/Nm^3 x 2,228,822Nm^3/h x 2 x 24hours x 365days x 80% = 1,937 ton/year
4. SOx Emissions	Thousand ton / year	6.0	According to the study in Chapter 13, the volume of combustion gas effluence to generate electricity for one hour is estimated at 2,228,822 Nm^3, and SOx contents in unit Nm^3 is estimated at 200 mg. Accordingly, annual effluence of SOx for 2 units can be calculated as follows: 200mg/Nm^3 x 2,228,822Nm^3/h x 2 x 24hours x 365days x 80% = 6,248 ton/year
5. PM Emissions	Thousand ton / year	0.758	According to the study in Chapter 13, the volume of combustion gas effluence to generate electricity for one hour is estimated at 2,228,822 Nm^3, and PM contents in unit Nm^3 is estimated at 25 mg. Accordingly, annual effluence of PM for 2 units can be calculated as follows: 25mg/Nm^3 x 2,228,822Nm^3/h x 2 x 24hours x 365days x 80% = 781 ton/year
6. Coal Consumption	Thousand ton / year	3,973	In the above section of Economic Cost of Coal Fuel, Assessment of Economic Cost in Economic Analysis, coal consumption to generated unit kWh of electricity had been estimated as 0.4724 kg. Accordingly, the annual consumption of coal can be calculated as follows: Generated Electricity at Generation End × 0.4724 kg/kWh = 8,410 GWh × 0.4724 kg/kWh = 3,973 thousand ton/year

Source: Study Team

Chapter 16 Project Implementation Method

16.1 Examination of Procurement Method

16.1.1 Procurement Situation of Similar Businesses in Bangladesh

(1) General circumstances regarding bidding and contracts for general civil works

In the general civil engineering works, regarding various large-scale infrastructure development projects such as road works (including bridge construction), railway works, water and sewage works, and flood control works, the country's ability to raise funds is limited. So, in most cases, the funds are financed by borrowing from Multilateral Development Banks such as the World Bank and the Asian Development Bank and ODA donor countries. As a result, almost all bids for such projects are conducted by international competitive bidding, and almost all contractors are foreign companies.

(2) General circumstances of local consultants (basic design, bidding support, construction supervision)

It must be said that local consultants are not experienced enough, except for foreign-affiliated consultants who have an advantage in some environmental and social considerations-related operations. Even under such circumstances, some local consultants receive technical transfer by engaging in large-scale infrastructure development projects as described in (1) above together with foreign consultants, and gradually improve their construction supervision ability, etc. On the other hand, it is assumed that it will take a little more time than the construction supervision skill for the skills such as basic design and bidding (especially international competitive bidding) support.

(3) General circumstances of local contractors (actual record, owned construction equipment, etc.)

The maturity status of local contractors is similar to that of local consultants in (2) above. It does not yet have the ability to get orders for large-scale infrastructure development projects alone or as a main body and carry out the business, and most of them participate in the projects as subcontractors of contractors in developed countries and India, etc.

They do not have enough large-scale construction equipment, but they are gradually increasing the number of them they own, such as by taking over the equipment which were brought into the country by a foreign company for a large-scale infrastructure development project after the construction was completed.

(4) Circumstances of procurement of necessary materials and equipment such as steel and cement

Regarding the materials required for construction such as steel and cement and the equipment such as measuring equipment, although the production capacity of general materials such as crude steel and cement is gradually increasing, but it cannot be said that it is sufficient for large-scale infrastructure development projects quantitatively and qualitatively.

In particular, almost all high-functioning materials such as stainless steel and alloy steel and measuring devices have to be imported.

16.1.2 Bidding Method, setting of Contract Conditions

(1) Bidding method

The single lot contract packaging method is considered to be the most suitable way to carry out this project. The survey team also considered a plan to separate the contract into the power generation facility construction block and the port facility reinforcement block, but decided to recommend one lot because there is a strong technical relationship between the two blocks.

Contract package: Construction of power plant and reinforcement of port facility

(a) Civil works related to power plant construction and port facility reinforcement

1) Reinforcement of the port berth for importing limestone, ammonia and exporting coal ash and gypsum (if necessary)
2) Civil & Architectural (power plant area) works including intake and discharge of cooling water
3) Additional civil works (land development in the power plant area, ash disposal area and dike - if

necessary)

(b) Power Plant Construction - Boilers and Auxiliary Equipment

Ultra-supercritical boiler with all accessories and the following equipment:

1) Boiler equipment (main steam, turbine bypass, auxiliary steam for boiler, water supply pipe between final heater and economizer, blower, etc.) and auxiliary equipment
2) Water treatment plants including desalination and wastewater treatment, etc.
3) Exhaust gas treatment facilities
4) Stacks and foundation
5) Instrumentation control (DCS and boiler control)

(c) Power Plant Construction - Steam Turbine Generators and Auxiliary Equipment

Turbine generators with all accessories and equipment in the following range, including main transformers and auxiliary transformers:

1) Steam turbine equipment (Condensate water system, feed water heaters, steam extraction system, boiler feed pump and auxiliary steam for turbine, etc.), generator equipment (including hydrogen generation system, etc.) and auxiliary equipment
2) Circulating water facilities including circulating water pump (CWP) building and circulating water pipe (between circulating water pump building and condenser)
3) Electrical equipment such as transformers, switchyard equipment, switches, etc.
4) Instrumentation control equipment for steam turbines and generators

(d) Power Plant Construction – Coal and Ash Handling

1) Coal handling system with coal receiving equipment (coal unloading and transportation conveyors), stackers/reclaimers, conveyors, sampling and movable equipment (if required)
2) Fly ash processing system equipped with a conveyor and movable equipment after the ash collection hopper and bottom ash processing equipment after the bottom ash silo

(2) Contract Conditions

In this project, the contractor will carry out the detailed design of the project and the construction work on site, but it is assumed that the Owner's Engineer will prepare the basic design and determine the specifications for power plant construction and port facility reinforcement. Therefore, the survey team is considering the adoption of the JICA SBD Design Build or FIDIC Yellow method as the most effective contractual agreement in which states these obligations that covers the construction of power plant and the port facility reinforcement as required.

16.1.3 Selection Method of Consultant

(1) Formulation process of shortlist

The short list for selecting a consultant shall be prepared in accordance with Section 3.04 of the "Guidelines for the Employment of Consultants under Japanese ODA Loans".

Section 3.04 are consisted of the following three paragraphs.

(1) Once JICA and the Borrower have agreed on the Terms of Reference for the consulting services required, as described in Section 3.03, the Borrower shall prepare a Short List of Consultants to be invited to submit proposals, taking into account the factors mentioned in Parts I and II. (See Annex II)

(2) Such a Short List shall normally consist of not less than three and not more than five consultants. There is usually little advantage in inviting more than five consultants to submit proposals, because with a larger number some are likely to be less interested and the quality of proposals is likely to suffer.

(3) Should the Borrower find it difficult to compile a satisfactory Short List of qualified consultants from the information available to it from its own past experience and other sources, JICA will, at the request of the Borrower, make available information on consultants, from which the Borrower may draw up its own Short List.

Further, the conditions for consultants to be nominated in the short list are described in Note 1 of Article 3.04 in the above guidelines as follows;

1. In principle, the consultants shall satisfy the following conditions to be listed in the Short List:
(01) The consultants have satisfactory overseas experience of the consulting services concerned (e.g. detailed design, supervision) in the sector in question (in a narrow sense, e.g. ports other than fishing ports, irrigation). However, if the consultant is from a developing country and is to provide the consulting services in that country, it need not have any overseas experience in the area of the consulting services concerned.
(02) Consultants must have experience in a developing country.
(03) Experience with Japanese ODA projects is preferable.

(2) Authority / process for approval of consultant's proposal evaluation

It is considered that JICA has the authority to approve the proposal evaluation of the consultant.

Regarding the proposal evaluation of consultants, there is a description related to Section 3.08, 3.09 and 3.10 of the "Chapter 1: Guidelines for the Employment of Consultants under Japanese ODA Loans" in the Handbook.

Section 3.08 Evaluation of Technical Proposals

(1) Consultants shall be required to submit technical and financial proposals in separate sealed envelopes at the same time. The financial proposals shall remain sealed until evaluation of the technical proposals is completed. When QBS is applied, a financial proposal can be requested to submit only to the highest-ranked consultant for contract negotiation.
(2) Proposals received by the Borrower in response to the invitation shall be evaluated in accordance with the criteria stipulated in the Request for Proposals concurred by JICA.
(3) Such criteria shall normally include:
(a)The consultant's general experience and record in the field covered by the Terms of Reference;
(b)The adequacy of the proposed approach, methodology and work plan; and
(c) The experience and records of the staff members to be assigned to the work.
(4) The relative importance of the three above-mentioned factors will vary with the type of consulting services to be performed, but in the overall rating of the proposals most weight shall normally be given either to the qualifications of the staff members to be assigned to the project or to approach and methodology, rather than to the fame or reputation of the consultant.
(5) To assess the qualifications of the staff members to be assigned to the project, their curricula vitae shall be evaluated on the basis of the following three criteria:
(a) General qualifications (education, length of experience, types of position held, length of service with the firm, etc.);
(b) Suitability for the project (experience of performing the duties which will be assigned to them in the project); and
(c) Familiarity with the language and the conditions of the country in which the work is to be performed or experience in similar environments.
(6) In its evaluation of technical proposals, the Borrower shall use numerical ratings and prepare an evaluation report including a summary evaluation sheet as soon as possible. The evaluation report shall normally give detailed information on the following items, supplementing the summary evaluation sheet:
(a) Selection Committee or other similar organization, if any, responsible for the evaluation, and the domestic laws, ordinances or orders which govern the establishment and/or functioning of the Committee or other similar organization;
(b) Selection criteria and relative weight distribution, with reasons for adopting each criterion and the basis for deciding the weight distribution;
(c) Rating: reason for arriving at the rating given for each item for each consultant.
(7) After the technical quality is evaluated, consultants whose technical proposals did not meet the minimum qualifying score, or were considered non-responsive to the invitation requirements, will be advised and their financial proposals will be returned unopened.

Section 3.09 Public Opening of Financial Proposals (Applicable only to QCBS)

(1) Consultants that have secured the minimum qualifying technical score will be advised of the location, date, and time for opening of financial proposals.

(2) The name of the consultants, the technical quality scores, and the proposed prices shall be announced, and recorded when the financial proposals are opened.
(3) For the purpose of evaluation, "cost" shall exclude local identifiable indirect taxes (all indirect taxes levied on the contract invoices, at National, State (or Provincial) and Municipal levels) on the contract and income tax payable to the country of the Borrower on the remuneration of services rendered in the country of the Borrower by non-resident staff of the consultant.

Section 3.10 Evaluation of Financial Proposals and Ranking of Proposals (Applicable only to QCBS)

(1) The Borrower shall review the congruency of the technical and financial proposals, make adjustments as appropriate, and correct arithmetical or computational errors.
(2) The total score shall be obtained by weighting and adding the technical and financial scores; this will determine the overall ranking of the consultants‟ proposals. The weight for the "cost" shall be chosen, taking into account the complexity of the assignment and the relative importance of quality. It shall normally be 20%.

In addition, since there is a following description in Section 3.13, the borrower is required to carefully and fairly evaluate and select a consultant with the concurrence of JICA.

Section 3.13 Information to be Made Public

(1) After a contract is determined to be eligible for JICA‟s financing, the names of all consultants who submitted proposals, the technical points assigned to each consultant, the offered prices of each consultant, the overall ranking of the consultants, the name and address of successful consultant concerning the award of contract, and the award date and amount of the contract may be made public by JICA.
(2) The Borrower shall have all provisions and measures necessary to ensure that the above information shall be available for being made public incorporated in documents related to selection, such as the Request for Proposals and contracts.

16.1.4 Selection Policy of Contractor

[Confidential Information]

16.1.5 Contract Management

(1) Investigate and analyze important points in contract management, such as correspondence to design changes during construction, with reference to past trouble cases in ODA loan projects or other donors' projects.

The following are assumed points to keep in mind in contract management, such as responding to design changes during construction.

(a) Whether the cause is due to either the execution agency, the contractor, or neither, nevertheless it is clear that a design change is necessary, in case the consensus is not be made in a timely manner between the contracting parties or with the government agencies of Bangladesh or JICA, there is a risk that the construction schedule will be delayed.
In such a case, the contractor may have to proceed with the construction while taking risks without a commitment to increase the contract amount due to the design change.

(b) There is a possibility that the execution agency and the consultant shall have to spend time on the assessment and processing due to frequent declaration of Force Majeure, EOT (Extension of Times), request for variation order, etc. by the contractor.

(c) If the contractor is a JV or the main contractor is a trading company, there is a possibility that the person in charge of negotiations regarding design changes does not have real decision-making authority, and/or the responsibility of negotiation is unclear, then it takes time to negotiate.

(d) In the case of ODA loan project, the tax exemption will be applied to Japanese companies which will be stated in the exchange note. However, if there is no unification regarding the scope and processing method of this tax exemption measures (zero declaration or once pay tax & refund by the executing agency; in case refund, regarding the method and deadline for refunds), the contractor including the consultant may suffer disadvantages.

(e) Payment delays occur due to excessively strict measures taken by the executing agency or the auditing agency of the country concerned regarding payment for the degree of design and construction progress, there is worry that the contractor including the consultant suffers a disadvantage.
In such cases, there is possibility that the examination department of the execution agency or the auditing agency lacks an understanding of the contract details.

(f) In addition, it is necessary to be aware that if the parties do not make sure in advance that they have confirmed and agreed on the payer of maintenance costs and transfer fees for the bank account in the country, it may cause troubles.

16.2 Risk Analysis

16.2.1 Identification of risks

The implementation of a large scale infrastructure project involves many complex and diverse risks. The identification and allocation of those risks is critical in implementation of such project. The internationally established financial institutions in which the project finance technique is used thoroughly analyze the risks of infrastructure projects explicitly or potentially faced and implement appropriate measures for mitigation. Unlike the project financed under a commercial basis, the project formulated under the public sector relies upon the credibility of the government in arranging financing for implementation. Especially, in project finance implemented using ODA loans, the government will share the ultimate responsibility for the project implementation and debt burden of the Executing Agency (Project Company). For donors who provide finance, the implementation, completion, operation and sustainability of the project will be the management focus points. Donors' interests will be primarily focused on the smooth implementation of the project, efficient operation, the expected outcomes, the realization of project effects and the achievement of impact by the project. The technique used for project finance in identifying and allocating the risks and establishing the safeguarding measures remains valid and reflective in enabling the government to organize the finance tor the infrastructure development project. In general, a large scale infrastructure project is conceived to be associated with the following materially significant risks;

- ✓ Political risk,
- ✓ Natural calamities, etc.,
- ✓ Social and environmental risk,
- ✓ Capability of the executing agency for implementation,
- ✓ Occurrence of fatal accident,
- ✓ Project completion,
- ✓ Economic and financial viability,
- ✓ Availability and stable supply of fuel,
- ✓ Related infrastructure such as the transmission lines, and
- ✓ Others

16.2.2 Analyses of risks

The risks listed above are reviewed and the mitigation measures to be taken are described in the following table for each of the risks mentioned;

Table 16.2-1 Risk Management Framework (prior to COD)

Risk Category	Sub-category	Profile of Risk	Risk Born by			Contract for Risk Covering	Mitigating Measures	Possible Impact from Non-Mitigated Risks
			GOVT/ BPDB	CPG CBL	SHA-RED			
Political risk	War or civil commotions, etc.	Suspension or destruction during the implementation phase.	X (GOB)					・Suspension, postponement of the project and/or destruction of the plant under construction.
	Seizure by government	Seizure of the Project resulting in disruption or deterioration of the efficiency	X (GOB)			・Power purchase Agreement (PPA)		・same as above
	Foreign exchange control	Change in the exchange control	X (GOB)			・Power purchase Agreement (PPA)		・same as above
	Law, policy or taxation change	Changes in Power Sector Policy, Coal Policy, taxation, etc.	X (GOB)			・Power purchase Agreement (PPA)		・same as above
	Socio-economic instability	Riot, strikes, social unrest, etc.	X (GOB)			・Power purchase Agreement (PPA)		・same as above
	Concession or operational right	Revocation of license or changes in the business rights	X (GOB)			・Power purchase Agreement (PPA)		・same as above
Natural calamities, etc.	Cyclone				X	・Insurance	・Design standard (raising the ground level by 10m) and insurance	
	Tidal wave				X	・Insurance	・Design standard (raising the ground level by 10m) and insurance	
	Earthquake				X	・Insurance	・Design standard (aseismic structure) and insurance	
	Tsunami				X	・Insurance	・Design standard (raising the ground level by 10m) and insurance	
	Others	Lightening, Storm, Tornado, Radioactive contamination, Fire,			X	・Insurance	・Design standard (various), insurance and other	

Risk Category	Sub-category	Profile of Risk	Risk Born by			Contract for Risk Covering	Mitigating Measures	Possible Impact from Non-Mitigated Risks
			GOVT/ BPDB	CPG CBL	SHA-RED			
		Epidemics, etc.					appropriate measures.	
Social and environmental risk	Non-acceptance of the Project by the local government	Failure or delay in starting construction of the plant	X (MPEMR)			・Implementation Agreement	・Consultation	
	Resistance by local inhabitants	Failure or delay in starting construction of the plant	X (MPEMR)				・Consultation	
	Congestion in surfac transport	Delay in construction schedule	X (MPEMR)				・Construction of access road	
	Identification of the rare species (animals or plants)	Disruption or suspension of project implementation	X (MPEMR)				・Environmental Impact Assessment	
	Contamination/ pollution to the site environment			X			・Compliance with environmental protection guidelines	
	Deficiency financing risk	Temporary deficiency in cash flow (delay in budget execution, etc.)		X		・Borrowing Facilities from Banks	・Financial assistance by GOB or BPDB	
	Budgeting and financing	Purchasing of fuel for plant testing and working capital required prior to COD				・EPC Contract	・Preparation of budget and fund raising for budget implementation	
	Fluctuation of exchange rate	Unexpected cost increase in construction cost, etc. and insufficiency of funds due to exchange loss.		X		・Borrowing Facilities from Banks	・Contingency	
	Increase in inflation	Unexpected cost increase in construction cost, etc. and insufficiency of funds due to cost increase.		X		・Borrowing Facilities from Banks	・Contingency	
	Insurance risk	Availability of specific coverage and/or fluctuation of insurance premium		X		・Insurance contract	・Consultation with insurance broker or company	
	Non-compliant bids	Delay in project implementation		X		・Invitation for Bidding, Conditions for Pre-qualification	・Quality enhancement of Bid preparation	

Risk Category	Sub-category	Profile of Risk	Risk Born by			Contract for Risk Covering	Mitigating Measures	Possible Impact from Non-Mitigated Risks
			GOVT/ BPDB	CPG CBL	SHA-RED			
						and Specifications		
Capability of Execution Agency risk	Managerial incapability	Unsophisticated management causing delay, over-run cost		X			・Recruitment of capable staff and employment of capable consultants	
	Financial incapability	Failure to attain healthy financial conditions for, timely provision of paid-up capital and funding support for covering the cost over-run.		X			・Recruitment of capable staff	
Occurrence of fatal accident	Occurrence of accident	Disruption and delay in construction due to accident investigation and introduction of countermeasures				・Insurance	・Continuous training for safety management and insurance coverage	
Plant Completion (incl. access road, port and coal unloading facilities, etc.)	Insufficient capability of the consultants			X		・Consulting Contract	・Technical assessment and screening through prequalification	
	Insufficient capability of the EPC contractor			X		・Construction Contract	・Technical assessment and screening through prequalification	
	Poor Performance or defaults of sub-contractors			X		・Construction contracts	・Performance management by prime contractors and supervision by consultant	
	Delay in Govt approvals in planning, development and operation		X (MPEMR)				・Effective and timely management by CPGCBL for total project	
	Delay in progress and completion	Failure to complete the project as has been planned and designed. Along with the Project, related infrastructure required for the Project needs to be completed.		X		・Construction Contract	・Construction management by sponsor, consultant and EPC contractor	
	Increase in the cost of plant and	Insufficiency of funds due to cost increase.		X		・Construction Contract	・Contingency	

Risk Category	Sub-category	Profile of Risk	Risk Born by			Contract for Risk Covering	Mitigating Measures	Possible Impact from Non-Mitigated Risks
			GOVT/ BPDB	CPG CBL	SHA-RED			
	material							
Availability and stable supply of fuel	Failure in procurement of the fuel for plant testing	Discontinuation or disruption of plant testing operation due to the shortage of fuel.		X		・EPC Contract	・EPC Contractor will be responsible	
Transmission lines	Failure in acquisition of the right of way	Delay in construction of the transmission lines	X (MPEMR)			・Implementation Agreement	・Consultation	
	Delay in completion of the inter- linked transmission lines	Non-readiness for trial run	X (MPEMR, PGCB)			・Implementation Agreement	・Formulation of the Project without relying on the other transmission lines	

Source: Study Team

On the same manner, the risks listed for the phase after the commissioning date are reviewed and the measures to be taken for mitigation are described in the following table for each of the risks mentioned;

Table 16.2-2 Risk Management Framework (post COD)

Risk Category	Sub-category	Profile of Risk	Risk Born By			Contract for Risk Covering	Mitigating Measures	Possible Impact from Non-Mitigated Risks
			GOVT/ BPDB	CPG CBL	SHA-RED			
Political risk	War or civil commotions, etc.	Suspension or destruction during the implementation phase.	X (GOB)			・Power purchase Agreement (PPA)		・Suspension, postponement of the project and/or destruction of the plant under operation
	Seizure by government	Seizure of the Project resulting in disruption or deterioration of the efficiency	X (GOB)			・Power purchase Agreement (PPA)		・same as above
	Foreign exchange control	Change in the exchange control	X (GOB)			・Power purchase Agreement (PPA)		・same as above
	Law, policy or taxation change	Changes in Power Sector Policy, Coal Policy, taxation, etc.	X (GOB)			・Power purchase Agreement (PPA)		・same as above
	Socio-economic instability	Riot, strikes, social unrest, etc.	X (GOB)			・Power purchase Agreement (PPA)		・same as above
	Concession or operational right	Revocation of license or changes in the business rights	X (GOB)			・Power purchase Agreement (PPA)		・same as above
Natural calamities, etc.	Cyclone	Continuous non-accessibility period for berthing by the coal carriers			X	・Insurance	・Design standard (coal storage for 60 days) and insurance	
	Tidal wave				X	・Insurance	・Design standard (raising the ground level by 10m) and insurance	
	Earthquake				X	・Insurance	・Design standard (a seismically strong structure) and insurance	
	Tsunami				X	・Insurance	・Design standard (raising the ground level by 10m) and insurance	
	Others	Lightening, Storm, Tornado,			X	・Insurance	・Design standard	

Risk Category	Sub-category	Profile of Risk	Risk Born By			Contract for Risk Covering	Mitigating Measures	Possible Impact from Non-Mitigated Risks
			GOVT/ BPDB	CPG CBL	SHA-RED			
		Radioactive contamination, Fire, Epidemics, etc.					(various), insurance and other appropriate measures.	
Social and environmental risk	Traffic congestion on surface transport				X		・Construction of access road	
	Contamination/pollution to the site environment			X			・Compliance with environmental protection guidelines	
	Malfunctioning and/or deterioration of environmental devices	Suspension in plant operation or reduction in operating ratio		X		・Manufacturer's Warranty ・Insurance	・Periodical maintenance and insurance	
Capability of Execution Agency risk	Managerial incapability	Unsophisticated management causing operational inefficiency		X			・Recruitment of capable staff and Incentive system	
	Financial incapability	Failure to attain healthy financial conditions for, timely provision of working capital.		X				
	Operational and maintenance incapability	Increase in accidents, maintenance cost, and inefficiency in operation		X			・Training system for operational staffs and incentive system	
	Incapability of the outsourced company	Failure to achieve the targeted level of performance under contract		X		・Outsourcing Contract	・Enhancement of training system and employment of foreign engineers	
Occurrence of fatal accident	Occurrence of a major scale of accident	Long term disruption in plant operation		X		・Insurance	・Preventing maintenance and insurance	
Plant Completion (incl. access road, port and coal unloading facilities, etc.)	Failure to achieve the designed capacity performance	Less revenue due to reduction of output		X		・Construction Contract	・Setting of long warranty period	
	Unexpected deterioration in operational performance	Increased consumption of fuel due to inefficiency or less revenue due to reduction of		X		・Construction Contract	・Periodical maintenance	

Risk Category	Sub-category	Profile of Risk	Risk Born By GOVT/ BPDB	CPG CBL	SHA-RED	Contract for Risk Covering	Mitigating Measures	Possible Impact from Non-Mitigated Risks
		output						
Economic and financial viability risk	Sales and collection risk	Sales price in short of cost recovery and/or slow collection		X		・PPA		
	Delay and/or insufficiency in tariff adjustment				X	・PPA	・Good operational performance, close monitoring and adjustment of tariff	
	Deficiency financing risk	Unexpected shortfall of funds for expenditure and/or debt servicing		X		・Borrowing Facilities from Banks ・Escrow Account	・Parental funding support by BPDB	
	Budgeting and financing	Failure in financial management for O&M, in particular, the fund shortage for periodical maintenance		X		・Borrowing Facilities from Banks	・Incorporation of sufficient budget for periodical maintenance）	
	Fluctuation of foreign exchange	Unexpected cost increase in fuel cost and O&M and insufficiency of funds due to exchange loss.		X		・PPA ・Borrowing Facilities from Banks		
	Insurance risk	Availability of specific coverage and/or fluctuation of insurance premium		X		・Insurance contract	・Consultation with insurance broker or company	
	Aggravation of inflation	Unexpected cost increase in fuel cost and O&M and insufficiency of funds due to cost increase.		X		・PPA ・Borrowing Facilities from Banks		
Availability and stable supply risk of fuel	Non-availability of Fuel and other materials	Occurrence of shortfall in fuel coal and/or other materials		X		・Coal Supply Contract	・Diversification of supply sources ・Sufficient stocks maintained	
	Non-availability of coal-carrying vessel	Occurrence of shortfall in fuel coal		X		・Charter-hire contract	・Medium term charter contract of spot hire contract diversified ・Sufficient stocks	

Risk Category	Sub-category	Profile of Risk	Risk Born By			Contract for Risk Covering	Mitigating Measures	Possible Impact from Non-Mitigated Risks
			GOVT/ BPDB	CPG CBL	SHA-RED			
							maintained	
	Long term contract risk	Discontinuation or disruption of stable operation due to the shortage of fuel while binding obligation for purchase for the contract term and/or take-or-pay obligation		X		・Coal Supply Contract	・Diversification of contract terms	
	Volatile market price	Instability in the import cost of fuel resulting in the loss of economic/financial viability		X		・PPA		
	Unbalanced qualities of fuel coal	Inharmonious quality for mixing		X		・Coal Supply Contract	・Construction of a reserve mills for coal of low calorific value	
	Non-availability of start-up fuel	Inability to start-up the plant		X		・Fuel Supply Contract ・Government Guarantee for Fuel Oil Supply	・Sufficient storage of fuel	
Transmission lines	Troubles at transmission lines	Inability to transmit the power causing the suspension of plant operation	X (PGCB)			・PPA ・Implementation Agreement		
Others	Sluggish increase in power demand	No dispatch instruction to the plant	X (MPEMR)			・PPA ・Implementation Agreement		
	Development of low cost gas field and/or procurement of LNG (provision of lower price gas)	Dispatch instruction to the coal fired plant becomes subordinate to other fuel and the coal fired plant to be operated as the middle-load system	X (MPEMR)			・PPA ・Implementation Agreement		

Source: Study Team

It should be noted that in the two tables given above, it shows that the risk categories as well as the sub-categories appear similar in many of the risk items but the profiles are described distinctively different as the risks surrounding the Project may appear in a different manner between the two phases of the Project.

16.3 Examination of measures for gender mainstreaming

16.3.1 Gender-related matters in legal systems, politics, policies, etc. in the energy/electric power sectors

Specific legal systems and politics for gender-related matters in the energy/electric power sectors is not observed. However, DoE is promoting to consider gender equality in the energy/electric power sectors even in the Power Plant Construction Project. In the comments on draft EIA report, DoE requested to describe the gender issue much clearly to CPGCBL.

16.3.2 Introduction status of gender perspective in support of other donors in the energy sector

In the report "Gender Equality Diagnostic of Selected Sectors" which is published by ADB (Asia Development Bank) in 2017, there are the description below;

Gender Equality in Energy: ADB Experience With its commitment to support the achievement of the United Nations Sustainable Development Goals (SDGs), including SDG 5 (Achieve gender equality and empower all women and girls), ADB is endeavoring to integrate gender considerations even in nontraditional sectors, such as energy infrastructure development. Table 15 presents the gender categorization of ADB-assisted projects in Bangladesh (see Box 5 for detailed definition of the gender categories). To date, no energy projects have been categorized as gender equity theme (GEN), which means that no energy project in ADB has been designed primarily to respond to gender issues in the sector. Nonetheless, the higher number of projects categorized as effective gender mainstreaming (EGM) and some gender elements (SGE) compared with the number of projects categorized as no gender elements (NGE) indicate the proactive efforts of project teams to integrate significant gender features in the projects. The Effective Gender Mainstreaming category means that the three projects are designed to directly respond to gender issues and achieve gender equality and women's empowerment results.

Table 15: Bangladesh Energy Projects by ADB Gender Category

Year Approved and Completed	GEN	EGM	SGE	NGE	Total
2009–2012	–	1	2	1	4
2013–2016	–	2	2	3	7
Total	–	3	4	4	11

EGM = effective gender mainstreaming, GEN = gender equity theme, NGE = no gender element, SGE = some gender elements.
Source: South Asia Department Gender and Development Database 2016.

According to the description above, it is observed that Bangladesh government has promoting gender features in energy sectors same as other sectors.

16.3.3 Measures to promote the employment of women in construction work

(1) Implement a detailed study to find out areas in which more women can be employed in the energy sector. This study should give an observation about many relevant aspects, including,
- Activities in new, non-traditional areas that might be provide good employment opportunities
- Women's barriers to pursuing careers in new fields and to accessing technology related to energy supply and use
- In order to construct much flexible organization, participation of female might be useful

(2) For government departments, such as BPDB, it should be promoted that employment of a specific number of women for specific activities once they receive the necessary training.

(3) Ensure market demand for career development programs and skills development programs coordinate with private and public sector employers' associations, corporate and individual employers. Undertake pilot projects to assess the feasibility of planned activities in training and skills development of women before scaling up.

(4) Promote women's entrepreneurship in manufacturing and marketing of potential energy saving technologies as long-term business and employment opportunities.

(5) Ensure enabling working environment by providing childcare, toilets, security for women employees

16.3.4 Male-female ratio of staff and operators in the executing agency, measures to promote the active participation of female staff, engineers and operators

(1) Male-female ratio of staff and operators in the executing agency

It is very difficult to determine the appropriate male-female ratio of staff and operators in the executing agency. Even in Japan or other developed country, male-female ratio of staff and operators in power sector is not high. So, it might be able to recommend that the rate should be increased 10 % from present value.

(2) Measures to promote the active participation of female staff

Basically, this issue might be mainly depending on the education environment in high school and university. The Government should promote participation of female in engineering field much strongly from younger generation. Around 10 or more years later, female staff may participate in the engineering field much actively.