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FEASIBILITY STUDY

WASTE TO ENERGY POWER PLANT FOR NAWABGANJ, KERANIGANJ, AND DOHAR

FICHTNER O.CREEDS Onushandhani Creeds Ltd.

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Policy Advisory for Promoting Energy Efficiency and Renewable Energy (PAP), GIZ Bangladesh

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Table of Contents

Glossary

A6.4	Article 6.4 of the Paris Agreement
A6.4ER	Article 6.4 Emission Reduction
ACT	Advanced Conversion Technology
AD	Anaerobic digestion
AGT	Advanced Gasification Technology
As	Arsenic
BDO(T)	Design, Build, Operate, with the option for Transfer
BECA 1995	Bangladesh Environment Conservation Act, 1995
BEIS	United Kingdom Department for Business, Energy, and Industrial Strat
BERC	Bangladesh Energy Regulatory Commission
BERCA 2003	Bangladesh Energy Regulatory Commission Act 2003
BPDB	Bangladesh Power Development Board
BREB	Bangladesh Rural Electrification Board
BSEC	Bangladesh Securities and Exchange Commission
BUET	Bangladesh University of Engineering and Technology
CCI&E	Chief Controller of Imports and Exports
Cd	Cadmium
CDM	Clean Development Mechanism
CER	Certified Emission Reduction
CHP	Combined Heat and Power
CLO	Compost-like outputs
CO	Carbon monoxide
Co	Cobalt
Cr	Chromium
Cu	Copper
DIFE	Department of Inspection of Factories and Establishments
DSCR	Debt Service Coverage Ratio
ECR 2023	Environment Conservation Rules 2023
Electricity Act	Electricity Act, 2018
EPC	Engineering, Procurement and Construction
ESIA	environmental and social impact assessment
FDS	Final Dumping Sites
FIRR	Financial Internal Rate of Return
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
HCl	Hydrogen chloride
HDPE	High-Density Polyethylene
HF	Hydrogen fluoride
Hg	Mercury
HRT	Hydraulic retention time
HSAD	High Solids Anaerobic Digestion
IDCOL	Infrastructure Development Company Limited
IFC	International Finance Corporation
IPP	Independent Power Producer
ITMO	Internationally Transferred Mitigation Outcomes
LDPE	Low-Density Polyethylene
LTSA	Long Term Service Agreement
Mn	Manganese
MPEMR	Ministry of Power, Energy and Mineral Resources
MRF	Materials Recovery Facility
MSW	Municipal Solid Waste
NBFI	Non-bank financial institution
NGO	Non-governmental organisations
Ni	Nickel
NO_3	Nitrate
NOx	Oxides of Nitrogen
NPV	Net Present Value
NTP	Notice to Proceed
Order 1972	Bangladesh Power Development Board Order, 1972
O.CREEDs	Onushandhani Creeds Limited

PAP	Policy Advisory for Promoting Energy Efficiency and Renewable Energy Bangladesh
Pb	Lead
PBS	Polli Bidyut Samiti
PCDD	polychlorinated dibenzo-p-dioxins
PCDF	polychlorinated dibenzo-furans
PET	Polyethylene Terephthalate
PGCB	Power Grid Company of Bangladesh
PGEPP 2008	Policy Guidelines for Enhancement of Private Participation 2008
PO_4	Phosphate
PP	Polypropylene
PPA	Power Purchase Agreement
PPP	Public Private Partnership
Project	Waste-to-Energy facility
PS	Polystyrene or Styrofoam
PSIG	Private Sector Infrastructure Guidelines 2004
PVC	Polyvinyl Chloride
RDF	Refused Derived Fuel
Sb	Antimony
SB	Supervisory Body
SO2	Sulfur Dioxide
SPP	Small Power Plants
SREDA	Sustainable and Renewable Energy Development Authority
SREDA Act	Sustainable and Renewable Energy Development Authority Act, 2012
SRF	Solid Recovery Fuel
TDS	Temporary Dumping Stations
Tl	Thallium
VGF	Viability Gap Funding
WACC	Weighted Average Cost of Capital
WTE	Waste-to-Energy

Executive Summary

The Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH is a service provider in the field of international cooperation for sustainable development and international education work (www.giz.de), that works on behalf of the German Government in 120 countries globally to develop effective solutions that offer people better prospects and improve their living conditions sustainably. In Bangladesh, GIZ has a history of 50 years of collaboration with the Government of Bangladesh (GoB) and other actors in business and society. Renewable energy and energy efficiency is one of the priority areas of the German development cooperation in Bangladesh. "Policy Advisory for Promoting Energy Efficiency and Renewable Energy" (PAP) is a project within this priority area which supports the Government of Bangladesh (GoB) in improving the conditions for implementing the green energy transition in the country. In a mutual implementation approach with the Ministry of Power, Energy and Mineral Resources (MPEMR), the project works for the improvement of the policy and regulatory framework to increase the share of renewable energy (RE) and energy efficiency (EE) in the power sector including the improvement of conditions for the dissemination of innovative RE/EE technologies.

Proper management of waste is a critical problem worldwide today, especially in cities. In Bangladesh, access to safe disposal of faecal sludge (FS) and solid waste (SW) is very limited and almost non-existent for low-income communities. The effective waste management is one of the main environmental issues in Bangladesh's metropolitan areas. Bangladesh has been experimenting with alternative technologies and administrative procedure reforms over the past few years to find innovative solutions to the problem of waste management.

Against this backdrop, Bangladesh Power Development Board (BPDB) requested GIZ Bangladesh to carry out a detailed feasibility study for a waste-to-energy power plant project considering the available waste of Nawabganj, Keraniganj, and Dohar upazilas. GIZ engaged a national and an international firm to conduct the feasibility study.

Fichtner GmbH & Co. was commissioned by GIZ to conduct a feasibility study that examines the general, legal, and economic frameworks concerning the quantities and characteristics of Municipal Solid Waste (MSW) collected from the upazilas of Nawabganj, Keraniganj, and Dohar. The study aims to identify the appropriate waste-to-energy (WTE) technology for implementation and to develop a project realization roadmap for the establishment of the waste-to-energy facility. Whereas, Onushandhani Creeds Limited (O.CREEDs) was engaged to analyse the current waste management system of the locations including estimation of waste generation, waste characterization, sources of solid waste and its physical compositions, evaluation of dumping sites, waste collection and its transportation, recommendation for improved waste collection and transportation system, solid waste management framework etc.

The current general, legal, institutional, and financial framework was found to be adequate for implementing power projects in Bangladesh. However, the existing waste management system in the three upazilas was found to be inadequately managed with low collection rates due to insufficient waste management infrastructure.

A report by the national consultant, O.CREEDs, which formed the input basis of this feasibility study, found that only 26% of the total waste generated is collected in Keraniganj and Dohar, and only 0.6% of waste is collected in Nawabganj. With potential improvements in the waste management framework, O.CREEDs projected the waste collection volume to rise from 105 tonnes per day to 348 tonnes per day, representing 55% of the total generated waste. This study considered the projected waste collection figures, and the findings are dependent on the achievement of the improved waste collection rate.

The MSW characteristics from the sampling results as discussed in Section 4 is characterized as non-homogenous or comingled with high organic fraction, very low NCV a.r. (2.15 MJ/kg – 4.25 MJ/kg), and very high moisture content (59.70%a.r. – 87.54%a.r.). These characteristics are consistent with findings from similar projects in Bangladesh. Due to these characteristics, a single direct waste treatment technology application is unsuitable due to limitations in each technology to treat the raw feedstock.

Five options of combined treatment systems were investigated to determine the most feasible techno-economic configuration for the Project.

- Option 1: Materials recovery facility with anaerobic digestion plant

- Option 2: Materials recovery facility with anaerobic digestion plant and refuse derived fuel incineration plant
- Option 3: Materials recovery facility with anaerobic digestion plant and incineration plant
- Option 4: Materials recovery facility with biodrying system and incineration plant
- Option 5: Incineration plant

Option 1 was assessed to be the only technologically and economically feasible option for the project. The viability of option 1 is largely driven by its relatively low CAPEX compared to other technologies, with revenue only from power export, despite a high escalation in OPEX, and anticipated inability to receive revenue from AD digestate due to its poor quality.

However, treating MSW with only MRF and AD does not result in a significant MSW volume reduction, as residues consisting of between 50% and 70% of the MSW input tonnage are required to be disposed to landfill due to the poor quality of digestate from the MSW waste stream. Incineration technologies would instead be effective in reducing MSW volume to around 20% of residues corresponding to ash content, however, incineration technologies are expected to only be viable with revenue from gate fees due to their high CAPEX.

A 20-hectare site for the project was proposed by O.CREEDs based on consultation with relevant stakeholders. Based on a desktop study, the site was assessed to have sufficient space for the WTE which requires an area of 2.5 hectares without landfill provisions, with acceptable proximity to waste sources, and nearby two 33/11kV substations for grid connection. However further investigations regarding site topography, grid connection studies and routes, vehicle access, environmental and social impact assessment (ESIA), water supply and effluent discharge are required to be implemented.

The Engineering, Procurement and Construction (EPC) construction of the project is anticipated to take 19 months from Notice to Proceed (NTP), with an operational period and Power Purchase Agreement (PPA) term of 30 years from Commercial Operation Date.

The following are recommendations from this feasibility study.

- The waste management framework in each upazila currently lacks the adequate infrastructure for dependable waste supply. It is imperative for each upazila to upscale and develop waste management systems and infrastructure to enable dependable waste supply to the project. Waste supply agreements are required to be established between the upazilas and the project.
- The preferred technology of MRF and AD plant was assessed to be marginally commercially viable and does not result in substantial waste reduction. As the electricity export is the only revenue stream for the project with unavailable tipping fees and no revenue from digestate sale due to poor digestate quality. a higher electricity export tariff is required to increase the commercial viability of the project. Additionally, a provision for escalation on the electricity tariff over the lifetime of the project is recommended to compensate the increase in prices due to inflation.
- To increase the overall viability of the project and for other technologies such as incineration technologies to become viable, an incentive through tipping fees is recommended.
- There is potential for other utilization of biogas from the AD process instead of electricity production, including exporting the gas to the national gas pipeline or utilization by industries or households. A separate detailed study is required to ascertain the feasibility of these potential utilizations.
- It is noted that the implementation of AD projects in Bangladesh have faced technical issues. For the successful implementation of the Project, the development of a detailed project specification and construction supervision, and selection of a DBO Contractor and equipment suppliers with proven experience in similar projects are essential for the success of the Project
- The project is recommended to be procured as a solicited project under a concession agreement which enables the participation of private developers through a Design, Build, Operate, with the option for Transfer (DBO(T)) contract. A competitive bidding procurement strategy is recommended to ensure competitive project costs.
- A tendering process and approvals under a Public Private Partnership structure is recommended, with the leading stakeholder, which is the procuring entity from the Government, required to be established.

- As the project is primarily classified as a waste management project, it is recommended that the main government procuring entity be established under the framework of the National Coordination Committee under the Solid Waste Management Rules 2021.
- Detailed studies such as topography and hydrological site studies, ESIA, grid connection studies and routes, vehicle access, and water supply and effluent discharge are required in the next stage of development for the Project
- During O&M phase, Long Term Service Agreements (LTSA) are recommended to be established to minimize risk of price escalation and ensure reliable maintenance support.

1 Introduction

1.1 Project Background

Waste management has been a long-standing issue in Bangladesh, and Bangladesh Power Development Board (BPDB) has been exploring alternative technologies and administrative procedures to find innovative solutions to the challenge of waste management. In collaboration with GIZ, BPDB has commissioned a feasibility study for a Waste to Energy (WTE) power plant project. The scope of the feasibility study focuses on the upazilas of Nawabganj, Keraniganj, and Dohar and has considered the collected Municipal Solid Waste (MSW) from residential, commercial, agricultural debris and other urban waste.

1.2 Objective

The objective of the feasibility study is to analyze the general, legal, and economic framework, collected MSW quantities and MSW characteristics from the upazilas of Nawabganj, Keraniganj, and Dohar to:

- analyze the current waste management system (volume, transportation system, characteristics and composition)
- assess the proper WTE technology to be implemented for the WTE project
- develop a project realization roadmap for the implementation of the WTE project

1.3 Approach

This report has been prepared based on waste data from 0.CREEDs, which carried out a qualitative and quantitative analysis to determine waste quantities and waste characteristics from the existing waste management system at the three upazilas. A comprehensive review of the data is undertaken and forms the basis for the feasibility study.

An analysis of the framework conditions for the successful implementation of the WTE was carried out. A legislative and institutional framework review including the current waste management scenario and policy in the three upazilas, the national and local energy and renewable energy policy, regulatory conditions and permitting requirements of proposed WTE plants were assessed. The economic framework for the three upazilas including industry, service sector, transport and communication were analyzed to assess the financial strength of the waste management sector. Additionally, the energy sector including energy generation, demand and supply, ongoing and future developments in the three upazilas and surrounding areas were analyzed.

A techno-commercial assessment based on these inputs compares various technology configurations to determine a suitable technology for the WTE, with the high-level concept design and description of processes of the WTE detailed. A project realization roadmap considering the business case, siting requirements and power export requirements to the local grid concludes the feasibility study.

2 Review of Framework Conditions

2.1 General Framework Conditions

2.1.1 Geography, climate, and demography

Keraniganj, Nawabganj upazilas and Dohar municipality are part of the Dhaka district. Keraniganj upazila is located some 15km South of Dhaka on the Buriganga river, covering an area of 167 km[1]. Approximately 794,360 people live in the upazila[1]. Nawabganj upazila is located some 45 km South-West of Dhaka and has a population of 320,822[1] and an area of 245 km[1]. Dohar municipality is located some 50 km South-West of Dhaka, with a population of about 71,365[1] and an area of 161 km[1]. River Padma is situated in the southern, south central-western, and south-western part of Dohar. The geography of the three upazilas are characterized by flat plains.

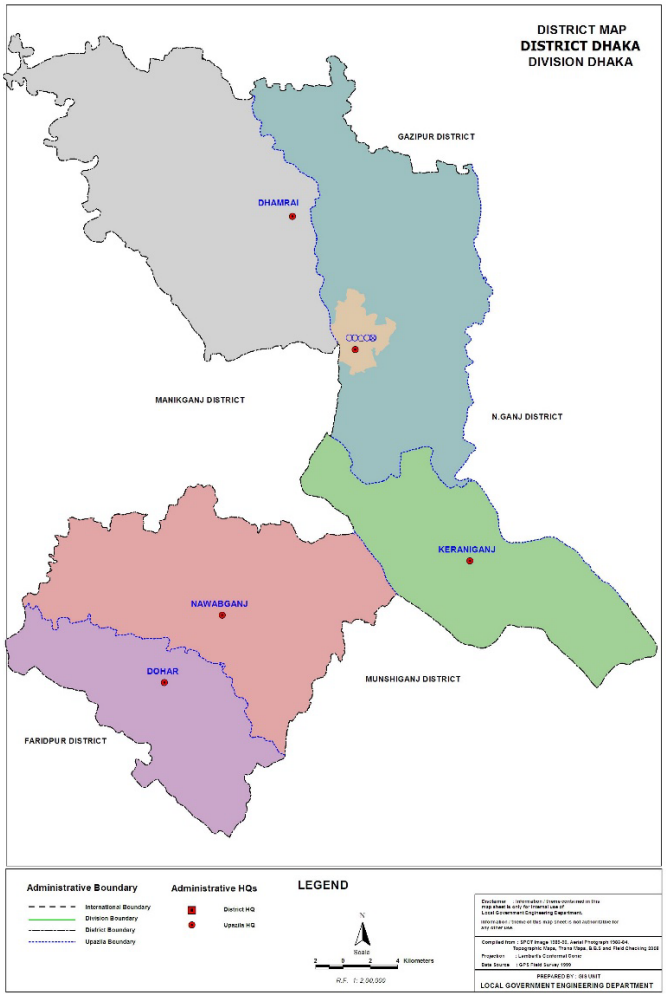


Figure 2-1 District map of Dhaka (source: http://oldweb.lged.gov.bd/DistrictHome.aspx?DistrictID=24)

Keraniganj, Nawabganj, and Dohar experiences a tropical monsoon climate typical to Bangladesh, characterized by high temperatures and humidity, substantial rainfall, and three major seasons of pre-monsoon, monsoon, and post-monsoon. The pre-monsoon season (March-May) is characterized by increasing temperatures, typically exceeding 30°C, with sporadic rainfall. The monsoon season (June-October) is the wettest period of the year, with over 70% of annual rainfall. The temperatures during this period range between 25°C and 35°C with high humidity levels,

[1] based on the 2011 population census (OCreeds, 2024)

typically above 80%. The post-monsoon season (November-February) is the driest and coolest period of the year. Temperatures typically drop to around 15°C with minimal rainfall, and relatively low humidity levels.

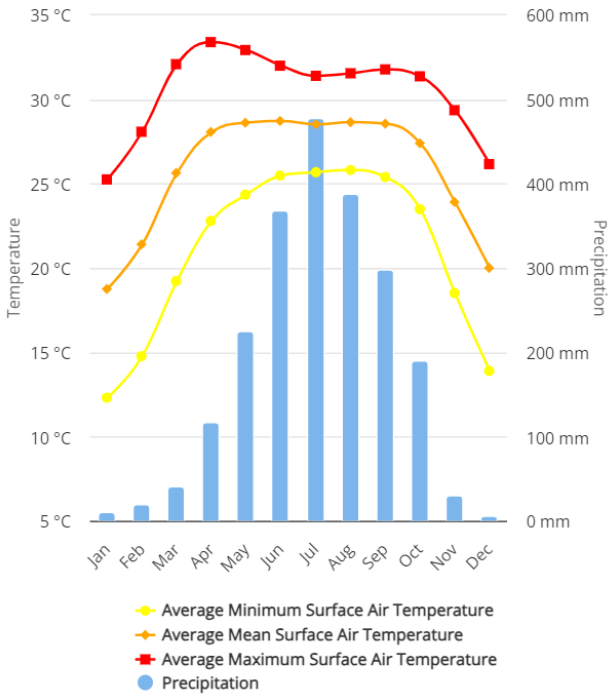


Figure 2-2 Monthly climatology data for Bangladesh between 1991-2020 (source: climateknowledgeportal.worldbank.org, 2024)

2.1.2 Environmental limits

2.1.2.1 Permissible air emission limits

For municipal solid waste incinerators, air emissions depend on the waste feed composition and may include NOx, SO_2, CO_2, metals, acids, and products of incomplete combustion, including polychlorinated dibenzo-p-dioxins and furans (PCDDs and PCDFs). The local air emission limits applicable for the Project is governed by the Air Pollution Control Rules 2022, which are based on section 20 of the Bangladesh Environment Conservation Act, 1995. The International Finance Corporation (IFC) Environmental, Health and Safety Guidelines for Waste Management Facilities refer to the EU Directive 2000/76/EC and US EPA Standards. For this study, the EU Directive 2000/76/EC is considered.

For technologies involving incineration of solid waste, the Air Pollution Control Rules 2022 specify operating standards for municipal solid waste incinerators under Schedule 5 (14)(a). Table 2-1 lists the required operating standards for municipal solid waste incinerators, while

Table 2-2 lists air pollutant emission limits from municipal solid waste incinerators extracted from the Air Pollution Control Rules 2022 and EU Directive 2010/75/EU as the updated standard from the EU. It is note that some parameters from Table 2-1 refers to specific incineration technologies and cannot be achieved for other incineration technologies in the wider application. For example, the requirement of achieving 1000 °C in the secondary combustion chamber only applies to hazardous waste treatment systems and not MSW incineration.

These air emission limits shall be considered in conjunction with the approved Environmental, Social, Impact Assessment (ESIA) results which will also be in accordance with the ambient air quality standards specified in the Air Pollution Control Rules 2022.

Table 2-1 Air Pollution Control Rules 2022 Schedule 5 (14)(a) operating standards for municipal solid waste incinerators

Parameters	Specification	Standard
Temperature	Primary Chamber	› 850 °C
	Secondary Chamber	At least 1000 °C
	Gases infiltrating air pollution devices	‹ 2000 °C
Gas residence time	After last injection of combustion air / secondary chamber	≥ 2 seconds
Air flow	Total combustion air	Additional 140 – 200 %
	Air supply and distribution to incinerator	Sufficient
	Mixture of combustion gases and air in all zones	Good mixing
	Particulate matter entrainment into flue gas	Minimize by keeping moderate air velocity
Oxygen concentration (excess)		Maximum 6%
Combustion efficiency	$CE = \frac{CO2}{\%\,CO2 + \%CO} \times 100$	Minimum 99%
Inspection	Continuous emission monitoring	Particulate matter, CO, SO_2, HF, HCl, NOx, and any other parameters mentioned in the permit conditions
	Continuous process parameter monitoring	Furnace temperature, flue gas outlet temperature, pressure, water vapor, and any parameters mentioned in the clearance conditions
	Regular discharge monitoring (2-4 times a year)	Heavy metals, dioxins and furans
Pollution control equipment	Installation of air pollution control devices	Fabric filter (usually with dry injection facility), packed bed, venturi, or other wet scrubber, electrostatic precipitator (ESP)
Chimney height[1]	Incinerator capacity ‹ 300 tonnes per day	45 meters
	Incinerator capacity ≥ 300 tonnes per day	70 meters

[1]*The minimum height of the chimney shall be determined by air dispersion modelling but shall not be less than the mentioned height*

Table 2-2 Emission limits from municipal solid waste incinerators

Pollutant	Air Pollution Control Rules 2022 (reference conditions undisclosed)		EU Directive 2010 75 EU (reference conditions 0°C, 1 atm, 11% O_2)	
	Limit value	Monitoring	Limit value	Monitoring
Total PM	30 mg/Nm^3	1 hour	10 mg/Nm^3	Daily average
	20 mg/Nm^3	24 hours		
Hydrogen chloride (HCl)	60 mg/Nm^3	1 hour	10 mg/Nm^3	Daily average
	50 mg/Nm^3	24 hours		
Hydrogen fluoride (HF)	1 mg/Nm^3	0.5 hours	1 mg/Nm^3	Daily average
Sulfur Dioxide (SO_2)	100 mg/Nm^3	1 hour	50 mg/Nm^3	Daily average
	80 mg/Nm	24 hours		
Oxides of Nitrogen (NOx)	300 mg/Nm^3	1 hour	200 mg/Nm^3	Daily average
	250 mg/Nm^3	24 hours		

Pollutant	Air Pollution Control Rules 2022 (reference conditions undisclosed)		EU Directive 2010 75 EU (reference conditions 0°C, 1 atm, 11% O_2)	
	Limit value	Monitoring	Limit value	Monitoring
Carbon monoxide (CO)	100 mg/Nm^3	1 hour	50 mg/Nm^3	Daily average
	80 mg/Nm^3	24 hours		
Cadmium (Cd) and Thallium (Tl)	0.1 mg/Nm^3	0.5-8 hours	Total 0.05 mg/Nm^3	Average over sampling period
Mercury (Hg)	0.05 mg/Nm^3	0.5-8 hours	0.05 mg/Nm^3	Average over sampling period
Antimony (Sb), Arsenic (As), Lead (Pb), Chromium (Cr), Cobalt (Co), Copper (Cu), Manganese (Mn), Nickel (Ni)	0.5 mg/Nm^3	0.5-8 hours	Total 0.5 mg/Nm^3	Average over sampling period
Dioxins and Furans	0.1 ng TEQ/Nm^3	6-8 hours	0.1 ng TEQ/Nm^3	Average over sampling period

In the case of biogas fueled engines, the Air Pollution Control Rules 2022 apply under power plants with other gaseous fuel apply as specified in below.

Table 2-3 Biogas fueled engines emission limits

Parameters	Unit	Air Pollution Control Rules 2022 (reference conditions undisclosed)
Total PM	mg/Nm^3	50
Sulfur Dioxide (SO_2)	mg/Nm^3	400
NOx	mg/Nm^3	200

2.1.2.2 Wastewater effluent limits

Any treated wastewater effluent from the Project shall be discharged to the stormwater drain. Bangladesh, under Schedule 3 (Effluent standards) of the Environment Conservation Rules 2023, has acceptable conditions for discharge to surface water streams. These conditions are listed in Table 2-4 below, however, the actual guideline to follow on site will be in accordance with the ESIA study results.

Table 2-4 Wastewater effluent limits from Environment Conservation Rules 2023

Parameters	Unit	Effluent limits
Temperature	°C	30
pH Value	-	6-9
BOD_5 at 20 °C	mg/L	30
COD	mg/L	125
Suspended Solids	mg/L	100
Oil and Grease	mg/L	10
Nitrate (NO_3)	mg/L	50
Phosphate (PO_4)	mg/L	15
Total Coliform	CFU/100 ml	1000

2.1.2.3 Ambient noise standards

The project shall comply to Schedule 1 of the Noise Pollution Control Rules 2006. The recommended guideline for the industrial zones is shown in Table 2-5 below. The actual guideline to follow on site will be in accordance with the EIA study results.

Table 2-5 Schedule 1 of the Noise Pollution Control Rules 2006

Area category	L_{Aeq} Day 6.00 am - 9.00 pm	L_{Aeq} Night 9.00 pm - 6.00 am
Silent area	50 dBA	40 dBA
Residential area	55 dBA	45 dBA
Mixed area	60 dBA	50 dBA
Commercial areas	70 dBA	60 dBA
Industrial areas	75 dBA	70 dBA

2.1.2.4 Project's impact on social and environment aspects

The Project primarily addresses environmental aspects through reduction of volume of municipal solid waste. This reduces the dependency on landfills and mitigates greenhouse gas emissions, particularly methane emissions due to anaerobic decay of organic waste. Various technologies may be applied to achieve effective waste management as addressed in the following sections of this report.

From a social aspect, the Project is expected to require a high level of expertise and labour, creating a high level of job creation.

Air and effluent emissions from the technologies applied in the Project shall be controlled within the limits of relevant applicable standards through emission control systems which have been proven throughout many similar applications all over the world. The environmental impact will be further assessed and approved through an ESIA which shall include air dispersion modelling to analyze impacts on the surrounding population and environment.

2.1.3 Potential applicability for carbon credits scheme

The carbon credits markets are categorized between mandatory markets by governments or voluntary markets by private sectors. An overview of the global volume of issuances by crediting mechanism between 2018 and 2022 is shown in Figure 2-3.

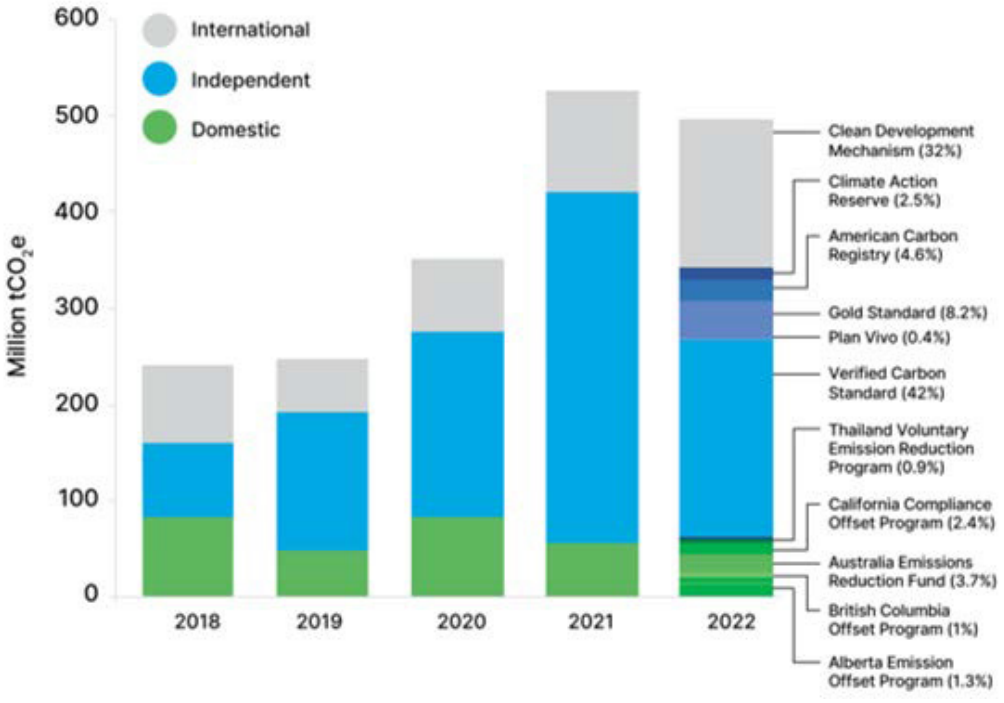


Figure 2-3 Global volume of issuances by crediting mechanism between 2018 and 2022 (source: World Bank, Carbon Pricing 2023)

Under the mandatory market, the Clean Development Mechanism (CDM), defined in Article 12 of the Kyoto Protocol under the United Nations Climate Change has historically been the carbon offset scheme which allows a country with an emission-reduction or emission-limitation commitment under the Kyoto Protocol (Annex B Party) to fund an emission-reduction project in developing countries by buying Certified Emission Reduction (CER) units from the CDM project. The CDM allows industrialized countries to invest in emission reductions where it is cheapest globally.

However, the Kyoto Protocol is being replaced by the Paris Agreement and CDMs will no longer be applicable. The new mandatory carbon credit scheme shall be Article 6.4 (A6.4) of the Paris Agreement. Similar to CDMs, Article 6.4 aims to promote the mitigation of GHG emissions by incentivizing participation by public and private entities though issuance of Article 6.4 Emission Reduction (A6.4ER). The framework for A6.4 is currently being developed and overseen by the A6.4 Supervisory Body (SB). Since January 2021, registered CDM projects must apply to request a transition to the A6.4 mechanism with a decision for acceptance by end of 2025.

To participate in the A6.4 mechanism, countries who are parties to the Paris Agreement must first designate a national authority, which shall function to demonstrate to the SB how its participation in the mechanism contributes to sustainable development. There are several eligibility criteria that projects under the host country must demonstrate under A6.4 which includes:

- Achieve real and measurable mitigation of GHG emissions that is additional to the baseline case
- Include activities reducing emissions, increasing removals, or mitigation co-benefits of adaptation actions and/or economic diversification plans
- Minimize the risk of non-permanence of emission reductions over long periods, and ensure that the reversals, if occurred, are addressed
- Apply a mechanism methodology that has been developed and approved by the SB following its technical assessment
- This mechanism methodology shall set a baseline for the calculation of emission reductions, demonstrate the additionality, and ensure an accurate monitoring of emission reductions
- Apply a crediting period for the issuance of A6.4ERs of:
  - Maximum 5 years, renewable maximum twice,
  - Maximum 10 years without renewal, or
  - Maximum 15 years, renewable max. twice, for activities involving removals

At present there are 136 projects under A6.4 which are mostly based in Switzerland and Japan.

Another pathway to participation in the mandatory carbon credit scheme is Article 6.2 (A6.2) under the Paris Agreement. Contrary to A6.4, it is based on a decentralized framework whereby two countries can tailor their own bilateral arrangements. Credits under this scheme is termed as Internationally Transferred Mitigation Outcomes (ITMO). At present, there have been 64 agreements from 47 countries, with 61% of these agreements from Asia.

Alternatively, there is a voluntary carbon credit market which are governed by the private sector. Some of these schemes include EU ETS, New Zealand ETS, California/Quebec ETSs, China National ETS, and Verified Carbon Standard from Verra and Gold standard. Among these schemes, the Verified Carbon Standard from Verra utilizes the highest market share (approximately 42%), followed by the Gold Standard (approximately 8.2%). However, it shall be noted that carbon prices under the voluntary market have a high fluctuating trend and some schemes have been under public criticism for various reasons.

A detailed assessment must be further carried out to ascertain whether the Project is eligible to qualify for any of the mandatory or voluntary schemes. However, at present, there is no certainty on obtaining carbon credits for the Project.

2.2 Legal and Institutional Framework Conditions

2.2.1 Current waste management scenario

The following section is based on the data from the report prepared by O.CREEDs. It is observed that the local government, with limited participation by the private sector is responsible for waste management in the three upazilas. Due to narrow roads and issues of accessibility, trucks are unable to collect waste at the source. Household waste, market waste, medical waste, institutional waste are collected by rickshaw vans or trolleys from dustbins and open dumping at the roadside and transported to a secondary dumping site. Trucks then transport these wastes to the final dumping site in each upazila. The typical waste management process is shown in Figure 2-4.

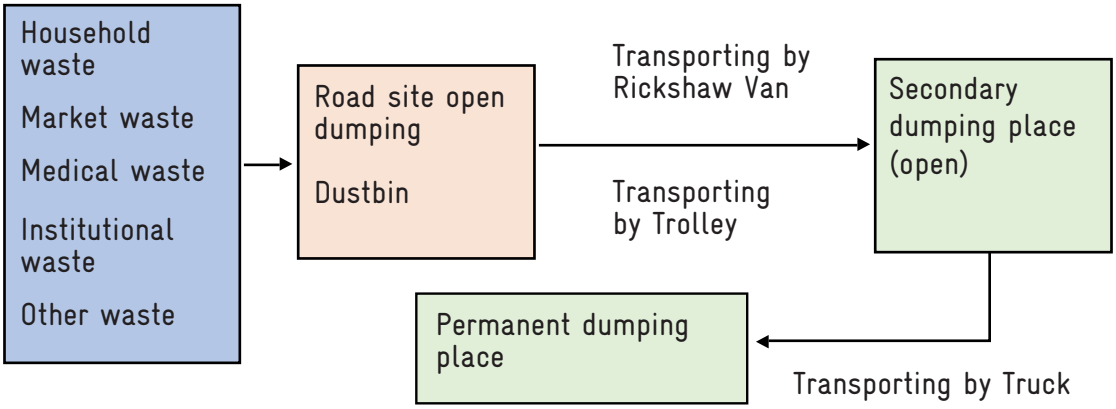


Figure 2-4 Waste management process in the upazilas (Source: OCreeds)

It is noted that the final dumping site in each upazila lacks the proper infrastructure to be classified as landfills, with no lining or leachate collection and treatment system. There is a high risk for ground water contamination at the dumping sites in all upazilas, impacting health of the surrounding communities. Figure 2-5 shows the dumping site at Dohar municipality.

Figure 2-5 Final dumping site at Dohar Municipality (Source: O.CREEDS)

Based on an evaluation on waste generation and collection, it was found that only 26% of total waste generated is collected in Keraniganj and Dohar, while only 0.6% of waste is collected in Nawabganj. A summary of infrastructure and waste collection quantities is summarized in Table 2-6. The low collection rates are attributed to insufficient waste management resources including workforce and infrastructure, and an inefficient waste collection system due to various reasons.

Table 2-6 Waste infrastructure, waste generation, and waste collection in Keraniganj, Nawabganj, and Dohar

Upazila / Municipality	Primary collection vehicle quantities, nos		Secondary collection vehicle quantities, nos	Total waste generated, tpd	Total waste collection, tpd
	Rickshaw	Trolley	Trucks		
Keraniganj	72	-	4	353.5	92.0 (26%)
Nawabganj	2	-	-	210.7	1.2 (0.6%)
Dohar	8	4	3	64.1	16.6 (26%)
Total				**628.3**	**109.8**

2.2.2 Administrative and legal institutional structure

On the national administrative level, the Government of Bangladesh initiated several guidelines and policies to reduce the country's carbon footprint and is leaning towards sustainable energy policies. Considering the costs of generating power, transmission and subsidizing it to reduce the impact on the industries and people, the government of Bangladesh is keen towards private investments in the energy and power sector.

Keraniganj, Dohar and Nawabganj fall under the category of local governments. A single-tier system applies under the urban authority category, with 12 city corporations and 328 municipalities. Dohar is categorized as under the Municipality category. Additionally, a three-tier system applies under the rural government system, whereby there are 64 districts, and 489 sub-districts (upazila), and 4562 Unions. Keraniganj Upazila which consists of 12 unions and Nawabganj Upazila which consists of 14 Unions are part of this rural government system.
In summary. waste management is under the jurisdiction of the local governments, while development of projects particularly involving the energy and power sector is under the jurisdiction of the national administrative government.

2.2.2.1 Waste management

The management of municipal solid waste for Keraniganj, Nawabganj, and Dohar are overseen by the local government entities. Several laws have been prescribed by the Parliament on the formation, and functions of different types of local governments in Bangladesh. The laws include:

- Upazila Parishad Act, 1998
- Local Government (Union Parishad) Act, 2009
- Local Government (Paurashabha) Act, 2009
- Local Government (City Corporation) Act, 2009

The functions of the Upazila Parishads or the Union Parishads as listed in the Upazila Parishad Act, 1998 and the Local Government (Union Parishad) Act, 2009 do not include waste management. However, the Solid Waste Management Rules 2021 provide detailed roles and responsibilities of the local government authorities for management of solid waste.

Solid Waste Management Rules 2021

Based on the Solid Waste Management Rules 2021, a National Coordination Committee was formed comprising of representatives from different ministries and private sector chaired by the Secretary of the Ministry of Environment, Forest, and Climate Change. The Committee is responsible for providing necessary instruction, recommendation and ensuring compliance regarding processing, segregating, reusing, customizing, recycling and disposal of solid waste and other related matters such as impact on ground water, air quality and leachate. The National Coordination

Committee is also responsible for providing necessary instruction to local government authorities after reviewing the annual reports, approving the solid waste management plan of the local government authorities, issue show-cause notice in the event of any non-compliance and demand written report from local government authorities or the Department of Environment after physical inspection.

The Rules outlines a list of the responsibilities of the local government authorities in managing the solid waste which includes:

- Carrying out solid waste management activities in an environment-friendly and hygienic manner and following the guidelines laid down in the Rules.
- Formulation of comprehensive solid waste management plans as outlined in the Rules following national strategies and guidelines on solid waste management including waste reduction, recycling, and recycling.
- Submission of the prepared plan to the National Co-ordination Committee subject to the approval of the Local Government Division.
- Separate collection, transportation and management of biodegradable and non-biodegradable solid waste and domestic hazardous solid waste from each household or any other source by engaging individuals or contractors or any other organization.
- To issue directions for dumping, piling, and burning of waste at designated places.
- Collecting and reusing, recycling or any other management method of waste in accordance with the Rules.
- Taking necessary measures to process, recycle, utilize and final disposal of solid waste in an environmentally friendly and hygienic manner set out in Schedules 2 and 3 of the Rules.
- Taking necessary measures to convert waste into fuel in an environmentally friendly manner following the instructions set out in Schedule 4 of the Rules.
- Undertaking necessary initiative in collaboration with public and private institutions and arranging free supply of decomposable solid waste if necessary.
- Recycling or providing recyclable waste to public or private waste processing plants.

Schedule 1 of the Solid Waste Management Rules 2021 outlines the list of wastes that are categorized as domestic hazardous solid waste. Moreover, Schedule 2 outlines the solid waste processing guidelines including the composting standard and chemical properties.

Schedule 4 of the Rules stipulates the standard for waste to fuel conversion. It states that non-recyclable waste which is 1000 kilocalorie or above must be converted into fuel and shall not be disposed in any landfill. Additionally, high kilocalorie quality waste can be directly converted into fuel, or any type of appropriate technology can be used to prepare Refused Derived Fuel (RDF). Other than that, these wastes can be used as feed stock for the purpose of preparation of RDF. It is also reiterated that the city corporation, municipality, or any other independent operator can take initiative to operate a waste to fuel project.

The National Coordination Committee is expected to enforce the appropriate waste management procedures and development of proper waste treatment by the local government under Schedule 4 of the Solid Management Rules 2021.

Bangladesh Environment Conservation Act, 1995 (further amended in 2010)

The Government of Bangladesh enacted the Bangladesh Environment Conservation Act, 1995 (BECA 1995) with the establishment of the Department of Environment which has been empowered for the purpose of environmental conservation, and control and mitigation of environment pollution. The authority shall issue instructions for the prevention of accidents which may cause environmental degradation and pollution, and adoption of remedial measures. Pursuant to the powers provided under section 6c, the Government of Bangladesh may lay down provisions to regulate the generation, processing, storage, loading, supply, transportation, import, export, disposal, and dumping of hazardous waste by rules.

Section 12 of the BECA 1995 explicitly mentions that no industrial establishment or project shall be undertaken in any area without environment clearance from the Director General of the Department of Environment in the manner

prescribed by the rules. This is also applicable if any industrial establishment or project is being expanded. Furthermore, section 12(4) of BECA 1995 provides guidance to adopt detailed rules on Environmental Impact Assessment (EIA) Report and preparation of Environment Management Plan. The Environmental Impact Assessment shall cover the impact on the environment that is water, air, land, components released from the industries that comes in contact with animals and humans etc.

The Environment Conservation Rules, 2023

The Environment Conservation Rules 2023 (ECR 2023) (previously Environment Conservation Rules 1997) is the key subsidiary legislation of the BECA 1995 which stipulates several methods and measures that are essential for compliance with the provisions laid down in BECA 1995. The ECR 2023 provides specific rules and procedures for various categories of projects in relation to their approval prior to construction and operation. It has classified industrial units and projects for purpose of issuance of Environment Clearance Certificate that is either green, yellow, orange, or red.

The classification is made based on the impact that an industrial unit or project will on the environment and human health. For instance, an industrial unit or project will have very little impact on the environment and human health is categorized to fall under the green category. Similarly, an industrial unit or project having moderate impact is categorized as yellow. Having a sufficient impact is categorized as orange and having heavy impact is categorized under the red category. The industrial units and projects that will fall under these categories are clearly stipulated in schedule 1 of the ERC 2023.

Rule 6 of the ERC 2023 further reiterates the BECA 1995 and states that industrial unit or projects that fall under the yellow, orange, and red category must first obtain a site clearance certificate and later an Environmental Clearance Certificate. The industrial units and projects that fall under category green are exempted from obtaining a site clearance due to having very little impact on the environment and human health.

In regards with the ESIA report required by the BECA 1995, the industrial unit or project that falls under the red category must submit an EIA report to the Department of Environment. The ECR 2023 categorizes waste to energy power plant (producing not more than 5 MW) to fall under the orange class. However, it does not clearly stipulate the category of waste to energy power plant producing electricity more than 5 MW. Nevertheless, it is likely that a waste to energy power plant producing more than 5 MW of electricity shall fall under the red category. Therefore, the Project must submit an EIA report to the Department of Environment, obtain site clearance (unless it is exempted due to the exceptions mentioned above) and obtain an Environment Clearance Certificate. The fees for obtaining and renewal of the Site Clearance and Environment Clerance Certificate is laid down in schedule 7 of the ERC 2023 which depends on the amount of investment that is being invested in a particular industrial unit or project.

2.2.2.2 Power sector

The power sector is governed and regulated by the Ministry of Power, Energy and Mineral Resources (MPEMR) that is responsible for the overall planning and development of the power and energy sector. The MPEMR has two separate divisions that is the power division and energy and mineral resources division. While the power division is mainly responsible for the implementation of energy efficiency in generation, transmission, distribution and renewable energy programs, the energy and mineral energy division deals with all policies and matters relating to Liquid Petroleum, Natural Gas and Mineral Resources. The MPEMR has established different cells for the management of these two divisions.

At the national level, the electricity sector is governed by the Bangladesh Power Development Board (BPDB) and the Bangladesh Energy Regulatory Commission (BERC). BPDB is the regulatory body responsible for awarding power projects to private investors who develop, construct, and own the power plants in Bangladesh. Additionally, BPDB owns several power-generating companies and several power plants in Bangladesh, which supply electricity to the national grid. BERC is responsible for awarding necessary licenses for the generation and sale of electricity to the power generating companies. BERC also sets the rates and tariffs for public electricity consumption in Bangladesh.

At the regional level, the Dhaka Electric Supply Company Limited (DESCO), Dhaka Power Distribution Company Limited (DPDC), Northern Electricity Supply Company Limited (NESCO), Western Zone Power Distribution Company Limited (WZPDCL), and the Bangladesh Rural Electrification Board (BREB), acting through regional bodies known as Polli Bidyut Samiti (PBS) are responsible for the distribution and supply of electricity to the public. The Bangladesh Rural Electrification Board is a corporate body established pursuant to the Bangladesh Rural Electrification Board Act, 2013. Its primary responsibility is to implement and monitor the generation and distribution of electricity in rural areas of Bangladesh. DPDC and DESCO are responsible for providing connectivity, supply, and billing for electricity in Dhaka city.

The following laws, regulations, rules, guidelines, and policies are the cornerstones of regulating the power sector in Bangladesh:

- The Electricity Act 2018
- Bangladesh Energy Regulatory Commission Act 2003
- Bangladesh Power Development Board Order, 1972
- Quick Enhancement of Electricity and Energy Supply (Special Provisions) Act 2010
- The Sustainable and Renewable Energy Development Authority Act 2012
- Rural Electrification Board Act 2013
- Bangladesh Environment Conservation Act 1995
- Environment Conservation Rules 2023
- Solid Waste Management Rules 2021
- Private Sector Power Generation Policy of Bangladesh 1996 (revised in 2004)
- Policy Guidelines for Enhancement of Private Participation in the Power Sector 2008
- Renewable Energy Policy of Bangladesh 2008
- Policy Guideline for Small Power Plant in Private Sector

The major laws and regulations that formulates the legal framework of the power sector of Bangladesh and the key provisions are summarized below:

Electricity Act, 2018

The Electricity Act, 2018 (Electricity Act), which repealed the Electricity Act, 1910, states that the Government of Bangladesh shall take measures for the reform, development, introduction of advanced technology and buying and selling, and other necessary steps for the production, transmission, supply, and distribution, of electricity in Bangladesh. A license for the generation, transmission, distribution, metering, and supply of electricity under the Electricity Act (as well as under the now repealed Electricity Act, 1910) is granted by the Bangladesh Energy Regulatory Commission.

The Electricity Act contains provisions relating to the process for the installation of electricity supply lines, the undertaking of construction or repairs works in relation to electricity supply lines, the acquisition of land for the installation of power plant or substations, the changing of the electricity lines or plants under the control of the licensee, compensation for damage, injury or inconvenience caused for undertaking any work, and other provisions relating to the various other aspects of transmission, supply and distribution of electricity in Bangladesh. The Government of Bangladesh may make rules under the Electricity Act, and until such time the rules have been made, it may issue general or special order to undertake and execute any action. Further, the Government of Bangladesh has expressly reserved the power to implement the objective of the Electricity Act by taking such measures as it deems necessary by notification in the official gazette.

Bangladesh Energy Regulatory Commission Act, 2003

The Bangladesh Energy Regulatory Commission (BERC) was established in 2004 under the Bangladesh Energy Regulatory Commission Act 2003 (BERCA 2003) to create an atmosphere suitable to private investment in the generation of electricity, transmission, transportation along with determination of tariff in this sector.

Section 28 of the BERCA 2003 stipulates that it is the responsibility of BERC to issue license for the following purposes:

- Power generation
- Energy transmission
- Distribution and marketing of energy
- Supply of energy
- Storage of energy

The other functions of the BERC include tariff-setting, setting performance norms, control of environmental standards, and dispute resolution among sector entities.

Bangladesh Power Development Board Order, 1972

BPDB has the mandate to regulate all power plants and grids in Bangladesh as may be considered necessary for its operations. It has the authority to prescribe standards for maintenance of power houses and grids and may develop plans for the utilization of power resources in Bangladesh. BPDB is the key institution responsible for purchase of power from the private sector for distribution to the national grid. It is also empowered by the Bangladesh Power Development Board Order, 1972 (Order 1972) to operate power plants itself, own properties and borrow money for the purpose of discharging its functions including operating power plants in Bangladesh. Order 1972 prescribes the general powers and duties of the BPDB in relation to its objective to develop and regulate the power sector in Bangladesh.

Pursuant to the powers and duties provided to the BPDB through Order 1972, BPDB invites bids for development of power plants in Bangladesh from private parties. Upon submission of bids from private parties, BPDB awards projects to private sponsors following which the private sponsors incorporate the project company. Under such projects, the BPDB purchases power from the private-owned project company operating the power plants for supply to the national grid. Order 1972 empowers the BPDB to negotiate and select rates at which the BPDB shall purchase power from such private power generating companies.

Quick Enhancement of Electricity and Energy Supply (Special Provisions) Act, 2010

The Quick Enhancement of Electricity and Energy Supply (Special Provisions) Act, 2010 is a special legislation which was enacted on an initial term of 4 years which empowers all enterprises owned or controlled by the government to accept any proposal with a view to enhance the generation, transmission, transportation and marketing of electricity and energy and quick implementation of any plan to import electricity and energy from abroad, if necessary. The 2010 act gives the government or any of its departments the advantage to take quick and effective initiatives to supply, distribute, transmit, transport, market and import power and energy. The validity of the Act has been extended to 16 years through several extensions and after the latest extension the act is set to expire in 2026 unless repealed earlier.

As per Section 3 of the Quick Enhancement of Electricity and Energy Supply (Special Provisions) Act, 2010, the Act has been given priority over other legislations, including the Public Procurement Act, 2006. Thus, the Public Procurement Act, 2006 can be bypassed while implementing any proposal undertaken under this act which would result in quick implementation of the proposals or projects. The Act stipulates formation of a proposal processing committee to assess the competency, experience and financial ability of the power producer or the private sector organization and the proposal. Then the proposal shall be approved by the Cabinet Committee of Government Procurement or Cabinet Committee of Economic Affairs. The power projects that have been implemented post 2010, are implemented under this Act.

Renewable Energy Policy of Bangladesh

The Renewable Energy Policy of Bangladesh was issued by the Power Division of Ministry of Power, Energy and Mineral Resources with the flowing objectives:

- Harness the potential of renewable energy resources and dissemination of renewable energy technologies in rural and urban areas
- Enable, encourage, and facilitate both public and private sector investment in renewable energy projects
- Develop sustainable energy supplies to substitute indigenous non-renewable energy supplies
- Scale up contributions of renewable energy to electricity production
- Scale up contributions of renewable energy both to electricity and to heat energy
- Promote appropriate, efficient and environment friendly use of renewable energy
- Train and facilitate the use of renewable energy at every level of energy usage
- Create enabling environment and legal support to encourage the use of renewable energy
- Promote development of local technology in the field of renewable energy
- Promote clean energy for CDM; and
- Achieve the targets for developing renewable energy resources to meet five percent of the total power demand by 2015 and ten percent by 2020

The Renewable Energy Policy further provides that all the entities related to power, local government engineering departments, other interested government, private sector organizations and NGOs will work together to implement the countrywide renewable energy development program. All the entities related to power, or any customer may, on mutual agreement, purchase electricity (below 5 MW) generated by renewable energy projects from both the public and private sectors. Renewable energy projects sponsors may use the existing electricity transmission and distribution system for the purpose of supplying electricity to their consumers, provided that the transmission/distribution facility has sufficient capacity. Sponsors have to pay wheeling charges for using the transmission and distribution system. The wheeling charge will be determined in consultation with BERC and MPEMR.

The Policy further states that for sale of electricity from renewable power plants the Renewable energy project shall be required to get power generation license from BERC if the capacity of the project is 5 MW or more. It is further provided that BERC shall approve the energy tariff in consultation with Power Division of MPEMR and SREDA as per the provision of the BERC Act 2003 if the capacity of renewable energy project(s) is 5 MW or more.

Sustainable and Renewable Energy Development Authority Act, 2012

Sustainable and Renewable Energy Development Authority Act, 2012 (SREDA Act) was enacted to establish Sustainable and Renewable Energy Development Authority (SREDA). The SREDA Act provides the following functions and responsibilities of SREDA, among others:

- to encourage the use of power and energy efficient equipment and take necessary steps for standardization and labeling of power and energy using equipment and appliances
- to encourage energy efficiency and conservation related research and development and to identify innovative financing for implementation of projects or associated works relating thereto, and arrange necessary training in this behalf
- to coordinate the implementation activities of energy efficiency and conservation in government, semi-government and autonomous bodies and create commercial market for sustainable energy in private sector through demonstration
- to assist the Government in making necessary laws, rules, regulations for sustainable energy development
- to prepare short, medium, and long-term development project to extend the use of renewable energy with specific targets and take necessary steps to implement it
- to assist the Government to coordinate the implementation of renewable energy development related activities in government, semi – government and autonomous bodies
- to encourage commercialization of renewable energy and energy efficiency activities in private sector through implementation of pilot project.

Policy Guidelines for Enhancement of Private Participation, 2008

The Policy Guidelines for Enhancement of Private Participation 2008 (PGEPP 2008) was issued for the power sector to promote private sector participation in the generation of electricity with a view to promote economic growth. Clause 4 of the PGEPP 2008 read with Clause 10(a) and (b) provides that private investors can establish and operate commercial power plants subject to the requirement that the commercial power plant has obtained license from BERC as an independent power producer (IPP) for commercial power plants or joint venture power plants. PGEPP 2008 also provides obligations and guidance towards commercial power plants developed by private investors such as compliance with the applicable standards of grid connectivity and operation. The term private investors include Bangladeshi private investors or foreign private investors or joint venture comprising Bangladeshi private investors and foreign private investors.

To be eligible for developing a commercial power plant, there are certain qualifications laid down in Clause 8 of the PGEPP 2008 which are as follows:

Qualifications for private investors:

- Proven financial capacity to arrange financing for the development of commercial power plant
- Proven experience in developing and operating power plant of same or higher capacity as independent power producer, rental power plant, small power plant, captive power plant and selling power to large consumers (such as large industrial enterprise, export processing zones. Special economic zones, private economic zones, high tech parks etc.

Qualifications for Bangladeshi private investors to develop joint venture commercial power plants:

- Proven financial capacity to arrange financing for any large project
- Proven experience in developing and operating power plant of same or higher capacity as independent power producer, rental power plant, small power plant, captive power or it can form a consortium with a third party having the same experience

Private Sector Power Generation Policy of Bangladesh

The Private Sector Power Generation Policy of Bangladesh adopted by MPEMR in 1996 (subsequently revised in 2004), also provides guidance on power sector in Bangladesh. The Policy is administered by Power Cell, a body created under the Power Division of MPEMR, with a mandate to lead private power development, recommend power sector reforms and restructuring, conduct study on tariffs and formulation of a regulatory framework for the power structure.

The Policy regulates foreign investment in the power industry in Bangladesh and sets out the procedures for the engagement of foreign independent power producer (IPP), and the financial arrangements and fiscal incentives that will be provided to the IPPs. The Policy also specifies:

- the minimum requirement for equity investment by the foreign investors in the IPPs is 20%
- the Government of Bangladesh will guarantee the obligations of government agencies of Bangladesh under the PPAs and FSAs
- tariff structures will consist of capacity and energy payments; a mechanism will also be provided for the adjustments of certain tariff components to reflect variations in the BDT/USD exchange rate, fuel price and inflation rates
- sites for power plants will be selected by the Government of Bangladesh in consultation with the investor or project sponsor

Policy Guideline for Small Power Plant in Private Sector

To enhance private investments in the country and to increase power generation promoted private sector investors to establish Small Power Plants (SPP) on fast-track basis, the government of Bangladesh issued the Policy Guideline

for Small Power Plant in Private Sector April 1998 (revised in 2008) for the generation of electricity for own use and sell the surplus to others. These types of plants could be in the order of 10 MW. However, permission may be granted by the government for setting up higher size plants as well.

2.2.3 Permitting requirements for development of WTE

Table 2-7 lists the relevant licenses and permits required for the development of a Waste to Energy plant in Bangladesh.

Table 2-7 List of licenses and permits for development of WTE

SL	Licenses/Permits/NOC/Legal Requirements	Relevant Authority
1	Registration of the Project Company as a private limited company	Registrar of Joint Stock Companies and Firms
2	Trade License (Office)	City Corporation/union parishad
3	e-TIN Registration Certificate	National Board of Revenue
4	VAT Registration Certificate (Business Identification Number)	National Board of Revenue
5	Membership of Recognized Chamber of Commerce.	Any recognized Chamber of Commerce
6	Trade License (Plant site)	City Corporation/union parishad
7	BIDA registration of the Project as an industrial undertaking	Bangladesh Investment Development Authority
8	Fire License	Department of Fire Service and Civil Defense.
9	Commercial IRC	Office of Chief Controller of Imports and Exports (CCI&E)
10	Recommendation for Ad hoc Industrial IRC	Bangladesh Investment Development Authority
11	Ad-hoc Industrial IRC	Office of Chief Controller of Imports and Exports (CCI&E)
12	No objection certificates for the Project Site as per the Local Government (Union Parishads) Act, 2009 (No-61 of 2009).	Union Parishad
13	Approval of Site/location for Environmental Clearance (Red category)	Department of Environment
14	Approval of Environmental Impact Assessment ("EIA") for environmental clearance (Red category)	Department of Environment
15	BIDA Approval for Foreign Loan *(obtained prior to financial closing)*	Bangladesh Investment Development Authority
16	Registration of the executed Financing Documents	Bangladesh Investment Development Authority

17	Approval for Foreign Currency Account	Bangladesh Bank
18	E-visa recommendation for employees *(depending on when the employees will be engaged by the company)*	Bangladesh Investment Development Authority
19	Work Permits and Security Clearance *(depending on when the employees will be engaged by the company)*	Bangladesh Investment Development Authority
20	Environmental Clearance Certificate (Subject to obtaining the approvals referred under 11 and 12 above) (Red category)	Department of Environment
21	Government Authorization for the installation, construction and operation of a deep tube well at the Site.	Union Parishad (Department of Public Health Engineering)
22	Recommendation for Regularization of Industrial IRC	Bangladesh Investment Development Authority
23	Regularization of Industrial IRC	Office of Chief Controller of Imports and Exports (CCI&E)
24	Approval for installations and use of boilers at the Facility under Sections 6 and 7 of the Boilers Act, 1923 (Act V of 1923).	Office of the Chief Inspector of Boilers
25	Approval of layout plans for the construction, establishment, or extension of any factory pursuant to Section 326 of the Bangladesh Labour Act 2006. [approval subject to site inspection]	Department of Inspection of Factories and Establishments (DIFE)
26	Registration of factory pursuant to Section 326 of the Bangladesh Labour Act 2006. (If the Independent Power Producer is considering setting-up a separate office, the registration for office should also be obtained separately)	Department of Inspection of Factories and Establishments (DIFE)
27	Notice of commencement of operations (Should be obtained for both office and factory sites 15 days prior to commencement)	Department of Inspection of Factories and Establishments (DIFE)
28	Approval of HR Handbook/Service Rules	Department of Inspection of Factories and Establishments (DIFE)
29	License under the Bangladesh Petroleum Act, 2016 (Act XXXII of 2016) for storage of petroleum products at or proximate to the Facility.	Department of Explosives
30	License for the term of the Power Purchase Agreement permitting the Company to generate and supply electricity under the Power Purchase Agreement.	Bangladesh Energy Regulatory Commission
	MISCELLANEOUS	

31	Statutory notifications granting exemption from Customs Duties and VAT on the importation of plant and equipment (including spare parts) for incorporation into the Facility and the temporary importation of erection materials, machinery, and equipment (subject to re-export). Generally, such exemption is expressly provided in the Implementation Agreement.	Internal Resources Division, Ministry of Finance
32	(a) Statutory notification granting the Company exemption from taxation on its income including all withholding taxes related directly to the Project. Generally, such exemption is expressly provided in the Implementation Agreement. (b) Statutory notification granting foreign collaborators, companies and experts exemption from tax or withholding tax on such of their income as is paid as "royalties", "technical assistance fees" and "technical know-how fees" by the Company in connection with the Project. Generally, such exemption is expressly provided in the Implementation Agreement. (c) Statutory notification granting the Foreign Investors of the Company exemption from capital gain tax in respect of any transfer or disposal of shares in the Company. Generally, such exemption is expressly provided in the Implementation Agreement. (d) Statutory notification granting foreign employees of the Company exemptions from taxation on their personal income in Bangladesh (for 3 years after their arrival). Generally, such exemption is expressly provided in the Implementation Agreement. (e) Statutory notification for exemption from income tax on interest payments to lenders.	Internal Resources Division, Ministry of Finance
33	Statutory notification granting the Company an exemption from any duty on the sale of electricity to BPDB. Generally, such exemption is expressly provided in the Implementation Agreement.	National Board of Revenue
	(a) Statutory notification granting exemption from stamp duties in respect of the registration of all deeds, documents and instruments contained in the Financing Documents. Generally, such exemption is expressly provided in the Implementation Agreement.	Ministry of Finance
	(b) Statutory notification granting exemption from registration fees in respect of the registration of all deeds, documents and instruments contained in the Financing Documents. Generally, such exemption is expressly provided in the Implementation Agreement.	

34	(a) Government Authorization for payment by the Company to persons outside Bangladesh under Section 5 of the Foreign Exchange Regulations Act, 1947 (Act VII of 1947) (FERA) in respect of all transactions of the Company necessary to implement the Project. (b) Government Authorization for the issuance, export and transfer of securities in Bangladesh or outside Bangladesh under Section 13 of FERA, purchased in Taka or in Foreign Currency (c) Government Authorization for the purchase of Dollars for Taka through normal commercial banking channels in Bangladesh and for the transfer of such Dollars from bank accounts inside Bangladesh into bank accounts outside Bangladesh. (d) Government Authorization to make or remit payments in Dollars from bank accounts in Bangladesh or outside Bangladesh.	Bangladesh Bank
35	Government Authorization for creation of security interests in favour of the Lenders in the Company's bank accounts.	BIDA
36	License for the Company to obtain and have arms for the purposes of the security of the Facility.	Ministry of Home Affairs
37	Exemption from Section 19 of Insurance Act 2010 (Act XIII of 2010) to permit the Company to obtain insurance for the Project from companies outside Bangladesh.	Insurance Development Regulatory Authority
38	Permission for transporting chemicals, toxic wastes and hazardous materials on land and water routes.	Department of Explosives
39	No Objection Certificate to build an exhaust stack and bypass stack at the site as part of the plant.	Civil Aviation Authority of Bangladesh

2.3 Financial and Economic Framework Conditions

2.3.1 Economic framework study

Keraniganj Upazila's economic framework consist of small-scale industries such as garment manufacturing, metal, and brick making. Expansion of such industries were highly associated with proximity to the rivers Buriganga and Dhaleswari and due to connections to Dhaka, while food processing, rubber and plastics manufacturing industries were clustered in relation to road proximity. The Upazila has three Economic Zones within its area including Dhaka SEZ, Bashundhara Economic Zone, and East-West Special Economic Zone. A survey conducted by Keraniganj Garments Traders and Shop Owners' Cooperative Association in 2015 revealed that the Upazila is home to over three thousand garment factories, more than 5,000 shops and 250 malls. Due to the huge production and supply of garments in the whole country from Keraniganj, it has become known as Bangladesh's apparel hub. Apart from garments, In Keraniganj, various machinery equipment is engaged in the manufacturing of basic power tools, hardware, small-scale machinery and other industrial components. The industry includes polishing and metal-working machines, drills, nuts, bolts, screws, springs, valves, and other basic industrial equipment.

Dohar Municipality is largely similar to Nawabganj Upazila, with several cottage industries such as Goldsmith, blacksmith, weaving, potteries, embroidery, cane work, bamboo work, and woodwork. The municipality exports weaving cloths, wheat, vegetables, and has several cotton mills, sawmills, welding factories and cigarette factories. Major sources of employment include agriculture, rent and remittance, and commerce services. Although all the wards and unions of Dohar and Nawabganj are under rural electrification program of BREB's PBS network, less than 50% of the households have electricity.

2.3.2 Fiscal incentives for development of WTE projects

The Private Sector Power Generation Policy of Bangladesh 1996 (further revised in 2004) and Policy Guidelines for Enhancement of Private Participation in the Power Sector 2008 specifies the fiscal benefits for the private power companies. The major incentives are provided below:

- Exemption from corporate income tax for a period of 15 years
- The companies will be allowed to import plant, equipment, and spare parts up to a maximum of ten percent 10% of the original value of total plant within a period of 12 years of commercial operation without payment of custom duties, Vat and any other surcharges as well as import permit fee except for indigenously produced equipment manufactured according to international standards
- Repatriation of equity along with dividends will be allowed freely
- Exemption from income tax in Bangladesh for foreign lenders to such companies
- The companies will be exempted from the requirement of obtaining insurance or reinsurance from the national insurance Company rather they will be free to determine their choice of insurance as per requirements of the lenders and the utilities
- The instruments and deeds required to be registered under the local laws shall be exempted from stamp duties
- Tax exemption on royalties, technical know-how and technical assistance fees, and facilities for their repatriation
- Tax exemption on interest on foreign loans
- Tax exemption on capital gains from transfer of shares by the investing company
- Avoidance of double taxation in case of foreign investors depending on bilateral agreements
- Exemption of income tax up to 3 years for the employed expatriate personnel
- Remittance of up to 50% of salary of the foreigners employed in Bangladesh and facilities for repatriation of their savings and retirement benefits at the time of their return
- No restrictions on issuance of work permits to project related foreign nationals and employees
- Taka, the national currency, would be convertible for international payments in current account
- Re-investment of remittable dividend to be treated as new foreign investment
- Foreign owned companies duly registered in Bangladesh will be on the same footing as locally owned companies regarding borrowing facilities

The tax incentives are further corroborated by the order issued by Internal Resource Division of the Ministry of Finance. Pursuant to S.R.O No. 05-Law/IncomeTax/2020 dated 02 January 2020, if the commercial power generation of a private power generation company (excluding coal-based power generation companies) starts within 01 January 2020 to 31 December 2022 then the private power generation company shall enjoy the following tax benefits:

- Income from power generation shall be exempt from the commercial power generation date income tax till 31 December 2034
- Income of expatriate employees of the private power generation company shall be exempt from income tax for a period of 3 years from the date of entering into Bangladesh
- Interest payments on foreign loan availed by the power generation company from foreign lenders shall be exempt from income tax
- Payment of royalties, technical know-how and technical assistance fees shall be exempt from income tax
- There shall no capital gains tax on transfer of shares in the power generation company.

In addition to the above, pursuant to S.R.O No. 100-Law/2000/1832/Duty dated 18/04/2000, private power generation companies have been exempted from payment of import duty, value added tax, supplementary duty and infrastructure development surcharge on import of spare parts of plants and equipment necessary for construction of a power plant, provided that:

- Costs of the spare parts are no more than 10% of the cost of purchase of the plants and equipment
- This exemption shall be valid from the date of import of the plants and equipment till the expiry of 12 years from the date of commercial operations date of the power plant
- The importer must obtain a certificate regarding the tax exemption from the relevant government authority as per the S.R.O. and file the certificate with the customs station at the time of release of the spare parts
- The importer has to file an undertaking with the Commissioner of Customs.

2.3.3 Financing Models

2.3.3.1 Public Private Partnership

The policy framework for Public Private Partnership (PPP) was introduced in Bangladesh in 1996 with the Private Sector Power Generation Policy. The initial projects under this scheme were the 450 MW Meghnaghat and 360 MW Haripur power projects. The policy for encouraging partnerships with the private sector continued with the introduction of the Private Sector Infrastructure Guidelines (PSIG) 2004 which is then replaced with the Policy and Strategy for Public Private Partnership 2010. It updates policies and incorporates best international practice to further boost use of PPPs across multiple sectors and to provide a clear and transparent regulatory and procedural framework. The Government of Bangladesh has enacted the Bangladesh Public Private Partnership Act, 2015 (Act No. XVIII of 2015) after repealing the policy.

Subsequently in 2015, the PPP Act was enacted, with the purpose of facilitating the development of certain vital sectors using this methodology of financing. A new PPP unit was established under the Ministry of Finance, and it approves government funding to a PPP. In order to strengthen the regulatory framework, the Bangladesh Government published the "Procurement Guidelines for PPP Projects 2016", followed by the "Procurement Guidelines for PPP Projects 2018", setting out the applicable guidelines with regard to the process, time scales, and institutional roles and responsibilities involved in the selection of a private sector partner. Other specific guidelines are related to project screening, technical assistance, financing methods, Viability Gap Funding (VGF), and treatment of unsolicited proposals.

A total of 69 PPP projects across various sectors were implemented between 1990 to 2019, with widespread interest in PPPs from the energy sector. Projects implemented during this period include sectors for roads, railways, ports, airports, energy, water and wastewater, ICT, and social infrastructure. Given the trend it can be assumed that this method of financing will gain impetus in the years to come.

2.3.3.2 Green Financing

Green financing is to increase level of financial flows (from banking, micro-credit, insurance and investment) from the public, private and not-for-profit sectors to sustainable development priorities. A key criterion is to better manage environmental and social risks and adopt opportunities that bring both a decent rate of return and environmental benefit and deliver greater accountability. As such, green financing has gained momentum in recent years. In 2022, banks and non-banks disbursed Tk 122,260 million in green finance, up from Tk 72,320 million in 2021. Similarly, sustainable finance rose to Tk 1,307,620 million from Tk 825,510 million in 2021. Bangladesh's energy portfolio remains almost entirely dependent on conventional methods of energy generation, with 1% to 2% on renewable energy projects.

Green bonds offer investors and issuers a product dedicated to raising finance for green or sustainable projects. The term 'green bonds' refers to bonds that exclusively finance low carbon and climate-resilient projects. The financed projects must clearly deliver defined environmental benefits.

In 1997, the Government set up the Infrastructure Development Company Limited (IDCOL). The Company was licensed by the Bangladesh Bank as a non-bank financial institution (NBFI) on 5 January 1998. Since its inception, IDCOL is playing a major role in bridging the financing gap for developing medium to large-scale infrastructure and renewable

energy projects in Bangladesh. The company's lending rate for the type of project under study is 6% with a tenure of 8 years including 1 year grace period.

Some of the leading commercial banks have started promoting the issuance and sustainability of Green Bonds. A policy paper titled "Policy on Green Bond Financing for Banks and FIs was published by the Bangladesh bank outlining the process and procedure of issuing such instruments. In 2021, the Bangladesh Securities and Exchange Commission (BSEC) published a Gazette Notification outlining the legal/regulatory framework of different types of bonds including green bonds.

2.3.3.3 Bank Finance

The Renewable Energy Policy 2008 had set a target to generate 10% electricity from renewable sources by 2020. However, contribution of renewable energy in the country's energy balance is approximately 2% for grid connected power generation up to date. The Sustainable and Renewable Energy Development Authority (SREDA) under the Ministry of Power Energy and Mineral Resources has realized the necessity to revisit the policy and streamline the policy on renewable energy development in the country.

To promote renewable and green energy, Bangladesh Bank, which is the Central Bank of the country announced its sustainable finance policy for lenders in December 2020 and made it mandatory for 2% of all the loans by the banks and other financial institutions for devoting to renewable energy facilities and 'green projects'. The Central Bank further announced that the achievements of the banks and financial institutions in 'green banking and sustainable financing' would be taken into consideration in their rating. Having said that, it is important to ensure that such funding is available at a comparatively low cost and the loans must be readily available. Also, there is no dedicated fund created by the banks so far for renewable energy project financing.

2.4 Review of Grid Structure

2.4.1 Energy scenario

For generation and distribution purposes, Bangladesh is divided into nine zones. As of August 2023, the total generation (installed) capacity of the country is 24,611 MW. However, with some old generators unable to produce at rated capacity and derated capacity of the system has come down to 23,871 MW. At the national level, to-date maximum demand recorded was 15,648 MW on 19th April 2023. The area wise generation capacity is given in Table 2-8.

Table 2-8 Area wise generation capacity as of August 2023 (Source: BPDB)

No.	Area	Installed Capacity, MW	Present (Derated) Capacity, MW	Remarks
1.	Dhaka	5763	5422	
2.	Chattogram	2605	2545	
3.	Cumilla	2959	2896	Includes 160 MW import from India
4.	Mymensing	717	614	
5.	Sylhet	2472	2427	
6.	Khulna	3125	3121	Includes 1,000 MW import from India
7.	Barishal	2265	2265	
8.	Rajshahi	3675	3631	
9.	Rangpur	1030	950	
	Total	24,611	23,871	

Power Grid Company of Bangladesh (PGCB), a public company, is the sole operator of the power transmission system of Bangladesh. The Bangladesh transmission system consists of 400kV, 230 kV, 132 kV transmission lines. In addition, the transmission system includes one Back-to-Back HVDC station (2 blocks), 400/230 kV Grid substations (SS), 400/132 kV Grid SS, 230/132 kV Grid SS, 230/33 kV Grid SS & 132/33 kV Grid SS.

A summary of the national grid system is specified in Table 2-9.

Table 2-9 Bangladesh national grid overview as of June 2023 (source: PGCB)

No.	Voltage	Length in km	Length, km
1.	400 kV	997	1,972
2.	230 kV	2067	4,236
3.	132 kV	4998	8,508

Table 2-10 shows transmission lines and Table 2-11 shows grid substations are in Keraniganj, Nawabganj, and Dohar.

Table 2-10 Transmission lines in Keraniganj, Nawabganj, and Dohar (source: PGCB)

No.	Name of Transmission Line	Voltage	Length in km	Length, km	Remarks
1.	Meghnaghat- Hasnabad T/L	230 kV	24.50	49.00	Double Circuit
2.	Aminbazar-Hasnabad	230 kV	21.50	43.00	Double Circuit
3.	LILO Hasnabad-Aminbazar at Keraniganj	230 kV	0.39	1.57	
4.	LILO Hasnabad-Aminbazar at Shyampur	230 kV	0.12	0.46	
5.	Hasnabad - Lalbag	132 kV	30	30	Single Circuit
6.	Kallyanpur_Keraniganj	132 kV	20	20	Single Circuit
7.	Hasnbad- Keraniganj	132kV	13.6	13.6	Single Circuit
8.	Hasnabad- Sitalakhya	132 kV	4	4	Single Circuit
9.	Hasnabad - Shyampur	132 kV	30	30	Single Circuit
10.	Keraniganj - Sreenagar	132 kV	15.84	31.78	Double Circuit
11.	Keraniganj - Nawabganj	132 kV	27.08	54.15	Double Circuit
12.	Keraniganj – Lalbag & Kamrangichar	132 kV	31.24	124.96	
13.	Hasnabad - Postogola	132 kV	2	4	Double Circuit
14.	Hasnabad – Keraniganj T/L rerouting at Power Plant	132 kV	2.8	11.2	

Table 2-11 Grid substations in Keraniganj, Nawabganj, and Dohar (source: PGCB)

No.	Name of Grid substations	Voltage	Capacity MVA	Area
1.	Hasnabad Grid Substation	230/132 kV	3 x 225	Keraniganj Upazila
2.	Keraniganj Grid Substation	230/132 kV	3 x 300	Keraniganj Upazila
3.	Nawabganj Grid Substation	132/33 kV	2 x 50/75	Nawabganj Upazila

However, since WTE Power Plant capacity is expected to be not more than 20 MW, it will be not connected to above substations but instead at a lower voltage.

Dhaka Polli Bidyut Samiti 2 (Dhaka PBS-2) & Dhaka Polli Bidyut Samiti 4 (Dhaka PBS-4) of Bangladesh Rural Electrification Board (BREB) are responsible for distribution, supply and sales of electricity in the three Upazilas. Dhaka PBS-2 supplies electricity to Nawabganj & Dohar Upazila and in addition to four other Upazilas. Dhaka PBS-4 supplies electricity to Keraniganj Upazila and two other Upazilas. The maximum demand of Dhaka PBS-2 and Dhaka PBS-4 of are provided in Table 2-12 and

Table 2-13. In regard to future substation developments, two 33/11 kV substations (each 20 MVA) are planned in Dhaka PBS-2 (Dohar & Nawabganj), however, these are at an initial stage. There is also a plan to construct 15 numbers of 33/11 kV substation in Dhaka PBS-4 area.

Table 2-12 Dhaka PBS-2 substation and maximum demand

Sl.	Sub Station	Voltage	Capacity MVA	Peak Demand MW
1.	Nawabganj – 1 (H.Q)	33/11	2 x 10/14 = 28	9.5
2.	Nawabganj – 2 (Baruakhali)	33/11	3 x 3.3 + 5 =15	7.0
3.	Nawabganj – 3 (Sholla)	33/11	2 x 10/14 = 28	6.5
4.	Nawabganj – 5 (Bandura)	33/11	2 x 10/14 = 28	10.0
5.	Nawabganj – 7 (Agla)	33/11	2 x 10/14 = 28	11.5
6.	Dohar – 1 (Dohar)	33/11	3 x 5 +1 x 10/14 = 29	14.0
7.	Dohar – 2 (Kusumhati)	33/11	2 x 10/14 = 28	5.5
8.	Dohar – 3 (Nikra)	33/11	2 x 10/14 = 28	7.0
	Total		184	71

Table 2-13 Dhaka PBS-4 substation and maximum demand

Sl.	Sub Station	Voltage	Capacity MVA	Peak Demand MW
1.	Hasnabad	33/11	30	10
2.	Pangaon	33/11	20	10
3.	Baghor	33/11	20	10
4.	Chorgolgolia	33/11	20	10
5.	Jhilmil -1	33/11	20	9
6.	Jhilmil - 2	33/11	20	6
7.	Zinzira	33/11	40	24
8.	Aganagar	33/11	40	20
9.	Konkhola	33/11	20	9
10.	Bscic	33/11	20	10
11.	Kalatia	33/11	20	8
12	Atibazar	33/11	20	12
13	Washpur	33/11	20	5
14.	Hazratpur	33/11	20	3
15.	Shopnodhara	33/11	20	10
16.	Glove Heavy Chemical	33/11	20	7
18.	Booster Pump	33/11	8	3
19	Basundhara - 1	33/11	5	1
20.	Basundhara - 2	33/11	5	1
21.	Basundhara - 3	33/11	5	2
22.	Basundhara Gas & Oil	33/11	10	3
23.	Basundhara multi food	33/11	10	3
24.	Macca Multilyer	33/11	4	1
25.	Janani - 1	33/11	4	1
26.	Janani - 2	33/11	3	1
	Total		414	184

Depending on the location, the Project is anticipated to be connected to one of the substations listed in Table 2-12 and Table 2-13. The maps showing location of substations of these two PBS are shown in Figure 2-6 and Figure 2-7.

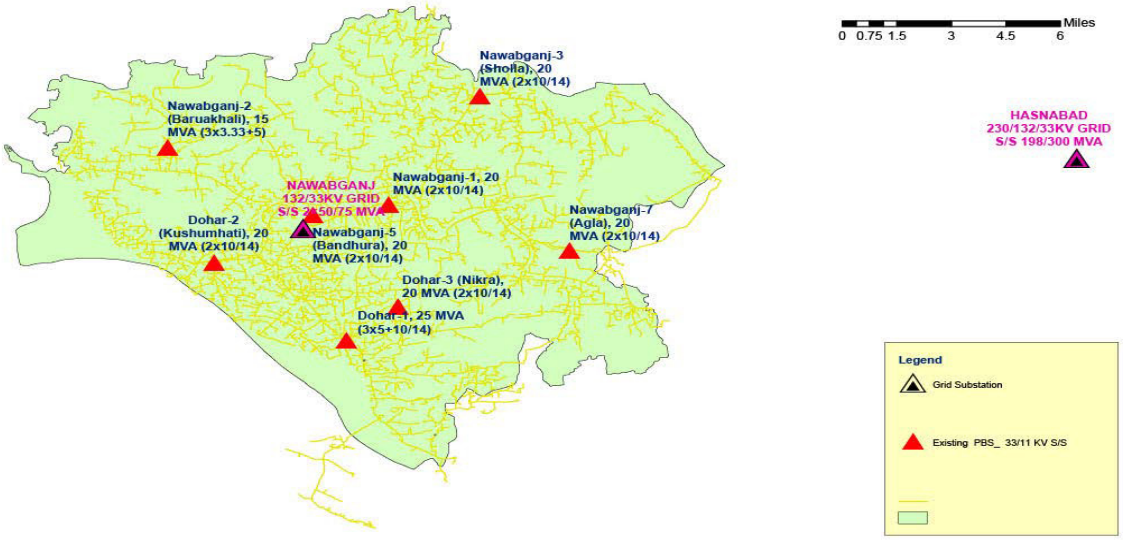


Figure 2-6 Map of Dhaka PBS-2 substation locations

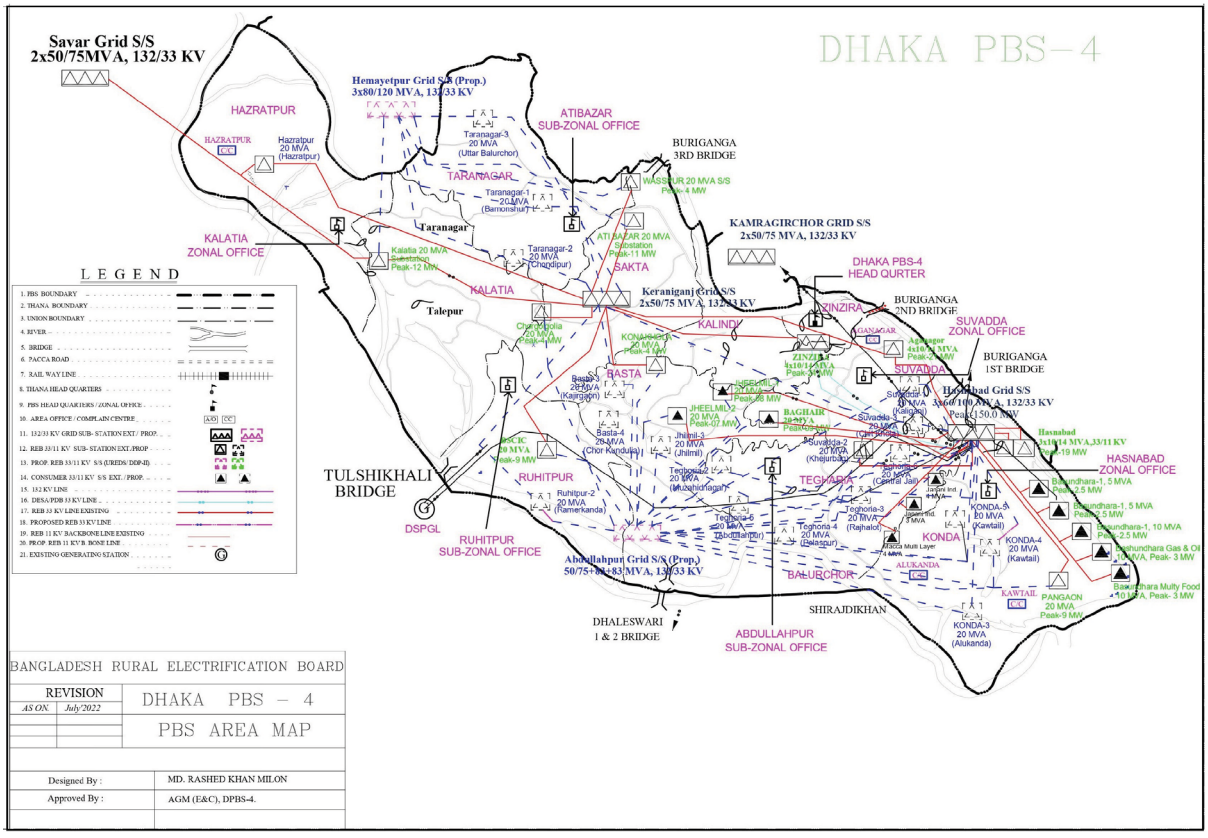


Figure 2-7 Map of Dhaka PBS-4 substation locations

The two main power plants supplying power for Dohar, Nawabganj and Keraniganj area utilizing HFO as fuel are shown in Table 2-14. However, due to shortage of fuel these plants are presently not able to generate at full load.

Table 2-14 Power plants in Dohar, Nawabganj and Keraniganj (source: PGCB)

No.	Area	Type of Fuel	Power plant capacity, MW
1.	Nawabganj (Southern Power)	HFO	55
2.	Keraniganj (Power Pac)	HFO	100

2.4.2 Project power evacuation to grid

Since the capacity of the Project is not expected to more than 20 MW, it is anticipated to be connected to the nearest 33/11 kV substation. Ideally, the distance between the Project and the substation should be less than 3 km and not more than 5 km. All the substations in the three Upazilas are receiving supply from three grid substations in the area namely Hasnabad 230/132kV, Keraniganj 230/132 kV and Nawabganj 132/33 kV. The three grid substations have 33/11 kV substations adjacent to them from where other 33/11 kV substations are getting supply. From a power evacuation point of view, it will be best If the Project can be connected to any of 33/11 kV Substation adjacent to Grid substations. If this is not possible, one of the 33/11 kV substation having higher demand may be chosen. One of the such substations is Nawabganj-7 (Agla ss). The Project shall comply with the relevant grid code requirements.

2.5 Summary of framework conditions review

Keraniganj, Nawabganj Upazilas and Dohar Municipality are part of the Dhaka district. Keraniganj, Dohar and Nawabganj fall under the category of local governments. The management of municipal solid waste for Keraniganj, Nawabganj, and Dohar are overseen by the local government entities. Solid Waste Management Rules 2021 provide detailed roles and responsibilities of the local government authorities for management of solid waste.

Based on an evaluation on waste generation and collection, it was found that only 26% of total waste generated is collected in Keraniganj and Dohar, while only 0.6% of waste is collected in Nawabganj. The low collection rates are attributed to insufficient waste management resources including workforce and infrastructure, and an inefficient waste collection system.

The power sector is governed and regulated by the Ministry of Power, Energy and Mineral Resources (MPEMR). At the national level, the electricity sector is governed by the Bangladesh Power Development Board (BPDB) and the Bangladesh Energy Regulatory Commission (BERC). At the regional level, the Dhaka Electric Supply Company, and the Bangladesh Rural Electrification Board (BREB), acting through regional bodies known as Polli Bidyut Samiti (PBS) are responsible for the distribution and supply of electricity to the public.

The current legal, institutional, and financial framework is robust enough for implementing power projects in Bangladesh. Many power projects have been awarded and being successfully operated in Bangladesh. All the aspects of the power sector such as generation, exploration, production, transmission and distribution is governed and regulated by well-established rules and regulation which has been continuously updated in light of the challenges faced by the stakeholders. However, the existing waste management system in the three Upazilas is found to be inadequately managed with low collection rates. An improvement of the waste management systems in the three Upazilas is required.

Various permitting requirements for the development of the plant have been listed. The local air emission limits applicable for the Project is the Air Pollution Control Rules 2022, which is based on section 20 of the Bangladesh Environment Conservation Act, 1995. The International Finance Corporation (IFC) Environmental, Health and Safety Guidelines for Waste Management Facilities refer to the EU Directive 2000/76/EC and US EPA Standards. These air emission limits shall be considered in conjunction with the approved EIA results which will also be in accordance with the ambient air quality standards specified in the Air Pollution Control Rules 2022.

The Project may be eligible for a carbon credit scheme either through mandatory markets by governments or voluntary markets by private sectors. A detailed assessment must be further carried out to ascertain whether the Project is eligible to qualify for any of the mandatory or voluntary schemes.

The policy framework for Public Private Partnership (PPP) was introduced in Bangladesh in 1996 with the Private Sector Power Generation Policy, encouraging partnerships with the private sector. Several green financing possibilities exist within the finance framework including, IDCOL which was established by the Government of Bangladesh to bridge the financing gap for developing medium to large-scale infrastructure and renewable energy projects in Bangladesh.

Fiscal incentives are available through various schemes which may facilitate the development of the Project. Applicable schemes include the Policy Guidelines for Enhancement of Private Participation 2008, Private Sector Power Generation Policy of Bangladesh 1996, and Policy Guideline for Small Power Plant in Private Sector.

The Project is expected to generate revenue from power export to the grid. There are no precedent cases or structure which enables consideration of gate fees, which are typically the main source of revenue for waste to energy facilities.

Although there are no legal challenges but negotiating and entering into the waste supply agreements with the relevant local government authorities (i.e. the upazila parishads of Nawabganj, Keraniganj, and Dohar) may pose some challenges which may be alleviated with the support of the Ministry of Local Government, Rural Development and Cooperatives. As per the template Waste Supply Agreement, the Waste Supplier (i.e. the local government authorities) shall be responsible for supplying the waste at the Waste Transfer Station free of cost. Additionally, there are also provisions for liquidated damages for both the parties if the waste supplier fails to supply the required quantity of waste and the power producer fails to receive the agreed quantity of waste.

Dhaka Polli Bidyut Samiti 2 (Dhaka PBS-2) & Dhaka Polli Bidyut Samiti 4 (Dhaka PBS-4) of Bangladesh Rural Electrification Board (BREB) are responsible for distribution, supply and sales of electricity in the three Upazilas. Since the capacity of the Project is not expected to more than 20 MW, it is anticipated to be connected to the nearest 33/11 kV substation.

3 Waste Characteristics

3.1 Waste Sampling Review

GIZ has appointed O.CREEDs to carry out a waste characterization study and lab analysis for the waste received at sampled Temporary Dumping Stations (TDS) and Final Dumping Sites (FDS) at each of the three Upazilas. O.CREEDs collected samples from 6 locations on three separate occasions, 18th October 2023, 4th November 2023, and 17th February 2024 and sent the samples for lab tests at the Bangladesh University of Engineering and Technology (BUET). The waste samples listed in Table 3-1.

Table 3-1 Waste Sampling

No.	Upazila	Area Name	Date of Sampling
1	Keraniganj	Suvadda Dumping Site (FDS)	18 October 2023
2	Keraniganj	Baspatti Aganagar (TDS)	18 October 2023
3	Keraniganj	Jinjira-Shuvadha Dumping Site (TDS)	18 October 2023
4	Nawabganj	Shapkhali Dumping Site (FDS)	18 October 2023
5	Dohar	Chakdighi Par Dumping Site (FDS)	18 October 2023
6	Dohar	Ratan Chattar (TDS)	18 October 2023
7	Keraniganj	Suvadda Dumping Site (FDS)	4 November 2023
8	Keraniganj	Baspatti Aganagar (TDS)	4 November 2023
9	Keraniganj	Jinjira-Shuvadha Dumping Site (TDS)	4 November 2023
10	Nawabganj	Shapkhali Dumping Site (FDS)	4 November 2023
11	Dohar	Chakdighi Par Dumping Site (FDS)	4 November 2023
12	Dohar	Ratan Chattar (TDS)	4 November 2023
13	Keraniganj	Suvadda Dumping Site (FDS)	17 February 2024
14	Keraniganj	Baspatti Aganagar (TDS)	17 February 2024
15	Keraniganj	Jinjira-Shuvadha Dumping Site (TDS)	17 February 2024
16	Nawabganj	Shapkhali Dumping Site (FDS)	17 February 2024
17	Dohar	Chakdighi Par Dumping Site (FDS)	17 February 2024
18	Dohar	Ratan Chattar (TDS)	17 February 2024

We note that O.CREEDS reported that sample 1-6 was done during wet season while sample 7-12 was done during dry season. We would like to point out that in Bangladesh the wet season peak is in June and July while dry season peak is December and January. While ideally, sampling would occur at the peak of both the wet and dry seasons to capture the full range of waste moisture, it is noted that the sampling was conducted towards the end of each season, in October for the late wet season and in February for the late dry season. This timing, while not optimal, still provides a useful approximation of seasonal variation in waste moisture content.

The waste characteristic studies are attached in **Annex 1**.

3.1.1 Sources

In general, waste from various sources namely, household, industry, hospital & clinic, general market, restaurant, institutions, and kitchen market are handled together. Typical waste management separation between Municipal Solid Waste (MSW), Construction & Industrial and Medical waste are not practiced at any of the three Upazilas. Having stated this, the wastes are comingled.

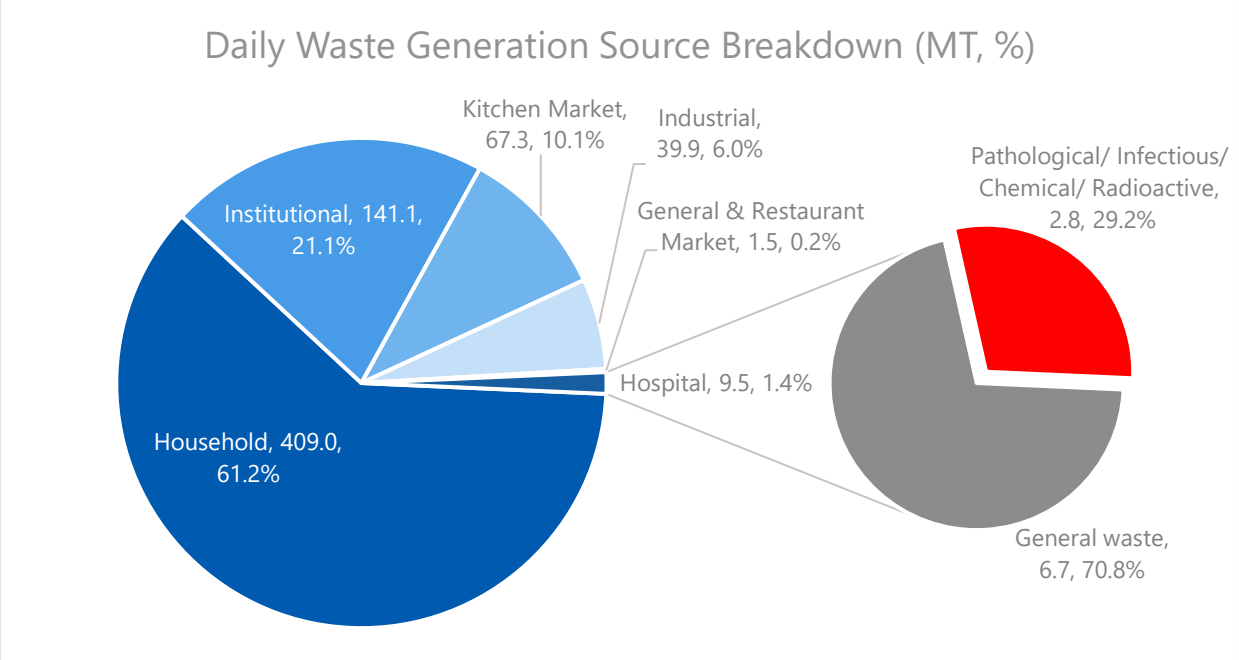


Figure 3-1 Daily Waste Sources Breakdown

Figure 3-1 shows that waste is largely from Household and Institutional sources which makes up of more than 80% of the total waste. However, it is important to note that Hospital waste accounts to 9.5MT/day, from which about 30% are from Pathological and Radioactive waste.

3.1.2 Waste Quantities

Table 3-2 shows the daily waste record attained by O.CREEDs during the Focus Group Discussions held on 30 September and 3 - 4 October, 2023 and the projected collection quantities if additional collection vehicles are made available.

Table 3-2 Daily Waste Record

Upazilas	Waste Tonnage (MT)			
	Generation	Collected @ TDS	Collected @ FDS	Projected Quantities
Dohar	64.06	16.56	15.00	58.00
Karaniganj	353.53	92.00	90.00	248.00
Nawabganj	210.70	1.20	No data	42.00
Total	628.29	109.76	105.00	348.00

In general, the current waste collection system is only able to collect about 18% of the total waste generated and we opine that unlike other projects, waste collection quantity is the limiting factor for this Project if no improvement in collection efficiency is attained. If improvements in collection were to occur, the total projected quantity of collection increases to 348MT which is 55% of the total waste generated. We note that O.CREEDs has provided the recommended number of additional collection vehicles to reach this projected amount which we have not reviewed.

For the purpose of our study, the projected quantity will be considered as the design basis.

3.1.3 Waste Composition

The overall solid waste composition is as follows.

Table 3-3 Waste composition

Material	Percentage (%)	Range (%)
Organic Matters including food & fruit wastes	81.5	69.7 - 97.1
Paper & Paper Products	3.2	0 - 7.3
Metals	0.5	0 - 3.8
Glass	1.2	0.0 - 4.4
Wood	0.1	0 - 1.6
Garden Waste (Tree trimming & straw)	0.1	0.0 - 0.9
Textile (Clothes)	2.8	0.0 - 10.0
Stone, Ceramic, Sand & Debris	0.1	0.0 - 0.9
Plastic & Polythene	9.3	0.0 - 21.2
Aluminum	0.0	0.0 - 0.0
Rubber	0.1	0.0 - 0.7
Hazardous (Household)	0.3	0.0 - 5.6
Medical Waste	0.8	0.0 - 3.7
Total	**100.0**	

3.1.4 Proximate Analysis

The proximate analysis of the waste design point shown below. The results are on "As Received" basis.

Table 3-4 Proximate analysis of the waste

Sr. No.	Parameters	Design Point (%)	Range (%)
1	Moisture	73.89	59.70 - 78.85
2	Fixed Carbon	2.52	0.44 - 4.63
3	Volatile matter	18.24	14.94 - 25.03
4	Ash	5.34	3.53 - 20.15
	Total	**100.00**	**-**

3.1.5 Ultimate Analysis

The ultimate analysis of the waste is shown below. The results are on "As Dry basis".

Table 3-5 Ultimate analysis of the waste

Sr. No.	Parameters	Design Point (%)	Range (%)
1	Carbon, C	45.22	27.90 - 48.38
2	Hydrogen, H	6.54	3.58 - 6.99
3	Nitrogen, N	3.29	1.13 - 3.29
4	Sulphur, S	-	-
5	Oxygen, O	23.51	12.59 - 30.86
6	Chlorine, Cl	0.79	0.32 - 0.79
7	Ash	20.47	16.69 - 52.40
	Total	**100.00**	-

3.1.6 Calorific Value

The Calorific Value of the waste is shown below.

Table 3-6 Calorific values of the waste

Sr. No.	Parameters	Design Point (MJ/kg)	Range (MJ/kg)
1	LLV (NCV) Lab As Received	3.43	2.45 - 5.62
2	LLV (NCV) Dulong's As Received	3.17	2.06 - 4.25

The calorific value presented above are from the lab test report and the Dulong's Formula calculated CV. In general, we observed a wide positive variation between the NCV reported by O.CREEDs and the calculated CV using Dulong's formula. As such, we have opted the more conservative NCV figures using Dulong's formula to be used as the design point.

A comparison between NCV figures from the lab test report and other countries is shown in Figure 3-2. Compared with other countries with established WTE plants such as Australia, Malaysia, and the United Kingdom, the calorific value of MSW in Bangladesh is relatively low, which is attributed to the high moisture content and high organic fraction. The NCV range will primarily drive technology selection, which is discussed in Section 7.

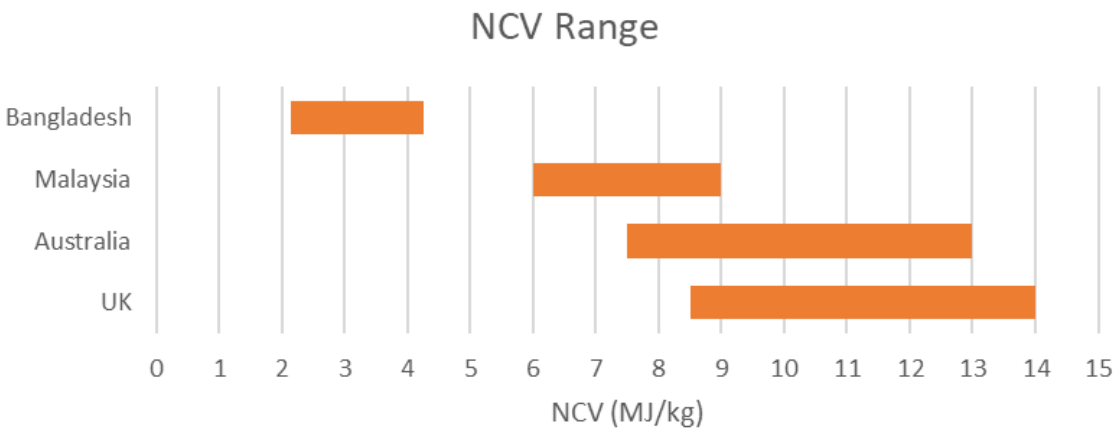


Figure 3-2 Comparison between NCV range of different countries (Fichtner Database)

3.1.7 Conclusion

The 18 samples taken for the waste study provides a useful approximation of seasonal variation in waste composition especially its moisture it and heating value.

Overall daily waste generation was identified to be about 630MT/day, however the current total daily collection is merely 105MT/day, with a projected future collection of 384MT/day. The waste sources are comingled comprising of MSW, Industrial and Medical waste of which 2.8MT/day (i.e. 0.41% of the total daily waste generation or 0.44MT/day) are categories as pathological, infectious, chemical and radioactive waste.

The waste predominantly consists of organic matter (~81.5% by composition) and a design point was chosen out of the 18 samples available with a total moisture of 73.89% and NCV of 3.17 MJ/kg.

4 Review of Projects in Bangladesh

Based on the publicly available information, we have provided a summary of waste to energy related projects in Bangladesh in the table below.

Table 4-1 Waste to Energy Projects in Bangladesh

No	Project name	Year	Location	Feedstock	Technology	Current Condition	Issues/Challenges
1	Paragon Agro	2012	▪ Chamiadi, Valuka, Mymensingh ▪ Member Bari, Gazipur	Chicken manure	CHP Biogas Digester (captive use)	Limited information	Limited information
2	LGED	Limited information	Kathaldia, Tongi	Slaughterhouse waste	Biogas Digester	Limited information	Limited information
3	Practical Action Bangladesh Gaibandha (2012)	2012	Gaibandha	MSW	Biogas Digester (Wet AD – captive use)	In operation for only 6 years (2012 to 2018)	▪ Waste separation (thin polyethylene) ▪ Poor management ▪ Funding
4	Practical Action Plastic Pyrolysis Plant (2021)	2021	Faridpur	Plastics	Pyrolysis *converts single-use thin plastic waste into high-grade oil and black carbon.*	Limited information	Limited information
5	Practical Action Composting Plant	2021	Faridpur	Limited information	Composting plant	Limited information	Limited information
6	Faecal Sludge Treatment Plant (FSTP)	2021	Faridpur	Fecal sludge	Limited information	Limited information	Limited information
7	WaterAid Bangladesh	Limited information	▪ Shakipur, Tangail ▪ Saidpur,Nilphamari	Faecal sludge and MSW	Co-composting facilities	Operational	Still receiving financial aid from WaterAid.
8	Zinjira Union, Amin Bazar	Limited information	Dhaka district	MSW	Incinerator	Not operational	Low waste volume
9	LGED	2016	Jessore	MSW	▪ Biogas digestor ▪ Composting	Poor production rate	Waste separation (thin polyethylene)
10	DOE Composting Plants	Limited information	▪ Rangpur ▪ Mymensingh	MSW	Composting	Abandoned	Not profitable Waste separation (thin polyethylene)
11	Municipal Waste Management Facility Project (Gazipur City	Limited information	Gazipur	MSW	Limited information	Development phase, current progress uncertain	Limited information

No	Project name	Year	Location	Feedstock	Technology	Current Condition	Issues/Challenges
	Corporation and BRAC)						
12	Incineration Plant (JICA)	Limited information	Dhaka	Medical waste	Incinerator	Development phase, current progress uncertain	Limited information
13	North Dhaka 42.5MW WtE Power Plant (CMEC)	Limited information	North Dhaka	MSW	Incinerator	Development phase, current progress uncertain	Limited information
14	Gazipur 42.5 MW WtE Power Plant (CEIC)	Limited information	Gazipur	MSW	Incinerator	Development phase, current progress uncertain	Limited information
15	6MW Pyrolysis Plant in Narayanganj City Corporation (U&D)	Limited information	Narayanganj	Limited information	Pyrolysis	Development phase, current progress uncertain	Limited information

Main challenges faced by waste to energy projects in Bangladesh are poor quality of MSW (due to comingled waste and high moisture thus low calorific value) of waste generated by the upazilas. While comingled waste is generally expected for MSW, it is not typical to have industrial and hazardous waste (from hospitals) comingle with MSW waste from households. This is mainly due to the absence of a proper waste management systems and any forms of waste separation at source. Waste-to-energy plants are typically designed to process a fixed and somewhat narrow range of waste composition and without an effective separation and pre-treatment process, the waste-to-energy plant might not be able to handle the varied range of waste that is sent to the plants. We opine that this is the main reason for the failures of most of the plants what we have studied.

We also note that there are a few projects that are heavily dependent on external funding for its operation and maintenance. The projects have either ceased operation due to insufficient funding or is currently in operation using funding from external entities. To ensure long-term operability, the proposed project has to be commercially viable that it can generate sufficient cash flow to cover the operational costs of the plant and keep it running continuously.

5 Waste Treatment Technologies

5.1 Overview of Waste Treatment Technologies

Waste treatment technologies can be categorized as mechanical treatment, biological treatment, and thermal treatment. This section provides an overview of these technologies and its applicability for treating MSW.

5.1.1 Mechanical treatment

Depending on the feedstock and plant input requirements, a mechanical treatment system may be required to separate waste streams or prepare the feedstock to an acceptable quality. A typical mechanical treatment system is a Materials Recovery Facility (MRF).

5.1.1.1 Materials Recovery Facility

A Materials Recovery Facility (MRF) is a mechanical pre-treatment process, consisting of a sequential combination of equipment on process lines to separate the inert, recyclable, combustible, or organic matter based materials.

A combination of both mechanical and/or manual sorting processes are considered for the separation of elements from the waste stream. Waste separation include sorting the mixed waste into different fractions by mechanical processes such as trommels and screens, magnetic separation, eddy current separation, air classification, among others to separate the waste for different end uses. These methods of sorting various feedstock and material streams are typically based on different physical properties such as size, weight, density, or magnetic properties. An automated sorting method involves electronic sensors devices could also be considered based on the process requirements. Eddy current separation removes non-ferrous metals based on conductivity and is a well-proven and established technology for resource recovery. Manual sorting can potentially produce higher quality material recovery and will result in considerable job creation from labour requirements.

Noise and emissions are controlled by fully enclosing the process with a negative air pressure system inside the building.

The MRF can operate with a combination of Refuse-Derived Fuel (RDF) or Solid Recovery Fuel (SRF) or pre-treated waste produced from municipal solid wastes, commercial wastes, construction & demolition wastes, and any other material not classified as hazardous & liquid waste.

5.1.2 Biological Treatment

Biological treatment may include a range of options including:

- Aerobic bio-drying or bio-stabilization which is a partial composting of waste.
- Aerobic in-vessel composting which is used to bio-stabilize the waste or produce a segregated organic rich fraction.
- Anaerobic digestion which is used to produce biogas and a segregated organic rich fraction.

However, MBT process configurations vary significantly and are dependent on local market conditions and off-takers for the products. Recyclables derived from MBT are typically of lower quality and therefore have a lower potential for high value markets.

5.1.2.1 Aerobic bio-drying

Biodrying is a viable method for moisture extraction and calorific value improvement of waste streams with high concentrations of organic matter and high moisture levels. This process leverages on the utilization of natural heat generated from the decomposition of organic matter to evaporate moisture, resulting in a fuel with a higher calorific value without the need for an external heat source. It is an auto-thermal process whereby the drying rate is

augmented by biological heat released during on-site decomposing of the organic matter. Biodrying leads to moisture reduction while improving the calorific value of the processed waste. Biodrying exploits the biological reactivity of the waste to produce a waste stream with an improved NCV due to the reduction in moisture. One of the many processes employed in Biodrying involves the use of semi-permeable membranes. These membranes permit the evaporation of water while preventing re-condensed moisture from re-entering. A slight air pressure from a nozzle positioned on the floor pushes air through the membrane once it becomes moisture saturated. During this process, nearly half of the total waste weight evaporates as water loss, while the reduced tonnage remains as a higher CV fuel. Non-combustible materials such as stones, glass, are disposed prior to the Biodrying process with mechanical treatment. As the water evaporates rather than drains off, the generated waste is captured beneath the membrane and decomposed.

The produced material is considered as a Refuse-derived fuel (RDF), which can be utilized for energy production. The major advantages of Biodrying are improvement of the CV of the fuel, waste mass reduction, reduction of CH4, CO2, SO2, NOx emission, and dust emission from waste landfills into the atmosphere. A typical scheme of a Biodrying system is shown in Figure 5-1.

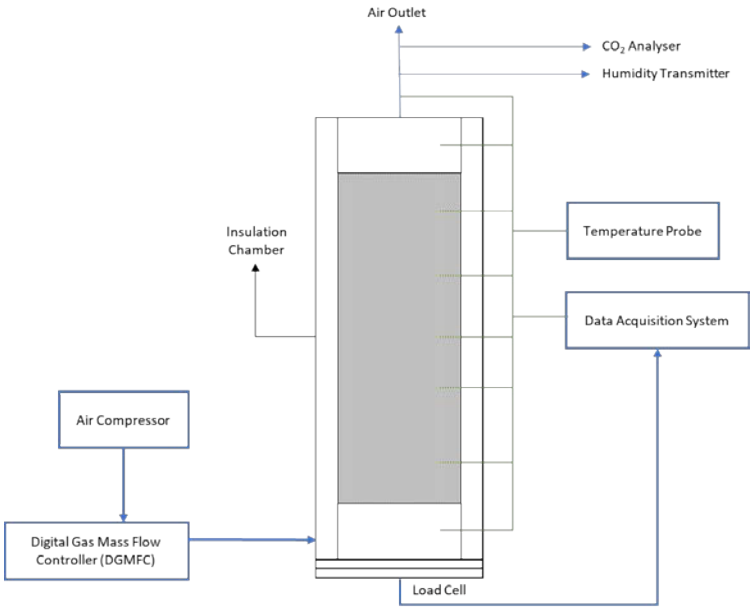


Figure 5-1 Typical Biodrying process

References of plants utilizing Biodrying are specified in Table 5-1.

Table 5-1 Biodrying references

Location	Operator	Facility Details
Frog Island & Jenkins Lane, East London, United Kingdom	Shanks	2 x 180,000 tpa
Southwark MBT Facility, London, United Kingdom	Veolia	87,500 tpa
Gipuzkoa Environmental Complex Phase 1, San Sebastian, Spain	GHK	200,000 tpa

5.1.2.1.1 Anaerobic Digestion

Anaerobic digestion (AD) of organic waste fractions is categorized into wet or dry processes based on the feed's solids content. For wet AD, the dry matter content of the residue is typically below 15%, and for dry AD, the dry matter content of the residue is typically between 20 and 40%.

For comingled MSW, the dry digestion process has the following advantages compared to wet technology:

- Better performance than wet technology regarding segregation of decanters and floats.
- Increased dryness of the digested solid after the dehydration process.
- Reduction of the equipment for preparation of the material before digestion as well as for equipment transferring suspension and water.
- Lower volume of the digester due to less water for dissolution in the inlet stream.
- Lower heating needs of the digester as it is smaller. This advantage is relative since in the anaerobic digestion processes there is a surplus of thermal energy.
- Dry systems allow to introduce a higher number of contaminants or improper elements (glass, ceramics, plastics) in the digester without generating problems in the feeding and extraction process.

Digesters operate under mesophilic (38–40°C) or thermophilic (50–55°C) conditions. The Mesophilic AD has been more widely applied in practice because of its lower process energy demand for reactor heating and its better stabilization. Thermophilic AD is preferred for its high biochemical reaction and low retention time in addition to stabilization. Thermophilic is also preferred for its conformity to discharge limits that are imposed by environmental regulatory authorities and the following advantages:

- Increased gas output due to the faster reaction; higher methane gas content and reduces hydrogen sulphide content in the biogas
- Shorter residence time
- Smaller reactor volume
- More effective pathogen destruction
- Enhanced sludge's dewatering
- Reduced foam formation inside the reactor

5.1.3 Thermal treatment

Thermal treatment of waste refers to a combustion process to reduce the waste volume leaving the remainder mainly inert, while recovering energy to generate electricity and/or heat. The most common types of industrial scale mass burn incinerators are either grate-based combustion, fluidized bed or rotary kiln technology.

5.1.3.1 Hearth

A hearth incinerator, also known as a multiple hearth furnace or multiple hearth incinerator, is designed to combust solid, liquid, or gaseous waste to reduce its volume and convert it into ash, flue gas, and heat. The hearth incinerator is particularly suited for the disposal of sewage sludge, industrial sludges, and other organic wastes.

In a multiple hearth incinerator, contaminants that are either solid or in sludge form are gradually introduced from the top of a series of vertically arranged hearths. For certain applications, hazardous gases and liquids can be introduced via nozzles on the sides. These incinerators, which were originally designed for the combustion of biosolids from municipal wastewater treatment, utilize gravity and mechanical scrapers at the top of each hearth to move the waste downwards through openings from the hotter upper hearths to the cooler lower ones. The rising hot gases are captured, analyzed for their chemical constituents, and treated as necessary before being released into the environment. Meanwhile, the descending ash is also collected, its chemical composition is checked, and it is treated appropriately before it is ultimately disposed.

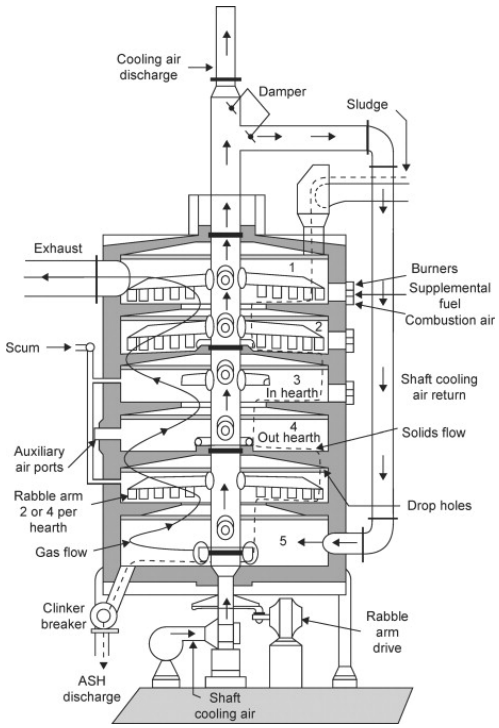


Figure 5-2 Multiple Hearth Incinerator

5.1.3.2 Grate combustion

Grate-based combustion is the most commercially proven in treating large volumes of MSW over many decades, with the technology developed to a mature level where technical risks are low, and costs are well understood. Incineration temperatures above 850°C is applied in the combustion process to eliminate traces of dioxins and furans, with mechanical grates utilized to convey the MSW through the drying, combustion, and burnout sections of the grate. The grates also act as stokers to promote loosening of the wastes.

Grate-based technologies have high fuel flexibility and can accommodate large variations in waste composition and calorific value. Reciprocating grates present the most flexible solution in terms of waste composition and waste size. Vibrating grates are also suitable for various waste types with limitations on waste size and travelling (chain) grates are often used for small scale industrial boilers with limits on waste size due to burnout. However, waste with excessive moisture content or waste in the form of powders, sludge, or liquid are not suitable due to burnout issues and the inability of the grate to support the waste.

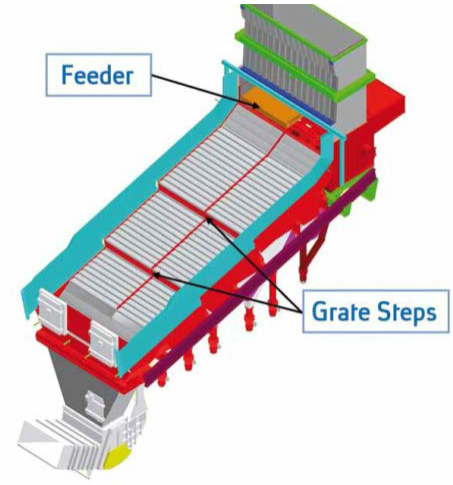


Figure 5-3 Mechanical grate type incinerator

5.1.3.3 Rotary kiln

Rotary kilns are widely used for the incineration of hazardous wastes such as medical waste under high temperatures. To increase the destruction of toxic compounds, a post combustion chamber is usually used. Additional firing using liquid waste or support fuel may be carried out to maintain the temperatures required to ensure the complete destruction of compounds in the exhaust gas.

Typical operating temperatures range between 850°C and 1,300°C which is maintained by burning higher calorific waste. Higher temperature kilns may be fitted with water-based kiln cooling systems. Firing at higher temperatures may even result in molten bottom ash as slag.

The rotary kiln consists of a cylindrical vessel slightly inclined on its horizontal axis. The vessel is located on rollers, allowing the kiln to rotate around its axis. The waste is conveyed through the kiln by gravity as it rotates. Direct injection is used for liquids, or gaseous wastes. The residence time of the waste is determined by the tilt angle of the vessel and the rotation speed – a residence time of between 30 to 90 minutes is typically sufficient to achieve good waste burnout.

A limitation of Rotary Kiln type incinerators is the maximum capacity limit of each incinerator which is only up to about 500 tpd. Therefore, it is not suitable for high volume incineration.

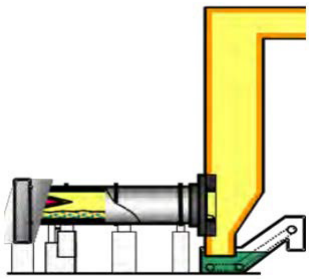


Figure 5-4 Rotary kiln incinerator

5.1.3.4 Fluidized bed

Fluidized bed incinerators are widely used for the incineration of finely divided wastes such as Refuse Derived Fuel (RDF) and sewage sludge. The technology has also been used for decades for the combustion of homogeneous fuels such as coal, raw lignite, and biomass.

The fluidized bed incinerator is typically in the form of a vertical cylinder which in the lower section consist of a bed of inert material (i.e., sand or ash) on a grate or distribution plate. The inert material is fluidized with preheated combustion air. The waste is continuously fed into the fluidized sand/ash bed for incineration from the top or side via any suitable mechanical means such as pump, star feeder, screw-tube conveyor, or an apron conveyor.

In the fluidizing bed, drying, volatilization, ignition and combustion will take place. The temperature at the fluidizing bed is around 650°C while the temperature at the free space above the bed (the freeboard as seen in Figure 5-5) is generally between 850°C and 950°C. The freeboard is designed to allow a sufficient residence time of the gasses in the combustion zone.

Because of the good mixing in the reactor bed, this technology generally has a uniform temperature and oxygen concentration, which results in a stable operation. However, for heterogeneous wastes such as MSW, fluidized bed combustion requires the selection and pre-treatment of the waste so that it conforms with the fuel size requirement.

The pre-treatment for this technology usually consists of sorting, crushing and shredding. Removal of ferrous and non-ferrous materials may also be required. The particle size of the waste must be small, often with a maximum diameter of 100mm. The relatively high cost of pre-treatment processes required for some wastes has restricted the commercial use of these systems burning MSW.

Fluidizing bed incinerator technology can be further categorized into three different configurations as follows:

- Bubbling fluidized bed
- Rotating fluidized bed
- Circulating fluidized bed

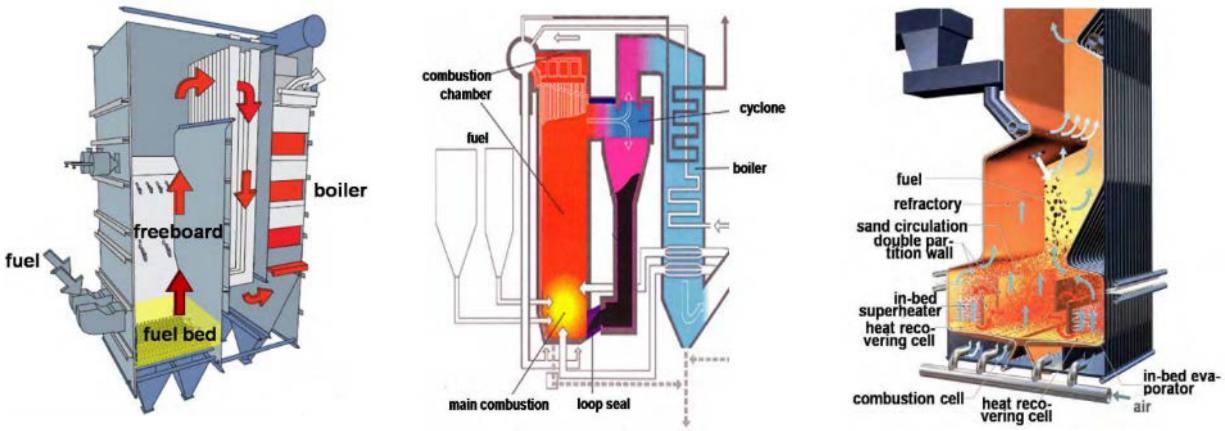


Figure 5-5 Bubbling (left), Circulating (middle), and Rotating (right) fluidized bed

5.1.4 Gasification and pyrolysis

Gasification is a thermochemical process that transforms carbon-based materials at temperatures exceeding 600°C, utilizing a reduced amount of oxygen (25% to 40% O2) than what is necessary for complete stoichiometric combustion. This process of partial oxidation generates syngas, a versatile product that can be used for heating, power generation, industrial applications, and the production of liquid fuels.

Similarly, pyrolysis also involves heating carbon-based materials to temperatures above 600°C. However, it differs from gasification in that it is conducted either without air or with less than 5% of the air needed for complete stoichiometric combustion. The outcome of this process is pyrolysis oil, which can be further refined to create transportation fuels.

Both gasification and pyrolysis can utilize a range of feedstocks, including biomass and MSW. However, these processes necessitate a uniform homogenous feedstock, which is easily attainable with biomass but more difficult with MSW due to its diverse composition. Therefore, pre-treatment of the feedstock is crucial to meet the technical requirements of the process.

The process is achieved through a gasifier or pyrolyser, where the feedstock directly interacts with oxygen and steam. This interaction results in the production of syngas, which comprises carbon monoxide (CO), hydrogen (H2), carbon dioxide (CO2), and water (H2O), or pyrolysis oil.

Plant configurations for gasification and pyrolysis facilities typically consist of a fuel preparation plant, fuel storage and transport systems, a fluidised bed gasifier or pyrolyser, syngas clean-up systems, a reformer to improve the syngas, upgrading systems to convert the syngas into the desired product and product clean-up systems. A typical flow diagram of a generic gasification system is shown in Figure 5-6.

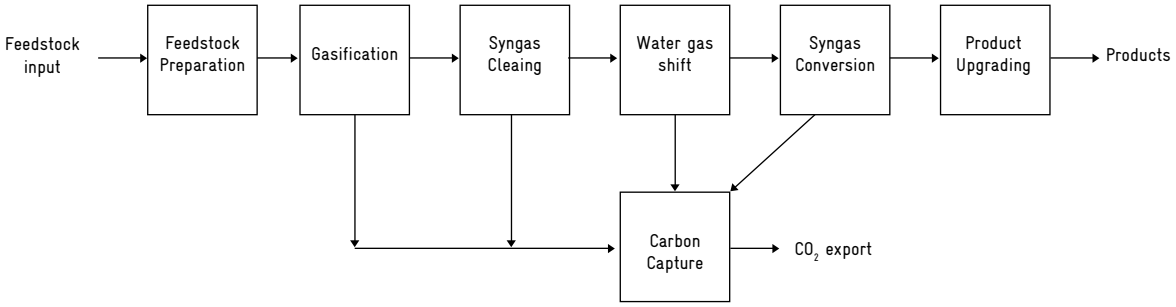


Figure 5-6 Flow diagram of a typical gasification system (Source: BEIS)

The terms Advanced Gasification Technology (AGT) and Advanced Conversion Technology (ACT) are frequently used in relation to gasification and pyrolysis. AGT refers to thermal conversion technologies (gasification or pyrolysis) for conversion of biomass or waste into aviation fuel, diesel, hydrogen, methane, and other hydrocarbons. On the other hand, ACT is used to describe gasification or pyrolysis technologies employed to produce electricity and heat.

According to a 2021 report by the United Kingdom Department for Business, Energy, and Industrial Strategy (BEIS), no gasification technologies associated with AGT were commercially operational at the time. The report highlighted that while these systems have been tested for other applications, they need to be integrated on a commercial scale to validate the technologies.

From a technical standpoint, ACTs are less complex than AGTs as they generate electricity without the need for syngas cleaning or upgrading. ACTs are considerably more technologically advanced and commercially prepared. However, ACTs powered by waste and biomass in the United Kingdom have encountered commissioning and performance challenges, such as extended construction periods. The best-performing ACT facilities reported an availability of approximately 62% based on waste processing capacity, compared to the typical availability of a conventional Waste-to-Energy (WTE) plant of around 90% (BEIS, 2021).

Several pyrolysis facilities are commercially operational, but these are generally small-scale modular plants with throughput capacities ranging from 7,000 to 10,000 tons per annum. These systems are well-suited for the conversion of specialized waste streams or the production of specific fuels, rather than large-scale production (BEIS, 2021).

5.2 Waste Treatment Technologies Comparison

A comparison of commonly implemented MSW treatment technologies is provided in Table 5-2.

Table 5-2 Comparison of commonly implemented MSW treatment technologies

	Incineration	Gasification	Pyrolysis	Anaerobic digestion
Process Temperatures	above 850°C with sufficient oxygen supply	between 800°C and 1400°C with insufficient oxygen to completely oxidize the waste	temperatures range from 400°C to 800°C in the absence of oxygen	digesters have a process temperature of approx. 55°C
Applicable to comingled waste with variable composition	Wider range of feedstock can be accommodated	Homogeneous feedstock	Homogeneous feedstock	Homogenous feedstock of high organic fraction
Commercially Proven Technology	Has a proven track record dating back many years	Commercially proven to a limited degree, more complex	Commercially proven to a limited degree, more complex than combustion and less	Commercially proven for specific applications with

		than combustion and less reliable, extremely costly	reliable, extremely costly	specific feedstock or offtakers
Availability of Manufacturers	Yes	Limited	Limited	Yes
Product of the process	Bottom ash and fly ash	Bottom ash and syngas	Char, pyrolysis oil and syngas	Compost-like outputs (CLO) or digestate, refuse derived fuel (RDF) and Biogas

The treatment of MSW in this study shall be considered with only commercially proven technologies. Due to its complexity, limited commercial proven technology, and limited availability of manufacturers, gasification and pyrolysis are not further investigated in this study.

The MSW characteristics from the sampling results as discussed in Section 4 is characterized as non-homogenous or comingled with high organic fraction, very low NCV a.r. (2.15 MJ/kg – 4.25 MJ/kg), and very high moisture content (59.70%a.r. – 87.54%a.r.). Due to these characteristics, a direct waste treatment technological application is unsuitable due to limitations in each technology to treat the raw feedstock. For example, the low NCV and high moisture is unsuitable for direct incineration due to combustibility issues. Additionally, excessive inert and plastic in the feedstock has an adverse effect the stability of the AD process.

Based on this, a technical and commercial assessment with five variable combinations of mechanical, biological, and thermal treatments for treating the MSW was carried out in this study to determine the most feasible techno-economic configuration for the MSW treatment.

Option 1 considers mechanical treatment and biological treatment, whereby an MRF functions to separate the organic fraction from the waste stream for further processing in a dry anaerobic digestion system with CHP for power export. Inert, and all non-organic materials are also importantly separated from the waste stream to prevent unsuitable waste streams from entering the anaerobic digester, although some carry-over will be unavoidable which is not expected to impact the stability of the process in the dry anaerobic digester. However, it is expected to result in poor quality digestate which is expected to be unsuitable for further uses and require disposal.

Option 2 considers mechanical treatment, biological treatment and thermal treatment. This is achieved with an MRF to separate the organic fraction from the MSW feedstock for processing in a dry anaerobic digestion system with CHP for power export. Similar to option 1, inert material is separated from the waste stream. Traces of unsuitable material will be present in the dry anaerobic digester resulting in poor quality digestate. Combustible waste streams such as plastics, are separated from the feedstock to result in an RDF with reduced moisture content which enables suitable combustion in a grate fired incineration plant. The incineration plant incorporates a boiler, turbine, and generator for power generation and export.

Option 3 considers the same treatment technologies as Option 2, however, instead of disposal of the digestate from the anaerobic digestion system which does not result in a significant waste volume reduction, the digestate is provided as input to the incineration plant resulting in a higher potential for energy generation and waste volume reduction. This results in a larger capacity incineration plant.

Option 4 considers mechanical treatment, biological treatment, and thermal treatment. Waste separation of organic and combustible fractions is achieved with an MRF, with the organic and combustibles waste stream fed into a Biodrying system to reduce moisture and increase the calorific value of the feedstock, resulting in a reduced feedstock tonnage consisting of high-quality feedstock for incineration. The incineration plant reduces the waste volume and results in power generation and export.

Option 5 features a direct thermal treatment achieved with an incineration plant. Although the MSW, with high moisture content and low NCV is not anticipated to achieve a level of self-sustained combustion, the option is investigated from a hypothetical perspective and only for comparison purposes. An assessment on feedstock combustibility is carried out in the following section.

6 Technical Assessment

6.1 Configuration Options

The different configuration options combining various waste treatment technologies are technically assessed in this section.

6.1.1 Option 1: MRF with AD Plant

6.1.1.1 Overview and process description

Option 1 consists of an MRF with an anaerobic digestion plant. MSW is transferred to the MRF for recovery of organic matter, separation of inert material, products with a valued market, and non-organic waste fractions.

A Schematic Diagram and Material Balance are shown below:

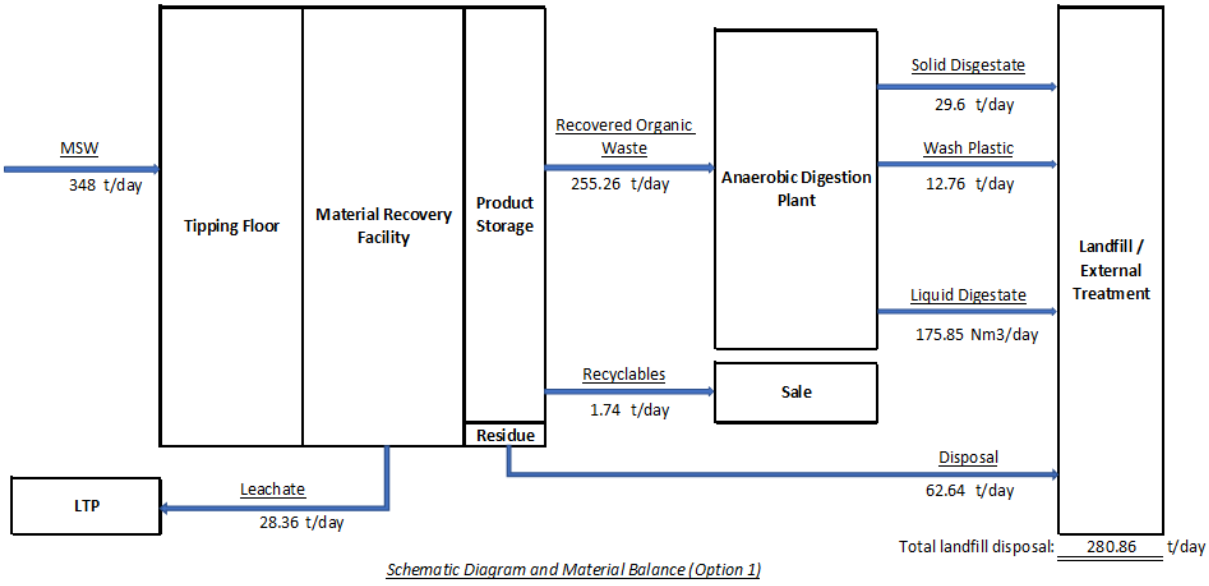


Figure 6-1 Option 1 schematic

6.1.1.2 Technical Summary

The following table shows the overall parameters for the power generation of the AD plant.

Table 6-1 Option 1 technical summary

		Option 1	
		MRF	AD Plant
Throughput	t/day	348.00	255.26
	t/a	118,900.00	87,213.83
Biogas produced	Nm3/a	-	10,039,637
Biogas energy value	kwh/Nm3	-	5.70
Energy yield	kwh/a	-	57,225,929
CHP Electrical Efficiency	%	-	39.00
Gross Electricity Output	MWe	0	2.72
Total Gross Electricity Output	MWe	2.72	
Gross Electricity Output	MWh/a	22,318	

6.1.2 Option 2: MRF with AD Plant, and RDF Plant

6.1.2.1 Overview and process description

Option 2 consists of an MRF with recycling, anaerobic digestion, and incineration plant for the RDF. The comingled MSW is transferred to the MRF for recovery of organic material for AD, combustible products for thermal treatment in the incineration plant, and products with a valued market.

A Schematic Diagram and Material Balance are shown below:

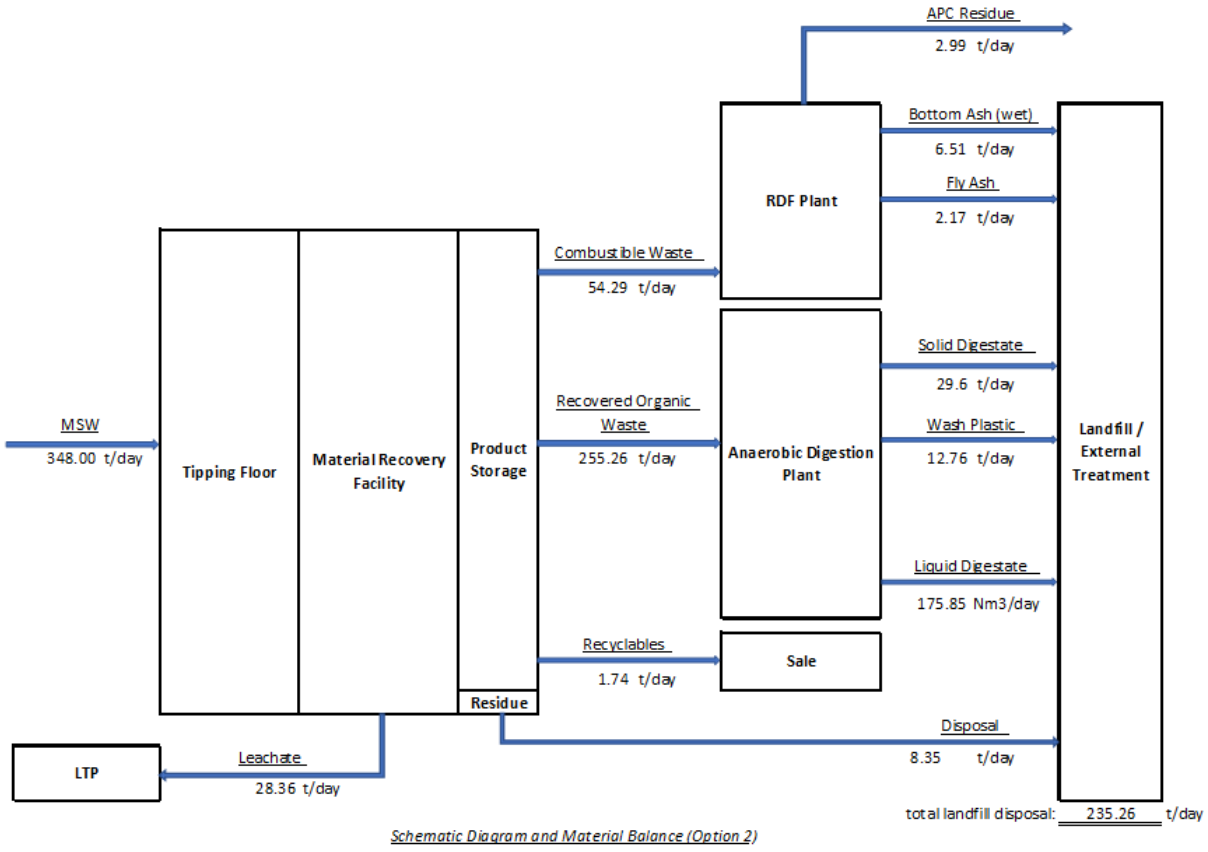


Figure 6-2 Option 2 schematic

6.1.2.2 Technical Summary

The following table shows the overall parameters for the power generation of the AD and Incineration plant.

Table 6-2 Option 2 technical summary

		Option 2		
		MRF	AD Plant	Incineration Plant
Throughput	t/day	348.00	255.26	54.29
Biogas produced	Nm3/a	na	87,213.83	na
Waste NCV	kcal/kg	-	-	1851.16
	kJ/kg	-	-	7745.24
Thermal input	MWt	-	-	4.87
Gross Plant Efficiency	%	-	39.00	20.0
Gross Electricity Output	MWe	0	2.72	0.97
Total Gross Electricity Output	MWe		3.70	
Gross Electricity Output	MWh/a		30,299	

6.1.3 Option 3: MRF with AD Plant, and Incineration Plant

6.1.3.1 Overview and process description

Option 3, which is similar with the Option 2 consists of an MRF with recycling, anaerobic digestion, and incineration plant. The comingled MSW will be transferred to the MRF for recovery of organic matter for AD, solid digestate and wash plastics (from the AD plant) and combustible products for thermal treatment (Incineration Plant), and products with a valued market.

A Schematic Diagram and Material Balance are shown below:

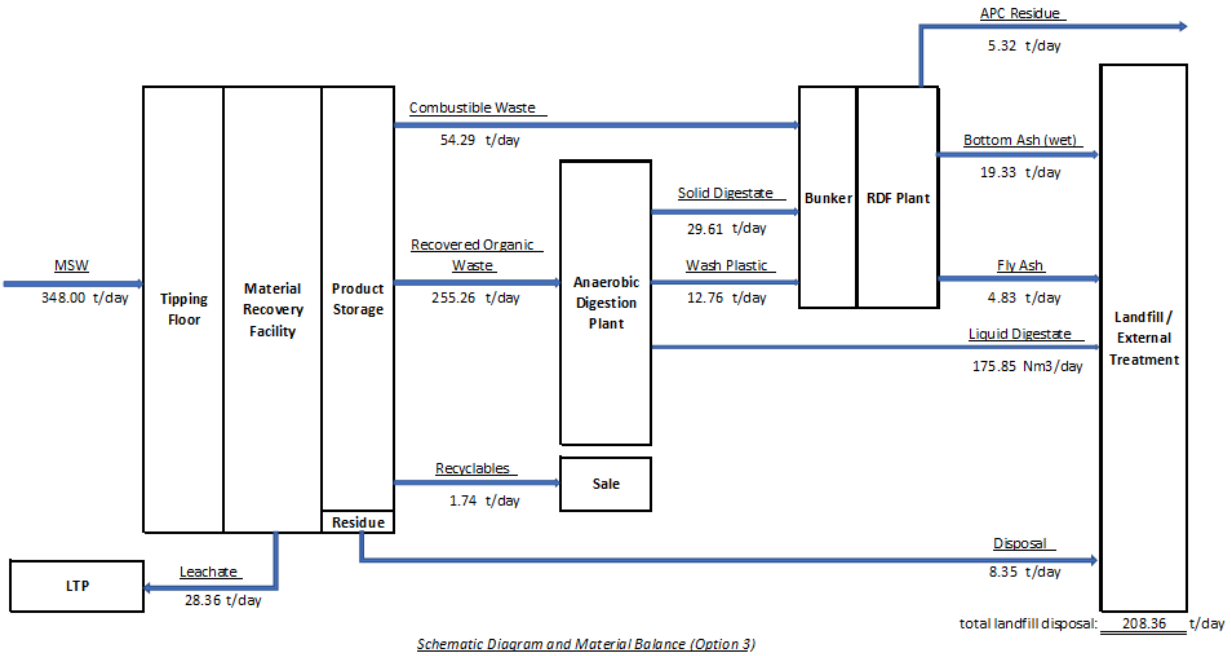


Figure 6-3 Option 3 schematic

6.1.3.2 Technical Summary

The following table shows the overall parameters for the power generation of the AD and Incineration plant.

Table 6-3 Option 3 technical summary

		Option 3		
		MRF	AD Plant	Incineration Plant
Throughput	t/day	348.00	255.26	96.66
Biogas produced	Nm3/a	N/A	87,213.83	N/A
Waste NCV	kcal/kg	-	-	1433.48
	kJ/kg	-	-	5997.69
Thermal input	MWt	-	-	6.71
Gross Plant Efficiency	%	-	39.0	22.0
Gross Electricity Output	MWe	0	2.72	1.48
Total Gross Electricity Output	MWe		4.20	
Gross Electricity Output	MWh/a		34,423	

6.1.4 Option 4: MRF with Biodrying System and Incineration plant

6.1.4.1 Overview and process description

Option 4 consists of an MRF with recycling, a biodrying system, and incineration plant. The comingled MSW is transferred to the MRF for recovery of organic waste products for the biodrying process, combustible products for thermal treatment via the incineration plant, and products with a valued market. The recovered organic waste will be transferred to the biodrying reactor to produce RDF for thermal treatment. The expected input specifications and RDF produced via the biodrying system are as follows.

Biodrying system inputs:

- Moisture content 73.89%
- Operating days 7 days/week

RDF specifications produced from biodrying system:

- Net Calorific Value ≥2500-3500 kcal/kg
- Maximum size 30mm
- Form Fluff or pellets
- Sulphur (%) <1
- Moisture content(%) <30
- Chlorine (%) <0.6 (dry)
- Hg (ppm) <0.5

A Schematic Diagram and Material Balance are shown below:

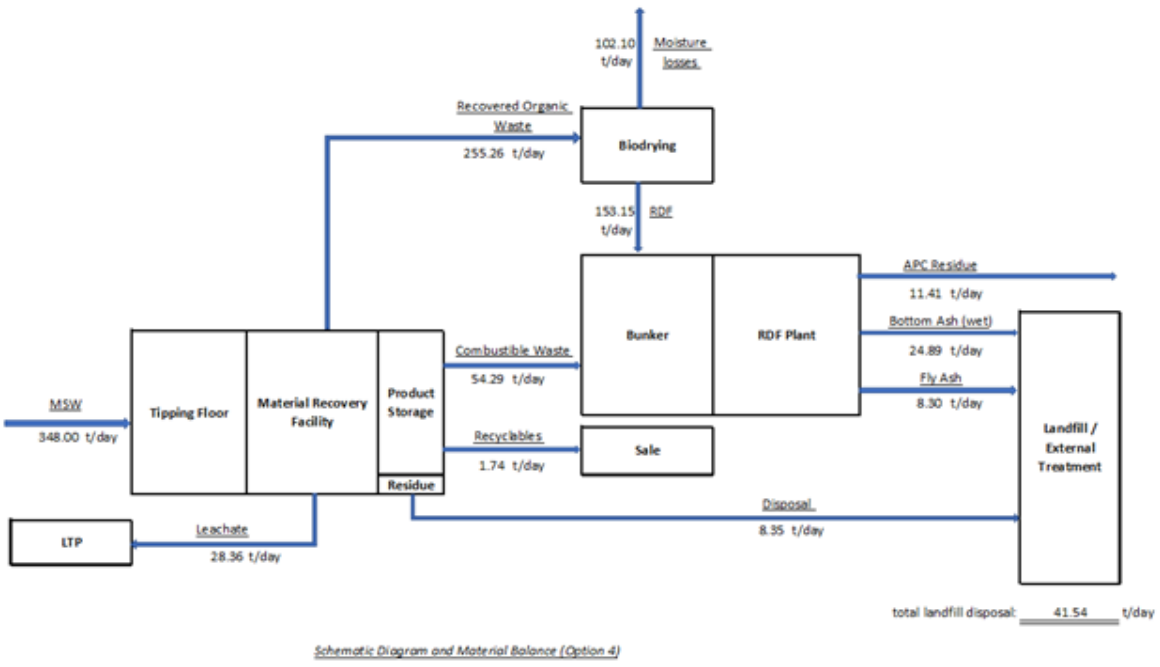


Figure 6-4 Option 4 schematic

6.1.4.2 Technical Summary

The following table shows the overall parameters for the power generation of the Incineration plant.

Table 6-4 Option 4 technical summary

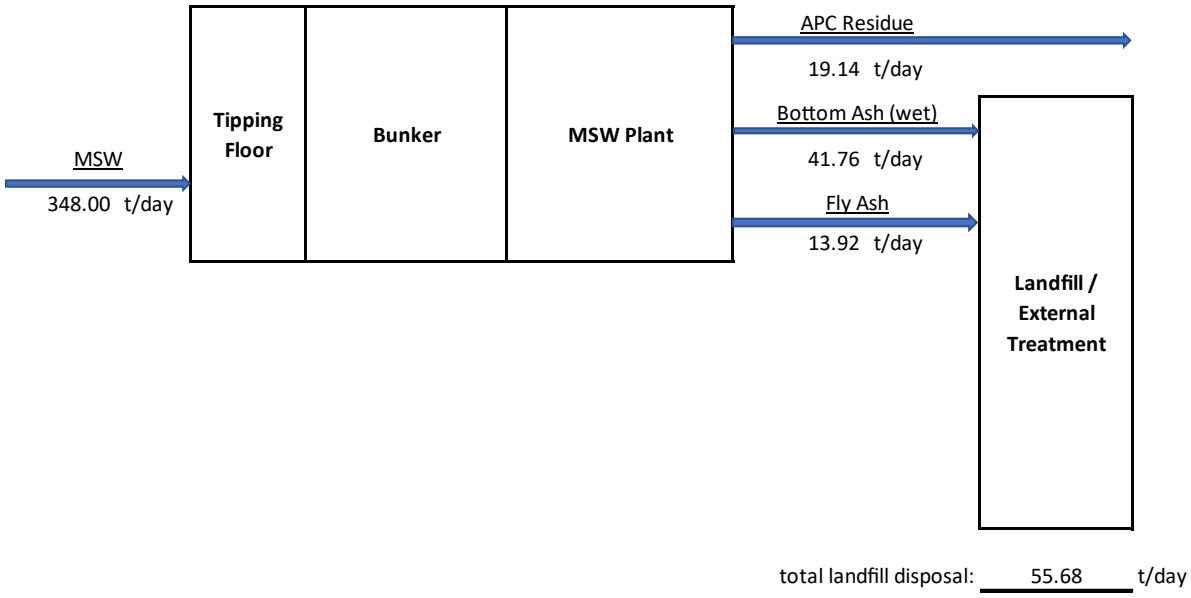
		Option 4		
		MRF	Biodrying	Incineration Plant
Throughput	t/day	348.00	255.26	207.44
Biogas produced	Nm3/a	na	na	N/A
Waste NCV	kcal/kg	-	-	1,911.56
	kJ/kg	-	-	7,997.98
Thermal input	MWt	-	-	12.75
Gross Plant Efficiency	%	-	-	24.4
Gross Electricity Output	MWe	0	0	3.11
Total Gross Electricity Output	MWe		3.11	
Gross Electricity Output	MWh/a		25,469	

6.1.5 Option 5: Incineration plant

6.1.5.1 Overview and process description

This plant consists of an Incineration plant. It is anticipated that the raw MSW will not be able to sustain combustion by itself without auxiliary support from other sources due to its high moisture content. This option is presented for comparison purposes only, with further explanations on combustibility in section 6.2.

A Schematic Diagram and Material Balance are shown below:



Schematic Diagram and Material Balance (Option 5)

Figure 6-5 Option 5 schematic

6.1.5.2 Technical Summary

The following table shows the overall parameters for the power generation of the Incineration plant.

Table 6-5 Option 5 technical summary

		Option 5		
		MRF	Biodrying	Incineration Plant
Throughput	t/day	Na	Na	348.00
Biogas produced	Nm3/a	na	na	na
Waste NCV	kcal/kg	-	-	756.82
	kJ/kg	-	-	3166.54
Thermal input	MWt	-	-	12.75
Gross Plant Efficiency	%	-	-	23.0
Gross Electricity Output	MWe	0	0	2.93
Total Gross Electricity Output	MWe		2.93	
Gross Electricity Output	MWh/a		24,054	

6.2 Combustibility Assessment

For an incineration process to be technologically considered, which is applicable to Option 2 to 5, it is important to first assess the self-sustaining combustibility of the waste derived fuel for each option. The Tanner Diagram, which assesses the feedstock against moisture content, ash content and combustible fractions, is used for this assessment and results are shown in the diagram below.

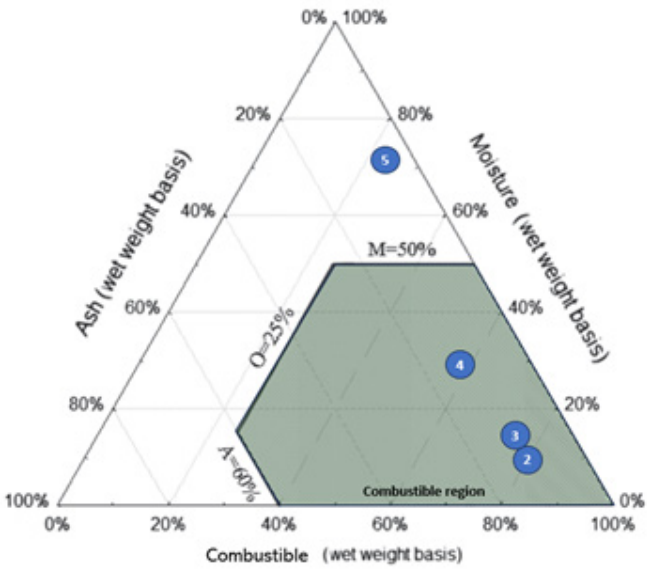


Figure 6-6 Tanner Diagram

Waste for Options 2 to 4 are found to be within the combustible shaded region while waste for Option 5 is not. This suggests the inability for waste in Option 5 to self-sustain a combustion, auxiliary firing will be required, which renders this option technically not feasible.

7 Commercial Assessment

This section provides a high-level description of the commercial aspects that was taken into consideration in the financial modelling in assessing the Options that were deemed to be technically feasible, i.e. Options 1 to 4 only.

Potential upside from carbon credit was not considered in this assessment as currently there is no certainty regarding this.

7.1 Financial Model Input

7.1.1 General

General technical and financial inputs are given as below:

Table 7-1 General technical inputs

Parameter	Unit	Input
Daily capacity	Tonnes per day	348
Plant availability hours	h per year	8,200
Plant lifetime	years	30

Table 7-2 General financial inputs

Parameter	Unit	Input
Share of Debt	%	70.00
Interest Rate for Debt	%	6.0
Share of Equity	%	30.00
Cost of Equity	%	14.4
WACC	%	8.52

7.1.2 Revenue

The typical revenues streams for such projects are from the following sources:

- Tipping fee from MSW collection/acceptance
- Electricity sales tariff
- Compost sales
- Recyclables sales

7.1.2.1 Tipping fee

Typically, in many countries like the UK, Singapore, Taiwan or Japan where many WTE projects have been established, tipping fees are governed by landfill taxes. Important to note that the tax does not include the charge each individual landfill is charging which is in addition to the landfill taxes.

In the studied area however, with neither landfill tax nor landfill fees being established, we consider that there will be no tipping fee possible for the project.

7.1.2.2 Electricity Sales

We note that there are no pre-defined electricity tariffs established and that tariffs are negotiated with BPDB. Based on information attained from the public domain[2], we note that the electricity tariff for WtE projects is given in as around 21 cUSD/kWh.

[2] Information attained from "https://www.newagebd.net/article/218300/approval-of-another-waste-power-plant-likely"

For the purpose of this study, we have assumed a PPA tariff of 20 cUSD/kWh as per feedback received from BPDB, a PPA term of 30 years and the respective net electrical output of each option as shown below.

Table 7-3 Net Electrical Output

Parameter	Option 1	Option 2	Option 3	Option 4
Net Electrical Output (MW)	2.72	3.70	4.20	3.11

7.1.2.3 Compost Sales

The quality of the digestate produced through the digestion process of comingled MSW waste is generally not acceptable for widespread use as fertilizer etc. because of the contaminants related to both the inert content (glass, plastic, etc.) and also to the heavy metals content arising from other wastes entering the stream (batteries, etc.). In some countries, the output waste may be used as landfill cover if contamination is low enough (low grade compost, grey compost or stabilized biodegradable waste), or else it may be landfilled.

For this project, we consider that the sale of compost produced as not applicable and will just be landfilled at an assumed cost of 2 USD/ton for transportation.

7.1.2.4 Recyclables Sales

Recyclables amount to approximately 0.5% of the waste input, i.e. 1.74 tpd.

At this point in time, the sale of recyclable revenues is not considered in the model. It should be established whether there is a market for offtake of such recyclables, but given the small amount the impact is considered to be marginal.

7.1.3 Cost

7.1.3.1 Capital Expenditure (CAPEX)

The total investment necessary for the construction of the plant and its commissioning has been estimated for the Options 1 to 4. The total costs correspond to a scheme of construction of the plant following the modality of EPC (Engineering, Procurement and Construction).

This scheme allows to guarantee the construction time, the performance guarantees and the integration of the different equipment in a functional unit that allows to reach the annual availability of the installation as a whole, and above all, of the electrical production (fixed at 8,200 h/year).

The plant cost has been estimated based on the following assumptions:

- It has been considered that the supply of equipment will be made from leading western manufacturers, with recognized experience that provide reliability and durability.
- The costs of import duties, fees or taxes on equipment in Bangladesh are not included.
- Civil works costs including buildings have been calculated with the standard values used in the countries of southern Europe and then adjusted for Bangladesh where we expect a cost reduction for this cost portion by 50%.
- Civil works costs have been calculated assuming that for the building and digester foundation no piling will be required (based on experience in other projects, actual site condition in Bangladesh may differ)
- Labour costs have been calculated based on the average values of the waste treatment sector in Bangladesh.
- Connection point for the export of electrical energy is assumed to be at the plant boundary.
- The total cost corresponds to a construction scheme through a contracting EPC, the cost of which has been estimated at 15% of the value of CAPEX.
- Likewise, a cost chapter evaluated in 5% of CAPEX for pre-development has been considered, which corresponds to permitting, due diligence and other studies to obtain financing.
- No cost has been considered for obtaining the land, whether for purchase or rent.

- It has been considered that the access road, the basic electrical connection, the water supply and other services already exist. Subsequently, it will be necessary to define any further investment for those interfaces, if applicable.
- BDT/USD conversion assumed is 115.

The CAPEX estimated for the various options are presented below.

Table 7-4 CAPEX

Cost Component	CAPEX (kUSD)			
	Option 1	Option 2	Option3	Option 4
MRF	8,348	8,348	8,348	8,348
AD Plant	9,688	9,688	9,688	-
Biodrying	-	-	-	6,059
Incineration Plant	-	25,125	36,470	75,320
Pre-development	902	2,158	2,725	4,486
EPC cost	2,705	6,474	8,176	13,459
TOTAL	**21,643**	**51,793**	**65,407**	**107,672**

7.1.3.2 Operating Expenditure (OPEX)

The annual operating cost has been estimated analysing the different components that are linked to OPEX, which are:

- O&M staff cost
- Maintenance and spare parts
- Cost of consumables
- Insurance

The O&M scheme for the project is considered to be done in-house by the project company and not outsourced to third party which the overall OPEX will potentially be higher.

The OPEX has been estimated based on the following considerations:

- Personnel costs have been calculated based on the average values in Bangladesh.
- OPEX annual escalation of 6.53% was assumed which is in line with the average inflation for the past 30 years.
- General administrative and cost associated to financing are not considered in the OPEX.
- The costs for insurance are estimated at 10% of total OPEX per year.

The CAPEX estimated for the various options are presented below.

Table 7-5 OPEX

Cost Component	OPEX (kUSD)			
	Option 1	Option 2	Option3	Option 4
Labour	383	558	584	668
Maintenance	347	881	1,122	1,122
Consumables	19	124	262	328
Insurance	75	156	197	212
TOTAL	**824**	**1,719**	**2,165**	**2,330**

7.2 Financial Model Output

Financial Model outputs that were considered are:

- Financial Internal Rate of Return (FIRR)
- Net Present Value (NPV)
- Debt Service Coverage Ratio (DSCR)

The above parameters are the key considerations for the financial viability of the project. The FIRR needs to be higher than the Weighted Average Cost of Capital (WACC), the NPV needs to be positive, and the Minimum and Average DSCR need to be higher than 1, the Average DSCR preferably at least 1.2. If these parameters are fulfilled, then the financial viability of the project is secured.

7.2.1 Output

Using the inputs described in earlier subsections, the output was tabulated.

Table 7-6 FM Output

Cost Component	Output				
	Financial Viability	Option 1	Option 2	Option 3	Option 4
IRR (%)	**>8.52**	8.82	<0	<0	<0
NPV (kUSD)	**>0**	393,192	-28,861,989	-42,019,716	-95,741,376
Average DSCR	**>1.2**	1.58	0.67	0.54	0.11
Min DSCR	**>1.0**	1.17	0.32	0.19	-0.12

The financial model output shows that only Option 1 was found to be a marginally viable project. The IRR of 8.82% is marginally higher than the WACC of 8.52%, NPV is positive, and both the Average and Min DSCR meets the requirement of 1.2 and 1.0 respectively. This financial consideration excludes, among others mentioned in Section 7.1, the cost of equipment import duty, fees and taxes.

For Options 2, 3 and 4, despite producing slightly higher electrical output compared to Option 1, the high CAPEX cost requirement for the incineration technology has rendered these options as non-financially viable projects.

The IRR of 8.82% is considered low in terms of attractiveness to potential investors and is primarily influenced by the export tariff. A sensitivity analysis on the IRR and export tariff is shown in Figure 7-1 below.

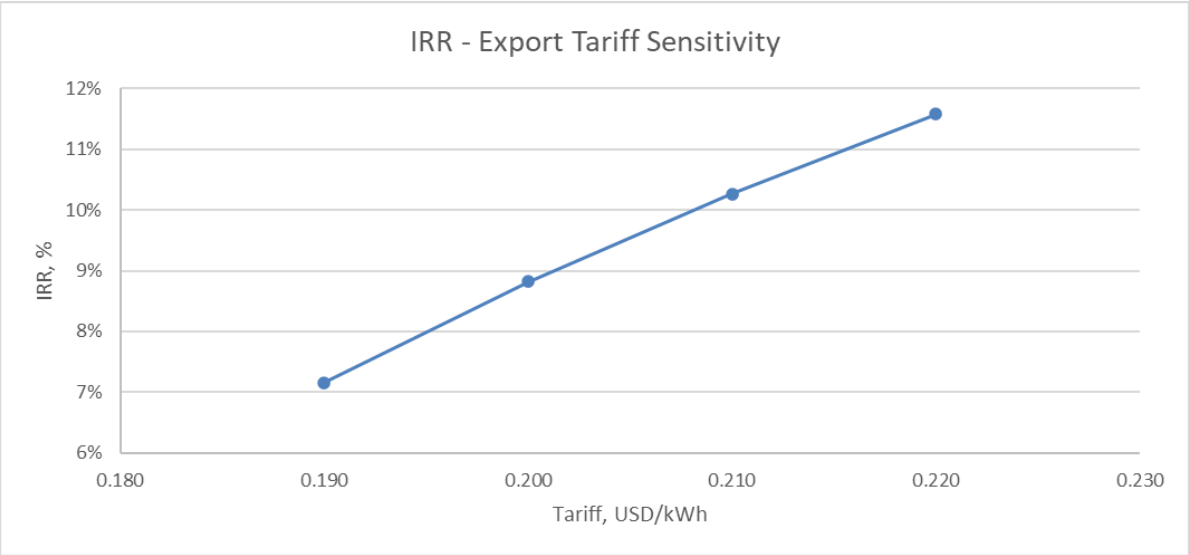


Figure 7-1 Sensitivity analysis for Option 1 in regards with IRR and export tariff

Table 7-7 Summary of sensitivity analysis for Option 1

Export Tariff, USD/kWh	IRR, %
0.19	7.16
0.20	8.82
0.21	10.27
0.22	11.58

To achieve up to 11.58% IRR, the export tariff is required to increase to 0.22 USD/kWh. As the electricity export is the only revenue stream for the plant, it is important to consider a higher export tariff to increase the attractiveness of the Project.

Based on the above, Option 1 is selected as the Preferred Option for the project realization roadmap development as presented in the following sections.

8 Project Realization Roadmap

8.1 Preferred Option for Projected Waste Collection Scenario

In the earlier technical and financial assessment, Option 1, which integrates a Materials Recovery Facility (MRF) with an Anaerobic Digestion (AD) Plant, was determined to be marginally financially and technically viable for the Project with the projected collection quantity of 348MT/day. The waste collection process feeds into the MRF, where a sorting system separates organic materials from the waste stream. These organics are then directed to the AD plant for processing.

Within the AD plant, the organic waste undergoes anaerobic digestion, a biological process that produces biogas. This biogas is primarily methane, which is then utilized as fuel in a Combined Heat and Power (CHP) unit. The CHP, equipped with a gas engine, generates both electricity for export to the grid and steam for internal use, optimizing the energy recovery from the waste.

The Project shall comply with the applicable emission limits related to Biogas fueled engines, as specified in Table 2-3.

An indicative layout of the preferred option is attached in **Annex 2**.

8.2 Process description of the facility

8.2.1 Access control and reception

The plant will include a vehicle weighbridge at the entrance for truck identification and weighing. A service building adjacent to the scale will handle access control. There will be two lanes for weighing purposes and a third lane for vehicles that do not require weighing. After weighing, collection trucks will proceed to the waste reception area.

8.2.2 Materials recovery facility

8.2.2.1 Storage and feed of waste to process

To allow proper management of the reception area and the subsequent pre-treatment process, it is sized for a minimum storage capacity of 3 days.

The waste acceptance area should ensure that front wheel loaders can work having bucket capacities of at least 5 m^3 and width up to 3 m, unloading specialized vehicles delivering waste. The acceptance area includes dedicated storage areas where waste can selectively and temporarily be stored for a period of at least 3 days. This area includes a reinforced unloading plate and three reinforced concrete boxes. The usable area of each box shall allow for storing waste up to a minimum height of 3.75 m, separated by walls with a minimum height of 4.0 m.

The waste reception area is an open, paved space, enclosed by walls on two or three sides to contain waste and prevent wind dispersion. It features a maneuvering platform at least 20 m wide to facilitate truck movement.

The storage area shall also be designed with effective drainage to allow for leachate natural extraction from the collected waste.

8.2.2.2 Mechanical treatment area (sorting)

The waste from the acceptance hall will be transferred by a wheel loader to a feeding conveyor of a low-speed bag splitter which functions to release waste from plastic bags

Thereafter, manual sorting is implemented to protect the sorting line from waste (bulky and dangerous) and from waste that should not be crushed (such as glass bottles) to avoid that the subsequent separation will be more difficult. The cabin shall be equipped with an AC system and a filter to maintain safe air quality for working conditions. The separation of the following waste streams shall be implemented:

- bulky waste,
- plastics (not bottles),
- mineral waste,
- construction waste,
- glass,
- cartons,
- large bags and foil,
- large metal parts,
- identifiable hazardous or otherwise problematic waste.

The pre-sorting cabin is equipped with a minimum of 4 chutes. There is 1 box per chute under the cab that allows inserting a hook container. In addition, the cabin is equipped with 4 side chutes to separate, among others: hazardous waste or other waste present in small quantities. Under these side chutes, self-unloading containers transported by forklifts will be placed. The sorting cabin is designed so that 6 workers can work simultaneously. Then the waste will be directed to the air separator where the films will be separated and then directed to a container.

The crushed material after the air separator will be directed to the 75 mm trommel (rotating sieve). As the waste is driven through the trommel it will be spread and the organic fraction will pass through perforations of the sieve.

Then the 0-75mm fraction waste will be directed to a ferrous metal separator field where ferromagnets will separate ferrous metals into a self-unloading container, transported with a forklift.

After the metal separator, the waste will be directed to a ballistic separator, in which inert hard waste will be separated, which will be directed to a different container.

The organic fraction measuring 0-75mm will be routed to an intermediate storage area that supplies the anaerobic digester. A substrate buffer bunker will serve as this intermediate storage to facilitate consistent feeding of the digester throughout the day.

The bunker is constructed of reinforced concrete limited by retaining walls of 4m height which shall be provided, for temporary storage of waste going to the fermenter. The minimum retention capacity should be sufficiently designed to ensure that a constant supply of fermenter input for 4 days is maintained, in case the pre-treatment line is not working for any reason.

The large fraction >75 mm will be channeled to the metal separator where magnetic metal will be separated.

Fraction >75mm after the metal separator will be directed to a manual sorting line with 8 positions where recyclable material will be recovered. The main objective of this line is the recovery of remaining metals and recyclable plastic materials such as:

- Polyethylene Terephthalate (PET)
- High-Density Polyethylene (HDPE)
- Polyvinyl Chloride (PVC)
- Low-Density Polyethylene (LDPE)
- Polypropylene (PP)
- Polystyrene or Styrofoam (PS)

The remaining flow (rejection) will be sent to a system of belts that feed containers for transport to the landfill.

8.2.3 Anaerobic digestion

The anaerobic digestion process is a continuous operation system with anaerobic technology using "dry" thermophilic fermentation.

The fermentation process is carried out continuously in a horizontal fermenter chamber, in which all phases of the anaerobic process and decomposition of the organic substance are to take place. It is required to carry out the process in a thermophilic system in a way that ensures sanitation of the material (it is usually considered in the sanitation regulations that a stay of 15 days at 55°C ensures the disappearance of pathogenic organisms in the digested material) and fertilizer use of fermentation process products.

Dry AD horizontal digesters have the advantage of mechanical agitation system and are based on the so-called plug and flow operation: waste flowing into the digester displaces digester volume, and an equal amount of material flows out. The genuine combination of these two characteristics has proven to be very effective from the point of view of energy consumption, biogas production and impurities content in the feedstock.

The anaerobic digestion process is fully automated to operate 24 hours a day continuously. The operations included in the automatic cycle are:

- substrate feed with weighing
- water input
- substrate extraction
- agitation
- inoculation
- biogas flow measurement
- biogas internal pressure control.

The operation of the digester is relatively simple and is based on the fact that the operator defines a daily recipe of the amount of waste fed and the necessary mixture with recirculated water from the process to obtain an adequate degree of humidity.

8.2.3.1 Feeding system

The feed-in mixer is receiving the substrate from a conveyor belt/screw. On the inlet side of the mixer, liquids like press water (liquid digestate coming from screw press) and rainwater are pumped inside via pipes. Inside the mixer two screw shafts are mounted. They can be operated in different modes. When the shafts are rotating in different directions the substrate is rotating in the mixer, which leads to a mixing effect. Once mixing is finished, both shafts are rotating in the same direction, so the mixed substrate is being pushed over the extraction point. Under the mixer, the feed-in pump is installed, which is sucking material from the mixer and then pumps it into the heat exchanger feed-in pipe. The latter heats the mixed substrate before it enters the digester. Additionally, the feed-in pump can suck digestate from the digester and pump it either into the heat exchanger for direct inoculation or into the mixer for humidification. The mixer is including weighing cells to estimate the amount of fed substrate.

The consistency of the inlet material to the digester is achieved in the mixer with dosed addition of water, be it recirculated process water, clean water or both. The mixer is emptied through a hydraulic piston pump system, which transports the mixed organic material to the digester through the feed pipe, which will be encased with circulating hot water through its exterior to preheat the substrate before entry to the digester.

This arrangement ensures optimal heat transfer to the feed substrate to the digesters, an ideal inoculation process, as well as the greater flexibility in operation and avoidance of thermal shocks.

The same piston pump as mentioned above is used to perform inoculation (via recirculation). This is done in regular intervals, sucking material from a high point on the digester extraction side (sediment-free) and sent through the feed pipe to the digester feed point.

8.2.3.2 Digester

The plug flow digestion module is ideal for processing dry organic waste containing a higher level of impurities.

The agitator is characterized by its ability to handle difficult materials and to carry out uniform and continuous digestion of different types of substrate. The dimensions of the blades and shaft ensure high stirring efficiency and virtually unlimited service life – even operating under overloads.

This is achieved by the special shape of the blade end, which are made of highly wear-resistant steel. With the special combination of the design of the blades and their distribution, sedimentation is avoided by up to 100%, since the entire substrate is continuously transported to the outlet of the digester, avoiding sedimentation and at the same time counteracting the formation of floating layers. In this way, the digester needs minimal maintenance, in the long term, even if the input material contains significant amounts and relatively heavy impurities.

Generally, for dry AD processes with high dry matter content and good agitation, the formation of a foam layer is very unlikely. This risk is more common in wet digesters with agitation by propellers.

The digestion process inside the digester is based on a completely biological process, with anaerobic and thermophilic characteristics, called High Solids Anaerobic Digestion (HSAD or less commonly called Dry Digestion-AD). The digester has a process temperature of approx. 55°C and average dry matter content greater than 35%. The residence time is approximately 21 days. The residence time of the material within the digester is controlled to ensure sanitation and therefore compliance with applicable regulations.

The residence time depends on the volume of the digester and the daily substrate feed. It is related to the volatile solids that are likely to produce methane. The initial design of the process has been thought for a standard feeding that allows an average residence time of 21 days. Normally, residence times for this type of substrate varies from 18 to 25 days. The EPPC must provide a mass balance of the AD process based on the HRT (Hydraulic retention time).

The temperature and level in the digester, the amount of gas produced, and the pressure of the gas are continuously monitored. The end-to-end controlled displacement of the material through the digester, referred to as a plug flow process, allows it to be a biologically and mechanically easy to control process, obtaining a high and constant performance of biogas.

Organic loading rate, pH-value, alkalinity, volatile fatty acids, and volatile solid parameters are measured in the laboratory of the plant itself with a weekly frequency during the start-up phase. In normal operation, these measurements can be performed monthly. The measurement of hydrogen in the biogas is carried out continuously through the built-in gas analyzer.

The digester is designed to work with a positive pressure of approximately 10 mbar and is equipped with devices to maintain that pressure.

As for the safety required when working with biogas, digesters have the following components:

- Hydraulic system or protection against over-pressure and negative pressure.
- Opening of foam evacuation, this allows access to the area of the digester cover.
- The maximum fill level is limited to 85% of the total volume of the digester, this allows the expansion of the digestate in case the stirrer remains at rest.
- Pressure measurement system inside the digester.
- The biogas extraction pipe is connected to the digester cover, thus maintaining as much distance as possible between the extraction of the biogas and the substrate.
- Gas tight digester: No formation of ATEX risk zones around it. Except for very localized points on flanges with gaskets for the gasometer.
- The slope of the biogas collection pipe allows the condensates to be evacuated to the collection system.

The volume of the digester is the effective volume useful at 80-85%, i.e. the process volume does not include the gas storage space.

The digest found inside the digesters will be sent by a hydraulic piston pump to the dehydration system.

8.2.3.3 Digestate extraction system

On the discharge side, the lowest point of the digester is fitted with a hydraulic discharge pump that delivers the digestate to the dewatering system. The valves in the discharge system are fitted with double lip seals to ensure long plant service lives and clean operating conditions. In case of a feeding system with a feeding screw, inoculation will be achieved with this discharge pump, by pumping digestate to the input of the digester.

8.2.3.4 Dewatering

The following dewatering processes have been chosen: a line of three different equipment:

- Vibrating screen
- Screw press
- Decanter

The vibrating screen is a very simple technology. Coming from the mining industry it is a very robust technology. The digestate is being moved up and down on the screen surface. The water in the digestate can then move through the meshes of the screen, while the solids stay above it and move to the end of the screen. Because the dewatering is achieved by weight and not through a mechanical force, less wear than e.g. with a screw press can be expected. It is the best technology for dewatering in the following cases:

- High content of abrasive contaminants (common technology for organic fraction of MSW).
- Dewatering only for humidification purpose.
- Pre-treatment of very wet digestate before usage of a screw press.

The screw press consists of three main parts: the pressing screw, a screen basket around the screw and a weir flap at the end of the screw. The screw presses the digestate against the pressure-controlled weir flap, so the digestate gets squeezed until the pressure of the screw is higher than the one of the flap. The dewatered solid digestate will fall out of the flap and is called press cake. The water, which is being pressed out of the digestate, will go through the holes of the screen basket around the screw shaft. This liquid digestate is called press water. The distribution of the liquid and solid digestate strongly depends on the input material. The dry matter content and throughput can be adjusted by changing the weir flap pressure and the revs per minute of the screw.

The screw press is the most common used technology for dewatering at dry digestion plants. Different types of screw presses are used to meet the different types of input material.

When liquid digestate is being produced in the first dewatering step, it can possess a dry matter content which is too high for the following application, a decanter centrifuge is used to remove remaining particles from the liquid digestate.

The liquid digestate is fed through a stationary pipe into the decanter. Inside the decanter is a cylindrical/conical bowl with is rotating. The scroll inside the bowl is rotating at a slightly different speed and conveys the separated solid towards the end of the bowl, while the liquids are leaving the bowl at the lowest point of the bowl in the input zone. The differential speed determines the residence time of the material in the bowl. The dryness of the decanter cake is mainly determined by the residence time.

8.2.3.5 Storage

The plant will have an intermediate storage upstream of the digester as buffers for the organic matter to be fed to the digesters. Besides that, liquid and solid storage tanks for digestate are included nearby the digesters.

8.2.3.6 Biogas cleaning systems

The obtained biogas is removed from the digester and sent to the energy recovery stage through a piping system.

The biogas cleaning system must comply to the any relevant local environmental standards.

In order to provide an additional stage of safety against excessive or insufficient pressure, a pressure protection system is available which is connected to the biogas pipe; such a protection system is located on the roof of the digesters. The system operates according to the siphon principle and consists of two compartments. One compartment ensures a positive pressure limit of +12 mbar and the other acts when the system pressure is less than -2.6 mbar.

Biogas produced in the digester has a lower density than air and is composed of 50-70% CH_4 and 30-50% CO_2 and max. 2% of total traces of nitrogen (N_2), oxygen (O_2), sulphur hydroxide (H_2S) and hydrogen (H_2) and water.

A scrubber for the H_2S is typically not necessary. With the proposed system, the maximum concentrations that ensure the correct operation of the CHPs are achieved.

The composition of the biogas is constantly monitored on-line, the measurement sensors are located in the gas pipeline.

The installation analyzes the following parameters:

- Biogas flow rate (4 % tolerance)
- Methane content (CH_4) (x1 % tolerance)

The resulting biogas has an energy value of typically 5.7 kWh/Nm^3.

Prior to its energy utilization in engines, biogas requires a conditioning stage, basically comprising desulfurization and cooling for the removal of condensate.

Biogas desulphurization in the digester is achieved by adding iron hydroxide, which binds to sulphur so that it cannot enter into the gaseous state.

The microbial degradation of protein components releases organic combinations of sulphides, with the addition of iron III the great affinity between iron (Fe) and sulphur (S) is used to form sulphites and thus selectively retain sulphur in the digest. The iron ion III found in the solution, can remain available for this reaction for an extended period of time, thus ensuring that iron III is distributed throughout the digester. Taking advantage of this chemical reaction, H_2S values less than 200 mg/Nm^3 can be maintained simply, reducing wear of power generation motors.

The relatively hot biogas (temp approx. 55°C), is cooled during flow through the pipes and, therefore, the water condenses into the gas lines. In order to perform this operation, the system consists of a biogas dehumidifier /dryer composed of:

- *Condensate* pot, built in stainless steel, which has a level meter and a pneumatic valve for the evacuation of condensates automatically.

- *Dehumidifier* formed by a single-pass biogas-water heat exchanger, with automatic condensate extraction system.
- *Drop separator:* Fog removal from the biogas flow, using a slat separator.
- *Condensate pump,* for the evacuation of condensate from thermal exchange and drop separator equipment.
- *Cooling machine*: Water circuit cooling equipment.
- *Gas blowers*.

In addition, active carbon filters will be available for the elimination of siloxanes and traces of H_2S installed prior to the biogas harvesting system. The capacity of the filter shall be sufficient for a 6-month operation period.

The capacity of the carbon filter should ensure a 6-month operation period without having to replace the filter bed.

8.2.4 Auxiliary systems

8.2.4.1 Heat and Power generation (CHP)

A cogeneration unit (synonym: CHP module) should be located in a container or building and work as a biogas CHP plant.

Main features of CHP are as follows:

Table 8-1 CHP Specification

Aspect	Specification
Biogas composition:	50 ÷ 70% CH_4
Gas engine	• turbocharging • cooling the fuel mixture (intercooler) • electronic speed controller • electric starter • automatic installation for checking and topping up engine oil without interrupting the operation of the aggregate with the oil tank • biogas supply path with necessary fittings
Three-phase power generator	• on a common (cushioned) frame with the engine • self-regulating, synchronous (for stand-alone / island operation or parallel to the network) • equipped with an automatic network monitoring device that will allow the generator to synchronize with the power grid and disconnect it from the grid in the event of damage • 50 Hz frequency • N-interference suppression according to VDE 0875 • type of protection IP 23

The CH_4 range of 50 to 70% is generally suitable for OEM standard specifications.

To control and supervise the entire combined economy of electricity and heat generation, a central computer unit with software enabling the rational use of the available biogas should be provided.

The system should enable such control of electricity production, depending on the amount of biogas in the tank, that the entire amount of biogas generated in the anaerobic stabilization chamber is used without combustion in the flare. The flare (torch) acts as a biogas emergency combustion only.

This Biogas Flares is intended for automatic combustion of excess biogas not used in the biogas management system. The torch will contain the following basic elements:

- Flame protection pipe,
- Automatic spark ignition,
- Mechanical fire fuse,
- Solenoid valve,
- emergency voltage support system,
- Non-return hydraulic fuse filled with low freezing liquid.

The capacity of the device has been selected in such a way that it can, in justified circumstances, allow the amount of biogas to be burned resulting from the total, maximum production in the Fermenter, however, not less than 500 m^3/h.

In the event of a breakdown and start-up needs, an additional gas-oil combined heat and power unit is required, which includes an emergency oil-fired boiler and a diesel generator.

The boiler is sized to provide sufficient heat for the digesters to work properly, and a fuel oil tank shall be sufficient to operate the boiler for 3 days, of at minimum 3 m^3 capacity.

The generator is sized to provide sufficient electricity power to feed electromechanical equipment of digester and their control system.

The cogeneration unit is equipped with an emergency cooler allowing continuous operation of the unit without removing heat.

8.2.4.2 Wastewater treatment system

The waters to be treated in the treatment plant shall consist in a mix of process water and sanitary water.

WWTP should include a biological process, an ultrafiltration treatment and a reverse osmosis process.

As the highest percentage of effluent to be treated is made up of the one from the biodigesters, its characteristics will be considered as the basis of the design parameters at the entrance to the treatment plant.

Therefore, the design basis for the water treatment plant is:

Biological and ultrafiltration treatment

- pH: 7.0 – 8.0
- Water temperature: <55 °C (input to biological <40 °C)
- Suspended solids <2.200 ppm
- Inert suspension solids: approximately 500 ppm
- Total COD: < 25,000 ppm
- Refractory COD: approximately 7,000 ppm
- Kjendahl Total Nitrogen: 3,500 ppm
- Ammoniacal nitrogen: 2,800 ppm
- Phosphorus: < 609.5 ppm
- Chlorides: < 2,555 ppm
- Conductivity: < 25,000 S/cm

Reverse osmosis

- Nominal flow rate: 35 m^3/d
- Design flowrate: 45 m^3/d
- Conversion: 70-75%
- Crude water flow rate: 2.63 m^3/h
- Permeated flow rate: 1.84 m^3/h
- Holding flowrate: 0.79 m^3/h

Pollutants are retained in the reverse osmosis concentrate in the same way as a large part of the salts contained in wastewater. In this way, the final purified water (reverse osmosis permeate) not only meets the demands of discharge to sanitation network but has also a high quality for internal reuse (possible contributions of fresh water to anaerobic digestion, equipment cleanings, etc.).

The operation of reverse osmosis is based on the application of a pressure, by means of a high-pressure pump to overcome the osmotic resistance / pressure produced by the membranes and which is necessary to filter the permeate. In such a way that the flow that passes through these membranes is water suitable for pouring or consumption in the plant, by means of a recirculation pump it is possible to maintain the necessary speed in the membrane block.

Thus, the filtration module separates the two currents: reverse osmosis permeate and reverse osmosis concentrate. The permeate of this step is reduced in its content in salts and non-biodegradable carbon compounds, while the retained effluent must be disposed by an authorized waste management company.

The installation consists of a series of membrane modules independent of each other, so that they can be independent without affecting the operation of the plant.

These membranes will have a washing facility, which will be activated when the differential pressure exceeds the set point. Cleaning and washing are carried out semi-automatically by washing sequences. Different types of washing are obtained with the dosing of different additives in the washing tank. The cleaning solution is introduced by the washing pump into the modules. At the end of the cleaning program, the dissolution of washing products is extracted from the installation.

Chemical detergents shall be used for the cleaning of RO membranes.

The water output of reverse osmosis process complies with the following discharge parameters:

- Permeated COD: < 100 ppm
- BOD permeated: < 10 ppm
- Ammoniacal Nitrogen: < 1 ppm
- Matter in suspension: 0 ppm
- Dissolved ions: Reduction 95 – 98%

8.2.5 Civil works and buildings

The construction of the plant includes earthworks for levelling the land, the foundation of buildings and platforms and the construction of buildings. Also included are internal streets and urbanization elements (drainage, lighting, etc.)

Specifically, the building elements included in the installation are:

- Access and internal roads
- Waste acceptance platform
- Pre-treatment building
- Administrative building
- Building for the administration of the plant.
- Operating building for the operation and personnel of the Plant.
- Auxiliary buildings
  - Electric rooms (CCM's, BT transformers, MT cabins, etc.).
  - Workshop for maintenance and spare parts warehouse

8.3 Land Requirements and Site Selection

The site selection is extracted from the findings of O.CREEDs report. A project plot of 2.5 hectares is required for the Project, without landfill considered. Based on consultation meetings conducted by OCreeds in the three Upazilas, a 20-hectare site for the plant is proposed in Keraniganj with coordinates 23.683204° Latitude, 90.377961° Longitude. The finalization of the site shall depend on BPDB's agreement. As per OCreed's report, the proposed land is government owned, categorized as "Khas land". It is also reported that land acquisition costs shall not apply for the procurement of the site.

An aerial view of the proposed site with the site boundary is shown below. A desktop evaluation of the site is presented in Table 8-2.

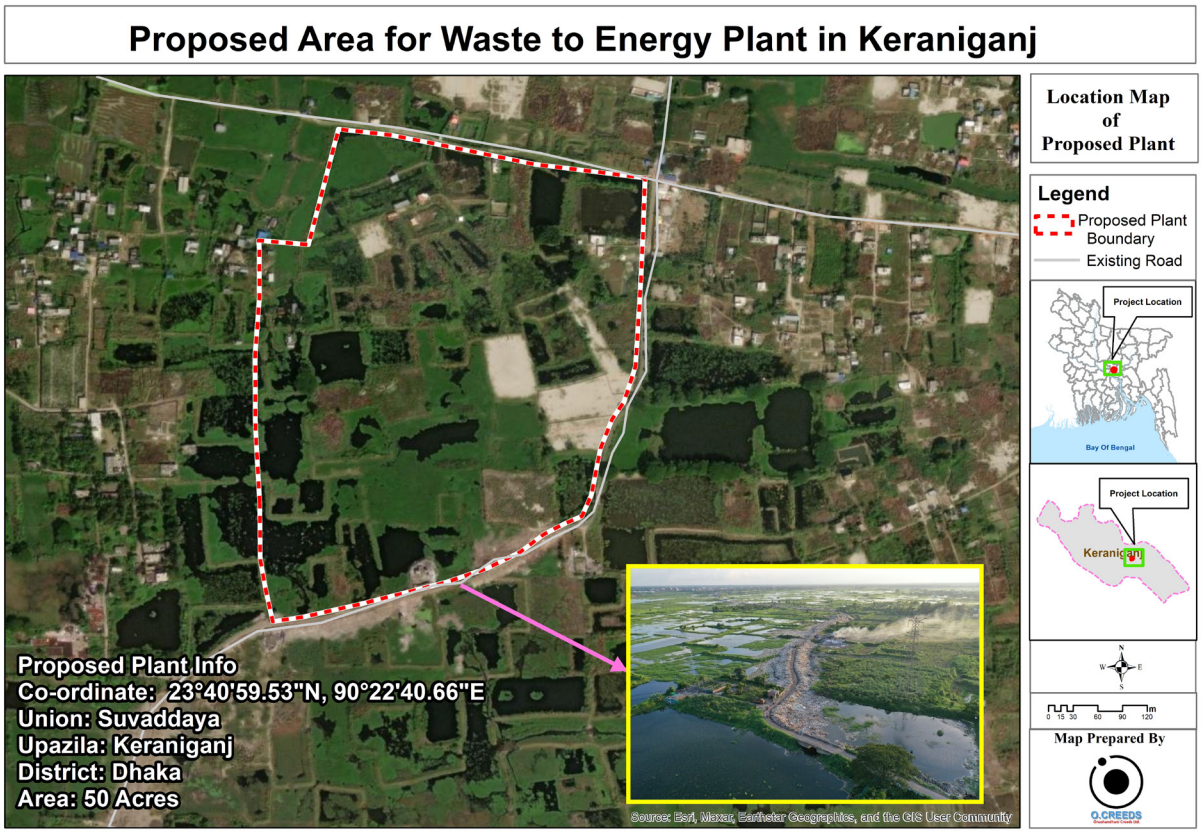


Figure 8-1 Proposed area for the Project in Keraniganj

Table 8-2 Assessment and evaluation of proposed site

Selection Criteria	Importance	Evaluation
Site size	High	The plot is with approx. 400m x 570m (not fully square shape) and large enough for an WTE facility which requires 2.5 hectares excluding landfill. Land size provision of approximately 20 hectares. No major concern.
Site Zoning / Land classification	High	The current site zoning is categorized as "Khas land", which is government owned. Legal procedures are required to utilize the land. No major concern, to be investigated further prior to development.
Site topography and restrictions	High	Site topography is flat, with some water ponds within the site boundary. OCreeds reported that the site is immune from flooding occurrences, however no justification was provided to support this claim. A detailed topography and hydrological site study is required to determine soil, groundwater characteristics and potential risk of flooding of the site. To be investigated further prior to development.

Proximity to waste sources from local councils	Medium	The site is located in Keraniganj, to the North-East of Nawabganj with a distance of 34 km and North-East of Dohar with a distance of 40 km. The transportation by road generally takes an hour from the adjacent Upazilas. No major concern, to be investigated further prior to development.
Grid connection	High	The site has a straight-line distance of 2.38km to 33/11 kV Jhilmil 1 substation, and 2.23km to 33/11 kV Jhilmil 2 substation. The specific right of way is required to be determined through a detailed study, and the grid injection capacity for this project has to be assessed further through relevant power system study (PSS). No major concern, to be investigated further prior to development.
Vehicle access	High	The roads surrounding the site are generally narrow and need to be widened to allow heavy trucks movement. To be investigated further prior to development.
Sensitive receptors	High	There are residential settlements around the site perimeter <100m. Depending on the technology utilized, specific emission and odour reduction measures are required. To be investigated further prior to development.
Water supply	Medium	Town water supply interface location and quantities available is required to be further studied. To be investigated further prior to development
Sewer / Effluent discharge	Medium	Sewer/Effluent discharge interface location and quantities available is required to be further studied. To be investigated further prior to development
Brownfield / Greenfield site	Low	Brownfield site. There exist some settlements within the site which require relocation. To be investigated further prior to development

8.4 Tentative EPC Project Schedule

The tentative time schedule for power plant development as well as engineering, procurement and construction (EPC) is shown below. The construction period is anticipated to be 19 months duration from start of construction (NTP) to commercial operation date (COD). This does not include project planning and development which will depend on negotiations between the developer and relevant parties and financial close.

Table 8-3 Schedule inputs

Parameter	Unit	Input
Construction period	Months	19
Operation period	Years	30
PPA term	Years	30

An indicative EPC construction schedule is specified in Figure 8-2 below.

Upon start of construction, the EPC Contractor under the supervision and responsibility of the developer immediately starts with the design and engineering of the WTE plant, which is anticipated to take 5 months. Once the Basic design is concluded, procurement and fabrication can start.

While design activities start, early site preparation can begin as well, with access road construction and other infrastructure works to start in month 2.

Piling and civil works is starting once the basic design is in an advanced stage. Erection can then follow once foundations are completed in specific sections of the plant.

Cold commissioning is expected to start after 13 months with hot commissioning and testing to take place during the last 5 months of construction.

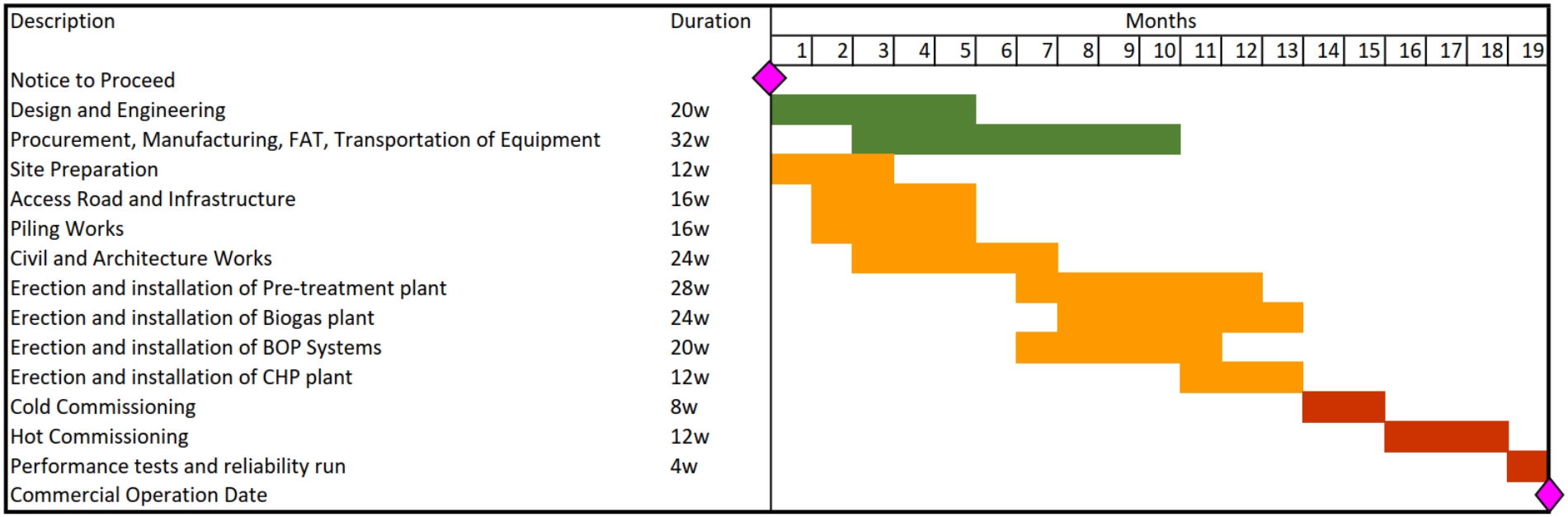


Figure 8-2 Indicative construction schedule

8.5 Project Realization Structure

The Project is recommended to be procured as a solicited project under the Public Private Partnership (PPP) framework which is established in Bangladesh by the Public Private Partnership Authority (PPPA). Under this framework, a government procuring entity from the ministry of the Government of Bangladesh shall propose the project to the PPPA. The PPPA, established under the Public Private Partnership Act 2015 (PPP Act) and guided by the Procurement Guideline for PPP Projects 2018 (PPP Guidelines) shall assess the Project for implementation. The Cabinet Committee on Economic Affairs (CCEA) shall thereafter review the proposal for in-principle approval. The government procuring entity may thereafter procure the project through tendering.

It is imperative to establish the government procuring entity for the Project. As the Project is primarily classified as a waste management project, it is recommended that the main government procuring entity be established under the framework of the National Coordination Committee under the Solid Waste Management Rules 2021.

The Project is recommended to the procured under a concession agreement which enables the participation of private developers through a Design, Build, Operate, with the option for Transfer (DBO(T)) contract. The MSW tonnage to the Project is required to be guaranteed by the government procuring entity under the DBO(T) contract. The electricity export shall be negotiated and formalized through a Power Purchase Agreement (PPA) with the offtaker being BPDB. The private developer shall be responsible for securing equity and project finance, with the fiscal incentives made available by the Government of Bangladesh. The private developer shall also be responsible to procure the EPC Contractor for the construction and commissioning of the Project, and the O&M Contractor for the operations and maintenance of the Project throughout the concession term.

8.6 Risk Analysis

8.6.1 Methodology

All risks identified are classified using a three-tier scheme. The classification of each risk is based on the probability to occur and its general impact on:

- Performance
- Cost (CAPEX, OPEX)
- Time

for technical issues, or

- Profits
- Schedule

for non-technical issues.

The overall statement is derived from the dimension with the highest individual risk classification.

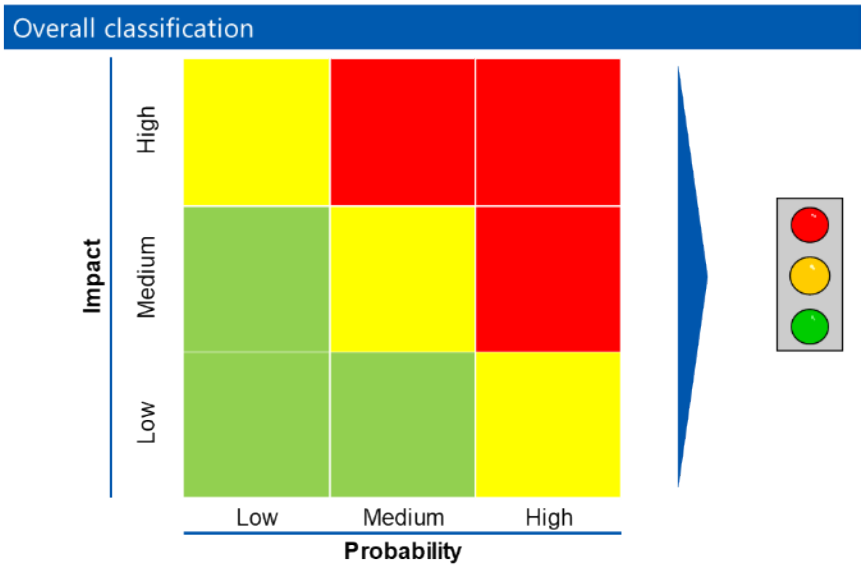


Figure 8-3: Overall classification for risk analysis

The following table provides a gauge for the classification of risk impact.

Table 8-4: Risk impact

Risk impact				
	Performance	CAPEX	OPEX	Time
High	≥ 10%	≥ 10%	≥ 10%	≥ 10%
Medium	≥ 2.5% up to 10%	≥ 2.5% up to 10%	≥ 2.5% up to 10%	≥ 2.5% up to 10%
low	< 2.5%	< 2.5%	< 2.5%	< 2.5%

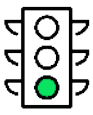
The following table provides a gauge for the classification of risk probability.

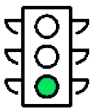
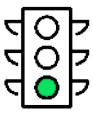
Table 8-5: Risk probability

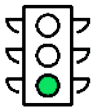
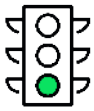
Risk probability	
	Likelihood
High	≥ 50%
Medium	≥ 25% up to 50%
low	< 25%

8.6.2 Risk register

Table 8-6: Risk register

Description	Mitigation Measures	Impact after mitigation	Probability after mitigation	Risk Classification
1. Risk of unstable Anaerobic Digestion process due to comingled waste				
MSW is comingled with many components not suitable to be treated in an AD plant. MBT technology is generally not suitable to treat comingled waste. There is anticipated high amount of reject, stability of process.	Comprehensive mechanical pre-treatment plant is selected, with selection of Dry Anaerobic Digestion technology which is more tolerant to impurities and gives more flexibility on waste composition.	Medium	Low	
2. Risk of revenue uncertainty due to insufficient waste				

Description	Mitigation Measures	Impact after mitigation	Probability after mitigation	Risk Classification
The Project assumes a certain amount of waste over the lifetime of the plant. However, this depends on the establishment of an effective waste management framework which is not satisfactory at present. There is a possibility that there may be insufficient waste throughput due to risk of insufficient waste collection infrastructure.	Each Upazila shall upscale and develop appropriate waste management infrastructure and enforcement of waste management practices. Waste supply agreements shall be established between the Upazilas and the project.	High	High	
3. Risk of water supply availability				
The water supply availability at the proposed site is not investigated in this study. The suitability of the site is highly dependent on water supply for the plant process.	Town water supply interface location and quantities available is required to be further studied.	High	Low	
4. Risk of project delay due to prolonged authority approvals				
Potential delays to the Project due to approvals required from various authorities	Early commencement and close monitoring of authority engagement and fulfilment of requirements.	Low	Low	
5. Risk of performance defects or project completion delay due to technical issues				
Mechanical Biological Treatment for MSW is a less matured technology in comparison with other treatment technologies. If project is not supervised well, it may face potential performance issues and unable to fulfil intended operations due to defects during procurement and construction. The project may be delayed due to technical problems during erection and commissioning.	To ensure selection of a suitable and experienced Technology provider and DBO Contractor. Ensure prudent selection of equipment suppliers are chosen for the main equipment, and to select a DBO Contractor with proven experience in similar projects. To implement key processes such as proper design review and construction supervision throughout all stages of the Project.	High	Low	
6. Risk of protest from surrounding communities or non-governmental organisations (NGOs)				
The surrounding communities are made up of particularly residential areas which, together with some non-governmental organisations, may have a negative outlook on the Project.	To incorporate an early engagement strategy with community leaders, council leaders, NGOs	Low	Low	
7. Risk of high CAPEX due to inflation on material costs				

Description	Mitigation Measures	Impact after mitigation	Probability after mitigation	Risk Classification
The pandemic has generally caused the cost of raw construction materials to increase compared to pre-pandemic periods	Implement a competitive bidding EPC procurement strategy to ensure price of material and equipment to be as low as possible.	Medium	Medium	
8. Risk of variation of waste composition				
There is a risk whereby the waste characteristics is different from the samples taken during the study. This is due to limited waste data available, particularly during the peak of rainy season, and can lead to a decrease of plant performance.	Selection of Dry Anaerobic Digestion technology which is more tolerant to impurities and gives more flexibility on waste composition	Medium	Low	
9. Risk of cost overrun during construction				
If the project requirements are not clearly defined, there is a potential for cost overrun during construction, leading to claims and variation orders	The development of a detailed project specification, thorough monitoring during construction provides a control mechanism to prevent potential cost overruns.	High	Low	
10. Risk of flooding at site location				
OCreeds reported that the site is immune from flooding occurrences, however no justification was provided to support this claim.	A detailed topography and hydrological site study is required to determine soil, groundwater characteristics and assess the potential risk of flooding of the site.	High	Low	
11. Risk of significant OPEX increase due to high and volatile changes in annual inflation rates.				
Inflation rates in Bangladesh has historically been quite volatile in the past 30 years. The range spans from 2.01% to 11.40%. This may significantly increase the annual OPEX of the project year-on-year	▪ A 30-year average inflation rate is used in the financial modeling. ▪ To negotiate an escalation provision for the electricity tariff. ▪ During O&M phase, Long Term Service Agreements (LTSA) should be established to lock in pre-agreed prices for routine services.	High	Low	

9 Conclusions and Recommendations

The feasibility study considers the general, legal and economic framework, collected MSW quantities and MSW characteristics from the Upazilas of Nawabganj, Keraniganj, and Dohar to assess the proper WTE technology to be implemented and develop a project realization roadmap for the implementation of the Project.

The current legal, institutional, and financial framework was found to be adequate for implementing power projects in Bangladesh. However, the existing waste management system in the three Upazilas is found to be inadequately managed with low collection rates. An improvement of the waste management systems in the three Upazilas is required.

A report by the national consultant, O.CREEDs, finds MSW in the three Upazilas consisting of a predominant composition of household and institutional waste, with over 80% of the total waste stream. Only 26% of the total waste generated is collected in Keraniganj and Dohar, and only 0.6% of waste is collected in Nawabganj, attributed to insufficient waste management infrastructure and workforce. This is a significant challenge for the Project's feasibility, as the reliability of waste supply to the WTE is a critical factor. With improvements in the waste management framework, O.CREEDs projected the waste collection volume to rise to 348 tonnes per day, representing 55% of the total generated waste. The technology assessment in this study utilizes the projected waste collection figures and the findings are dependent on the achievement of the improved waste collection rate.

The MSW characteristics from the sampling results as discussed in Section 4 is characterized as non-homogenous or comingled with high organic fraction, very low NCV a.r. (2.15 MJ/kg – 4.25 MJ/kg), and very high moisture content (59.70%a.r. – 87.54%a.r.). These characteristics are consistent with findings from similar projects in Bangladesh.

Due to these characteristics, a single direct waste treatment technology application is unsuitable due to limitations in each technology to treat the raw feedstock. Five options of combined treatment systems based on commercially proven technologies designed to treat specific waste streams from MSW feedstock were investigated to determine the most feasible techno-economic configuration for the WTE.

- Option 1: Materials recovery facility with anaerobic digestion plant
- Option 2: Materials recovery facility with anaerobic digestion plant and refuse derived fuel incineration plant
- Option 3: Materials recovery facility with anaerobic digestion plant and incineration plant
- Option 4: Materials recovery facility with Biodrying system and incineration plant
- Option 5: Incineration plant

Option 1 which is the MRF with AD plant was assessed to be the only technologically and economically feasible option for the WTE. The viability of Option 1 is largely driven by its relatively low CAPEX compared to other technologies, with revenue only from power export, despite a high escalation in OPEX, and anticipated inability to receive revenue from AD digestate due to its poor quality.

However, treating MSW with only MRF and AD does not result in effective volume reduction, as residues consisting of between 50% and 70% of the MSW tonnage are required to be disposed to landfill due to the poor quality of digestate from the MSW waste stream. Incineration technologies would instead be effective in reducing MSW volume to around 20% of residues (ash), however, incineration technologies are expected to only be viable with revenue from gate fees due to its high CAPEX.

A 20-hectare site for the Project was proposed by O.CREEDs based on consultation with relevant stakeholders. Based on a desktop study, the site is assessed to have sufficient space for the WTE which requires an area of 2.5 hectares (without landfill provisions), with acceptable proximity to waste sources, and nearby two 33/11kV substations for grid connection. However further investigations regarding site topography, grid connection studies and routes, vehicle access, environmental and social impact assessment (ESIA), water supply and effluent discharge are required to be implemented.

The EPC construction of the Project is anticipated to take 19 months from Notice to Proceed, with an operational period and PPA term of 30 years from the Commercial Operation Date.

The following are recommendations from this feasibility study.

- The waste management framework in each Upazila currently lacks the adequate infrastructure for dependable waste supply. It is imperative for each Upazila to upscale and develop waste management systems and infrastructure to enable dependable waste supply to the Project. Waste supply agreements are required to be established between the Upazilas and the Project.
- The preferred technology of MRF and AD plant was assessed to be marginally commercially viable and does not result in substantial waste reduction. As the electricity export is the only revenue stream for the Project with unavailable tipping fees and no revenue from digestate sale due to poor digestate quality. a higher electricity export tariff is required to increase the commercial viability of the Project. Additionally, a provision for escalation on the electricity tariff over the lifetime of the Project is recommended to compensate the increase in prices due to inflation.
- To increase the overall viability of the Project and for other technologies such as incineration technologies to be viable, an incentive through tipping fees is recommended.
- There are potential for other utilization of biogas from the AD process instead of electricity production, including exporting the gas to the national gas pipeline or utilization by industries or households. A separate detailed study is required to ascertain the feasibility of these potential utilization.
- It is noted that the implementation of AD projects in Bangladesh have faced technical issues. For the successful implementation of the Project, the development of a detailed project specification and construction supervision, and selection of a DBO Contractor and equipment suppliers with proven experience in similar projects are essential for the success of the Project
- The Project is recommended to be procured as a solicited project under a concession agreement which enables the participation of private developers through a Design, Build, Operate, with the option for Transfer (DBO(T)) contract. A competitive bidding procurement strategy is recommended to ensure competitive project costs.
- A tendering process and approvals under a Public Private Partnership structure is recommended, with the leading stakeholder which is the government procuring entity from the Government is required to be established.
- As the Project is primarily classified as a waste management project, it is recommended that the main government procuring entity be established under the framework of the National Coordination Committee under the Solid Waste Management Rules 2021.
- Detailed studies such as topography and hydrological site studies, ESIA, grid connection studies and routes, vehicle access, and water supply and effluent discharge are required in the next stage of development for the Project
- During O&M phase, Long Term Service Agreements (LTSA) are recommended to be established to minimize risk of price escalation and ensure reliable maintenance support.

Annexes

Annex 1 – Waste Characteristics Studies

EXECUTIVE SUMMARY

Managing solid waste in densely populated countries poses challenges. To address this, many nations, both developing and developed, are adopting the 'Waste to Energy' approach, converting waste into energy resources. In Bangladesh, the 8th Five-Year Plan emphasizes executing power and energy projects effectively, focusing on diversifying primary fuel sources for electricity and prioritizing renewable energy to enhance security and reduce greenhouse gas emissions.

In Bangladesh, the local government has two main parts: urban authorities with 12 City Corporations and 328 municipalities, including Dohar Municipality, and a rural system with 64 Districts, 489 Upazilas, and 4562 Unions. Keraniganj upazila has 12 Unions, and Nawabganj upazila has 14 Unions.

Each Upazila has urban (city corporations or municipalities) and rural sections (Upazila Parishads and Union Parishads). Solid waste management is mostly handled in urban areas, while rural areas, specifically Union Parishads, lack adequate funds and infrastructure for proper waste management. The waste management practices are regulated by the Municipality Act of 2009 and the Upazila and Union Parishad Act of 2009 in the study areas.

The Bangladesh Power Development Board (BPDB) has been planning for the establishment of a waste-to-energy facility in the regions encompassing Keraniganj and Nawabganj upazilas and Dohar Municipality, all located within the Dhaka District. To conduct the study, BPDB has entered into a collaborative partnership with GIZ Bangladesh, an organization based in Germany, to facilitate the necessary activities for the waste-to-energy plant within the aforementioned upazilas. GIZ Bangladesh has appointed Onushandhani Creeds Ltd. (O. CREEDS) as a National Consulting Firm to conduct the detailed study and FICHTNER as an International Consulting Firm to develop a design of efficient technologies for waste-to-energy projects.

A comprehensive survey by O. CREEDS considered waste from various sectors, classifying it into organic and inorganic categories. The study included waste from households, industries, institutions, markets, hospitals, restaurants, and more. Focus Group Discussions (FGD) with waste collectors and evaluations of formal and informal dumpsites provided a nuanced understanding.

Dohar Municipality possesses waste management facilities, while Nawabganj upazila lacks proper waste management. Keraniganj showcases a unique model with private sector cooperation. Challenges include narrow roads, slow waste collection using rickshaw vans, and the prevalence of illegal disposal sites. Regulatory failures and low environmental awareness contribute to the existence of these sites near water bodies and roadsides. The final disposal in Keraniganj, involving the mixing of waste with water bodies, raises ecological concerns. Land scarcity, driven by high property values near Dhaka, further complicates the situation.

Daily waste generation in the study areas totaled 628.29 MT (excluding industrial waste). Organic Matters dominate at 81.40%, while Plastic and Polythene follow at 9.27%, Textile at 2.80%, and Paper and Paper Products at 3.28%. Aluminum has negligible presence (0.00%), and the remaining categories contribute in the range of 0.05% to 1.19%. Currently, Dohar Municipality transports 26% of its generated 64.06 MT, Keraniganj upazila transports 26% of its 353.53 MT, while Nawabganj upazila transports 0.6% of its 210.7 MT, resulting in a total of 110 MT being collected daily.

In line with the study methodology, O. Creeds Ltd gathered waste samples from dumping sites and secondary transfer stations in the study areas to analyze various parameters, including moisture, carbon, volatile components, ash, hydrogen, nitrogen, oxygen, chlorine, and gross calorific value. The laboratory tests were carried out at the Bangladesh University of Engineering and Technology. Laboratory results showed moisture content fluctuations from 87.5% to 59.70% in the wet season (October-November) and between 62.54% to 75.59% in the dry season (February). Similarly, the highest gross calorific value was 4304 kcal/kg in October, and the lowest was 2248 kcal/kg in

November. During February's dry period, the average remained 3423 kcal/kg. Field visits and laboratory tests revealed minimal variation in moisture content between dry and wet seasons, indicating consistent waste composition and insignificant impact on collected waste weight despite logistical challenges during the rainy season.

FICHTNER's assessment indicates that 1 MW of power can be generated from 106 MT of waste daily. To achieve 2 to 3 MW, at least 300 MT of waste input is required. The proposed waste collection plan aims for 348 MT daily, distributing as 70% for Keraniganj upazila, 20% for Nawabganj upazila, and 90% for Dohar Municipality, involving additional vehicles and workforce expansion. The proposed number of vehicles required for the daily collection of 348 MT of waste is detailed in Chapter 7 of the waste characteristics report.

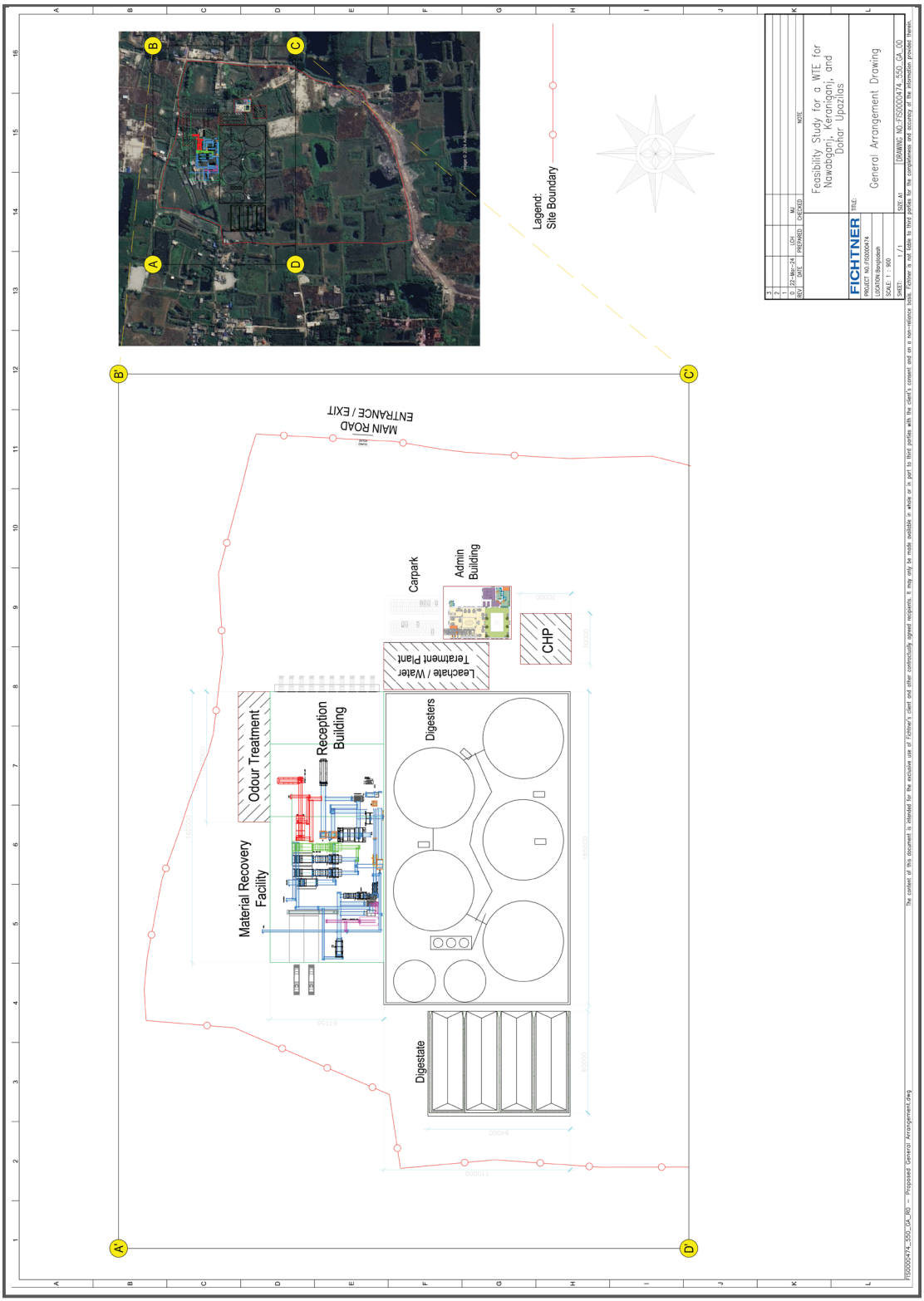
Consultations with private sectors, upazila parishad and municipal officials, coupled with an analysis of existing capacities, informed the proposed waste collection and transportation plan. It includes additional rickshaw vans and trucks for each area to achieve more effective waste collection rates. Finally, 39.9 MT of industrial waste is generated daily, with 31.72 MT of textile waste directed to the recycling market, and the remaining 8.18 MT is considered general waste, not included in the 628.89 MT figure.

After discussions in Keraniganj, Nawabganj, and Dohar, a proposal has emerged to establish a Waste-to-Energy (WtE) plant in the Suvaddya Union of Keraniganj. It is a 50-acre "Khas land" (owned by the government but currently used by the upazila parishad for various purposes). The selected site has electricity and road connectivity. There is a 12 ft wide road with brick soling. However, it is situated in a low-lying area. Thus, it requires road and land development.

As per Bangladesh's Solid Waste Management Rules 2021, waste-to-energy solutions take precedence in urban areas for effective solid waste management. Despite being designated as upazilas, Keraniganj and Nawabganj exhibit urban characteristics due to their proximity to Dhaka South City Corporation, featuring numerous high-rise buildings. These areas, housing a substantial population connected to the capital city, warrant attention for enhanced waste management. Local governments have the opportunity to update policies to ensure comprehensive improvements in waste management practices.

Please scan the QR code to access the comprehensive waste characteristics study.

Annex 2 – Indicative Project Layout



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