MUNICIPAL CORPORATION OF GREATER MUMBAI (MCGM)

DEVELOPMENT OF WASTE-TO-ENERGY (WTE) PROJECT AT DEONAR, MUMBAI

FEASIBILITY & DETAILED PROJECT REPORT

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Abbreviation:

AAI	Airport Authority of India
AC	Alternate Current
ACB	Air Circuit Breaker
ACMS	Ash Collection & Management System
ACW	Auxiliary cooling water
AMF	Auto Mains Failure
BARC	Bhabha Atomic Research Centre
BH	Bore Hole
BLF	Bioreactor Landfill
BOOT	Build Own Operate Transfer
BOP	Balance of Plant
C & D	Construction & Demolition
C & I System	Control & Instrumentation System
C/N ratio	Carbon to Nitrogen ratio
CBRI	Central Building Research Institute
CRRI	Central Road Research Institute
CSIR	Council of Scientific and Industrial Research
CCZM	Colour Coding Zoning Map
CEMS	Continuous Emission Monitoring System
CLCS	Closed Loop Control System
COC	Cycle of Concentration
CPCB	Central Pollution Control Board
CPHEEO	Central Public Health and Environmental Engineering Organization
CRZ	Costal Regulation Zone
CST	Central Sales Tax
CT	Cooling Tower
CTE	Consent to Establish
CTO	Consent to Operate
CW	Circulating Water
DBO	Design Built and Operate
DC	Direct Current
DCS	Distributed Control System
DESP	Dry Electrostatic Precipitators
DIC	District Industries Centre
DM	Demineralization
DP	Development Planning
DPR	Detailed Project Report

EC	Environmental Clearance
ECS	Emission Control System
EIA	Environmental Impact Assessment
EMP	Environmental Management Plan
EPA	Environmental Protection Agency
EPABX	Electronic Private Automatic Branch Exchange System
ESP	Electro Static Precipitator
ETP	Effluent Treatment Plant
EU	European Union
FFS	Feedstock Feeder System
FGD	Flue Gas Desulfurization
FID	Flame Ionization Detector
GoM	Government of Maharashtra
GT	Generator Transformer
HDPE	High-density polyethylene
HVAC	Heating, Ventilation and Air Conditioning
HVWS	High Velocity Water Spray
IBA	Incinerator Bottom Ash
ICB	International Competitive Bidding
ICT	Information Communication Technology
IDCT	Induced Draught Cooling Tower
IE	Independent Engineer
IS	Indian Standards
ISWM	Integrated Solid Waste Management
LTP	Leachate Treatment Plant
LVS	Large Video Screen
MB	Mixed Bed
MCCB	Module Case Circuit Breaker
MCF	Micro Cartridge Filter
MCGM	Municipal Corporation of Greater Mumbai
MHP	Municipal Handling and Pre Processing Plant
MoEF & CC	Ministry of Environment Forest and Climate Change
MOG	Magnetic Oil level Gauge
MPCB	Maharashtra Pollution Control Board
MPCS	Manufacturer Proprietary Control System
MSL	Mean Sea Level

MSW	Municipal Solid Waste
NDIR	Non Dispersive Infrared Sensor
NEERI	National Environmental Engineering Research Institute
NFPA	National Fire Protection Association
NOC	Non Objection Certificate
OLCS	Open Loop Control System
OHS	Occupational Health & Safety
OSR	Oil Surge Relay
PCB	Poly Chlorinated Biphenyl
PIL	Public Interest Litigation
PLC	Programmable Logic Controller
PPA	Power Purchase Agreement
PRD	Pressure Relief Device
PVC	Poly Vinyl Chloride
RCC	Reinforced Cement Concrete
RDF	Refuse Derived Fuel
RFID	Radio Frequency Identification
RO	Reverse Osmosis
RQD	Rock Quality Designation
SCADA	Supervisory Control And Data Acquisition
SCC	Submerged Scraper Chain Conveyor
SG	Steam Generator
SLF	Sanitary Landfill
SNCR	Selective Non Catalytic Reduction
SOC	Sequence of Events
SoR	Schedule of Rates
SPM	Suspended Particulate Matter
SPT	Standard Penetration Test
SS	Stainless Steel
STG	Steam Turbine Generator
STP	Sewage Treatment Plant
TAC	Tariff Advisory Committee
TCE	Tata Consulting Engineers
TPD	Tonnes Per Day
TPN	Triple Pole Neutral
UF	Ultra filtration
ULB	Urban Local Bodies

UPS	Uninterrupted Power Supply
USD	US Dollars
VAT	Value Added Tax
VCM	Vacuum Circuit Breaker
VED	Volumetric Energy Density
WESP	Wet Electrostatic Precipitators
WHO	World Health Organization
WtE	Waste to Energy
WTP	Water Treatment Plant
XLPE	Cross Linked Polyethylene

Executive Summary

The Municipal Corporation of Greater Mumbai (MCGM) a local authority for Brihanmumbai area formed under Mumbai Municipal Corporation Act, 1888 is responsible for providing municipal and civic services to the citizens of Greater Mumbai, including collection, transportation, processing and disposal of Municipal Solid Waste (MSW) generated within their jurisdiction. As part of this endeavour, the MCGM has planned to install a Waste-to-Energy (WtE) Project in Mumbai which will have a capacity of approx. 3000 Tons per day in modules (the "Project") and which is compliant with SWM Rules 2016 and all other applicable rules.

1. Background:

The Municipal Corporation of Greater Mumbai currently generates above 8000 tonnes of Municipal Solid Waste per day, with an average per capita generation rate of about 540 grams/ capita/ day. Currently, the waste dumpsite at Deonar receives approximately 5100 TPD of waste from Mumbai which includes approximately 4100 tonnes of MSW and 1,000 TPD of construction and demolition (C&D) waste[1]. Waste is being dumped at Deonar dumpsite without any processing.

The present project is for processing of 3000TPD waste by way of Waste to Energy (WtE) project at Deonar. The post processing rejects like ash (Bottom and Fly ash) would be utilized for useful purposes like making brick, tiles etc. The pre-processing rejects will also be used for construction purpose to the extent possible.

Project Objective

The objectives of the proposed project are as follows:

- Provide environmentally safe and sustainable solution to implement an affordable system and technology for the WtE project that is easy to maintain and in-line with the global standards
- To reduce the MSW burden on landfill
- To improve environmental condition

Project Benefits:

The implementation of WtE project will benefit in many ways as summarized below:

1.	Reduction of Landfill area requirement	Implementation of WtE project may reduce the waste volume by 90%[2]. Considering the lifecycle of 25 years, it will save Landfill area requirement by more than 80 Ha.
2.	Compliance to SWM Rules 2016	SWM Rules 2016 mandates waste processing. Rejects generated after waste processing can be sent to landfill.

[1] Initial Environmental Examination Report for 1000 TPD Waste to Energy Project for MCGM at Deonar, Mumbai

[2] Report of the Task Force on Waste to Energy Volume I, 2014

3.	Environmental Benefits	There are several environmental benefits from this project like: i. Prevention of frequent fire at Deonar site ii. Spillage of waste to CRZ Areas iii. Prevention of smoke and fugitive emission to the nearby areas. The study shows that about 22 diseases can be prevented by managing solid waste[3] iv. Prevention of pollution to surface and ground water
4.	Reduction in Green House Gas (GHG) Emissions	Using waste for production of energy will save on fossil fuel and in turn reduce Green House Gas (GHG) emission. It is estimated that implementation of WtE plant for Mumbai will save more than 8 million tons of CO_2 equivalent GHGs in 20 years period.
5.	Safety to Flying Zone	Risk due to bird menace can be prevented at Deonar dumpsite
6.	Social Benefit	The project may have multiple health benefits to the people of nearby areas and will improve the overall health benefits to entire city by way of achieving better air quality. The rag-picking menace, child labour and other hazardous recycling activities can also be prevented by implementation of WtE Project.
7.	Resource Conservation	The project will produce Energy from the plant having capacity of 25 - 30MW. This will help in conserving resources.

2. Waste Characteristics and Project site Information

A comprehensive study was carried out for waste characterization of Mumbai by National Environmental Engineering Research Institute (NEERI) in year 2014-15. The revised final report for this study was submitted in 2016. This report is taken as basis for project design for WtE in conjunction with several other reports/ studies carried out in last 4-5 years.

The waste analysis report clearly depicts that it has high moisture content (60-80%). The calorific value ranges from 530 - 1200 Kcal/Kg. The waste may require pre-processing (to reduce moisture content and enhance calorific value) to meet the requisite feedstock quality as mandated in SWM Rules 2016 (Calorific value should be above 1500 Kcal/Kg). Pre-processing is part of WtE technology. The calorific value can also be enhanced by pre-stream waste management i.e. during collection and transportation.

3. Technology Screening and Design Basis for WtE

Various technologies were evaluated for WtE considering the scale of the project, environmental sensitivities, land area availability etc. Their advantages and dis-advantages were discussed considering site constraint and meeting the regulatory requirement, i.e. SWM Rules 2016.

[3] Report of the Task Force on Waste to Energy Volume I, 2014

Thermal technologies, viz. Incineration (different types of incineration), gasification and Pyrolysis are better suited for the present scale of the project comparing biological process such as Bio-methanation. Pyrolysis is also not yet proven for large scale project for MSW.

4. Regulatory Framework and clearances

The proposed project requires clearances under several Acts and Rules, of Govt. of India (GoI). The important clearances required for the project are given below:

1. Solid Waste Management Rules (2016)
2. Coastal Regulatory Zone (CRZ) Rules 2011
3. EIA notification, 2006. The project category under EIA Notification is given in following table:

Project or Activity		Category with threshold limit		Conditions if any
		A	B	
(1)	(2)	(3)	(4)	(5)
1(d)	Thermal Power Plants	≥500 MW (coal/lignite/ naphta & gas based); ≥50 MW (Pet coke diesel and all other fuels including refinery residual oil waste except biomass). >20 MW (based on biomass or non-hazardous municipal solid waste as fuel).	<500 MW (coal/ lignite/ naphtha and gas based); <50 MW≥ 5MW (Petcock diesel and all other fuels including refinery residual oil waste except biomass) <20 MW>15 MW (based on biomass or non-hazardous municipal solid waste as fuel).	General Condition shall apply Note: (i) Power plants upto 15 MW based on biomass and using auxiliary fuel such as coal, lignite, petroleum products upto 15% are exempt (ii) Power plants upto 15 MW, based on non-hazardous municipal waste and using auxiliary fuel such as coal/ lignite/ petroleum products upto 15% are exempt. (iii) Power plants using waste heat boiler without any auxiliary fuel are exempt.
7(i)	Common Municipal Solid Waste Management Facility (CMSWMF)		All projects	General Condition shall apply

5. Project Design Concept

The 'Technology Screening' study clearly indicates that Incineration is one of the potential technology which may meet the present project objectives. The feedback from vendors and case studies of similar scale of projects worldwide has several examples of successful WtE project based on Incineration technology. Therefore, for present project, 'Incineration Technology' is adopted for feasibility study preparation of Detailed Project Report (DPR).

The DPR is prepared considering the requirement of SWM Rules 2016. Details of design consideration are given as below:

1. **Land Area Requirement:** The area of 12.19 Ha (contagious land) and another 2 Ha (Non-contagious land is identified for the project. In this land area is sufficient for Plant and machinery, all the peripheral infrastructure, Brick making facility from ash, Ash pond for 1.5 years, Interim storage of inert for 1.5 years etc. The area statement is given in following table.

Table E1: land Availability and Depth of Existing MSW

Land Availability and Depth of Existing MSW					
Land Parcels	**Area**	**Unit**	**Located in**	**MSW above Avg. Ground Level**	**Remark**
A	1.39	Ha.	Non-CRZ	3-4 m	Small Land Parcel near partial Closure toe
B	7.5	Ha.	Non-CRZ	3-11 m	Main Land Parcel
C	3.3	Ha.	In CRZ-II & 100 m away from HT Line	3-11 m	Add on for Land Parcel B
D	2.0	Ha.	Non-CRZ at the Southern side (near Entrance)	Not available	Separate land parcel
Total	**14.19**	**Ha.**			

Note:
RL of the Average Ground level is 7m.
As per Geotechnical Survey (July-2005), average depth of MSW below average GL is minimum 10m.
As per Contour map (December-2014), Average depth of MSW above average GL is undulating from 3m to 11m range.

The available land parcel is also shown in Figure E1.

The available land area as given in Table E-1 above is sufficient only for WtE plant and for interim storage of rejects (Ash and pre-processing). Ash generated from process (Fly and bottom ash) needs to be utilized 100% in various ways. Commonly, the fly ash is utilized in cement industries and making blocks. Bottom ash can also be utilized for brick making and as sub-grade material for road construction etc. Area of 2Ha is earmarked for establishing facility for utilization of rejects.

Other rejects, i.e. pre-processing rejects and some amount of process rejects needs to be land filled in Sanitary Landfill (SLF). The area required for SLF is about 14Ha, however, considering that 100% utilization of ash, the area required for SLF for 20 years would be about 10Ha.

This land can be developed from the existing dumping site by way of transporting of waste to other dumping sites, processing and utilization of inert in filling the low lying areas etc. Developing SLF will require separate project provision considering the large amount of waste lying at the site and this will also attract Environmental and CRZ Clearances.

2. **Pre-processing:** The waste needs to be pre-processed to meet the requirement of SWM Rules 2016 and also for reducing emission. Pre-processing will also ensure the homogenisation of the waste and uniform feed quality for seasonal and daily variation.
3. **Water Treatment and other Peripheral Infrastructure:** The water requirement for the plant would be taken from Ghatkopar STP lagoon by 3.5 km pipeline along the dumpsite. This water to be further treated for use in WtE plant.

   Utilization of STP water will help in reducing the burden on fresh water resources for the city on sustainable basis.
4. **Continuous Emission Monitoring System (CEMS):** CEMS is one of the important requirements for WtE plant to monitor the emissions for regulatory compliance and mitigation which is taken into consideration for project design.

   CEMS will help in timely action for mitigation of air emissions and maintaining the air quality to the required standard.
5. **Project Layout Plan:** The main objective of the proposed project is to process 3000 TPD waste on regular basis. While Power generation is one of the secondary output. For meeting this objective, the plant would have sufficient redundancy to cater for 100% waste processing with day to day and seasonal variability in waste quality.
6. **Emission Control:** The WtE plant will meet the emission standard as specified under SWM Rules 2016.
7. **Reject Management:** A facility for rejects management is proposed in the project in the area of 2Ha. Further to this, additional area is required for SLF, which needs to be developed separately.
8. **Power Evacuation:** The power generated from WtE plant will be evacuated through the nearest grid. This would either be sold to DISCOM or for captive use of MCGM. In later case, wheeling charges would be applicable.

6. Social & Environmental Analysis

There are many environmental and social benefits by implementation of WtE project. The major social and environmental benefits of the WtE project are summarized as below:

1. **Emission control:** The WtE project implementation will significantly lower the present un-controlled emission from dump site. It will also prevent the frequent fire at the site.
2. **Odor & Noise:** The proposed WtE project will comply to the SWM Rules 2016 and any noise or odour problem is not envisaged.
3. **Rag picking:** Rag picking and child labour is associated problem. The WtE project implementation to some extent will able to combat this menace.
4. **Health Benefits:** The air quality of the area will improve after implementation of this project. It is expected that many diseases like respiratory, tuberculosis etc will come down.
5. **Aesthetic Environment:** The aesthetic environment will improve after project implementation as it will reduce the dump area. The planned structure with green belt will significantly improve the aesthetic of Deonar.
6. **Employment:** There would be generation of employment in formal sector after WtE plant. This will benefit to large extent the local population.

7. Environmental Management Plan (EMP)

The EMP is prepared for Construction and Operation phase of the project. The EMP will meet the following specific objectives:

- To adopt construction and operational methods which will limit environmental degradation
- To protect physical environmental components such as air, water and soil
- To conserve terrestrial and aquatic flora and fauna
- To incorporate the views and perceptions of the local inhabitants on the project
- To generate employment opportunities wherever possible and feasible
- To provide environmental guidelines and stipulations to the construction Contractors to minimize the construction related impacts
- To provide adequate safety systems to ensure safety of public at large
- To establish post construction monitoring program to monitor effects of the project on the environment

Apart from EMP, Risk for the project are also identified.

8. Quantity & Cost Estimate

The block cost summary cost for the project is given in following Table:

Table E2: Summary of Block Cost Estimate of Waste to Energy Project

Component	Description	Cost (Rs. Crores)
Component-A	Cost Centre A1.1: Site & Peripheral Preparation including 1.Site Survey, 2.Geotechnical Investigation, 3.Waste Physico-chemical Characterization Study 4.Site Clearance, Excavation, Filling & Compaction 5. Compound Wall 6. Pipeline & Pumping Station 7.Preparation of Eastern Peripheral area slope 8. Landscaping 9. Storm Water Drain	146.95
Component-B	Cost Centre A1.2: Design including all approvals	28.64
Component-C	Cost Centre A1.3: Pre-Processing Plant	138.00
Component-D	Cost Centre A1.4: Processing Plant (Electric Power Plant) including Civil, Electrical, Mechanical, I&C, Water System, Construction, Supervision, Pollution Control Equipments, etc.	469.09
Component-E	Cost Centre A1.5: Allied Infrastructures including Internal Road, Storm Water Drainage, Fire Ring main, Weighbridge, Water Treatment Plant and Storage, Leachate Treatment Plant, Sewage Treatment Plant, Effluent Treatment Plant, Truck Parking area, Security Booth, Administration/ Laboratory Building, Pile Foundation Car Parking, Material Entry/ Exit Gate, Visitor Entry/ Exit Gate, Workers Area, Canteen, Landscape area with irrigation system complete, Pile Foundations, Continuous Emission Monitoring System (CEMS), Information Communication Technology (ICT), Auxiliary Power Supply System, Laboratory Equipments, Safety and security arrangement including electronic surveillance, etc.	54.53
Component-F	Cost Centre A1.6: Power Evacuation Line	21.17
Component-G	Cost Centre A1.7: Process by-product Management and Disposal (Ash/ Sludge/ Rejects/ other) Plant	4.99
Component-H	Cost Centre A1.8: Tests on Completion and Training	9.38
Component-I	Cost Centre A1.9: Provisional Sums – General	5.00
	Total (Rs. Crores)	**877.76**

Note:

Above estimate is subject to change based on following considerations

1. MCGM Schedule of Rate (SoR): 2014, Standard Manuals, Reports and Market Rates.
2. Site clearance, excavation and filling are calculated considering complete removal of legacy waste from the proposed plant area. There is scope for the Contractor to propose innovative technology which may lead to reduction in cost and time of site preparation.
3. Some of the sub-components considered for above estimate may not be applicable or may get replaced depending on the selection of the pre-processing and processing technology.
4. Above cost estimate is inclusive of prevailing taxes.

Figure E1: Land Parcel for the Proposed WtE Site

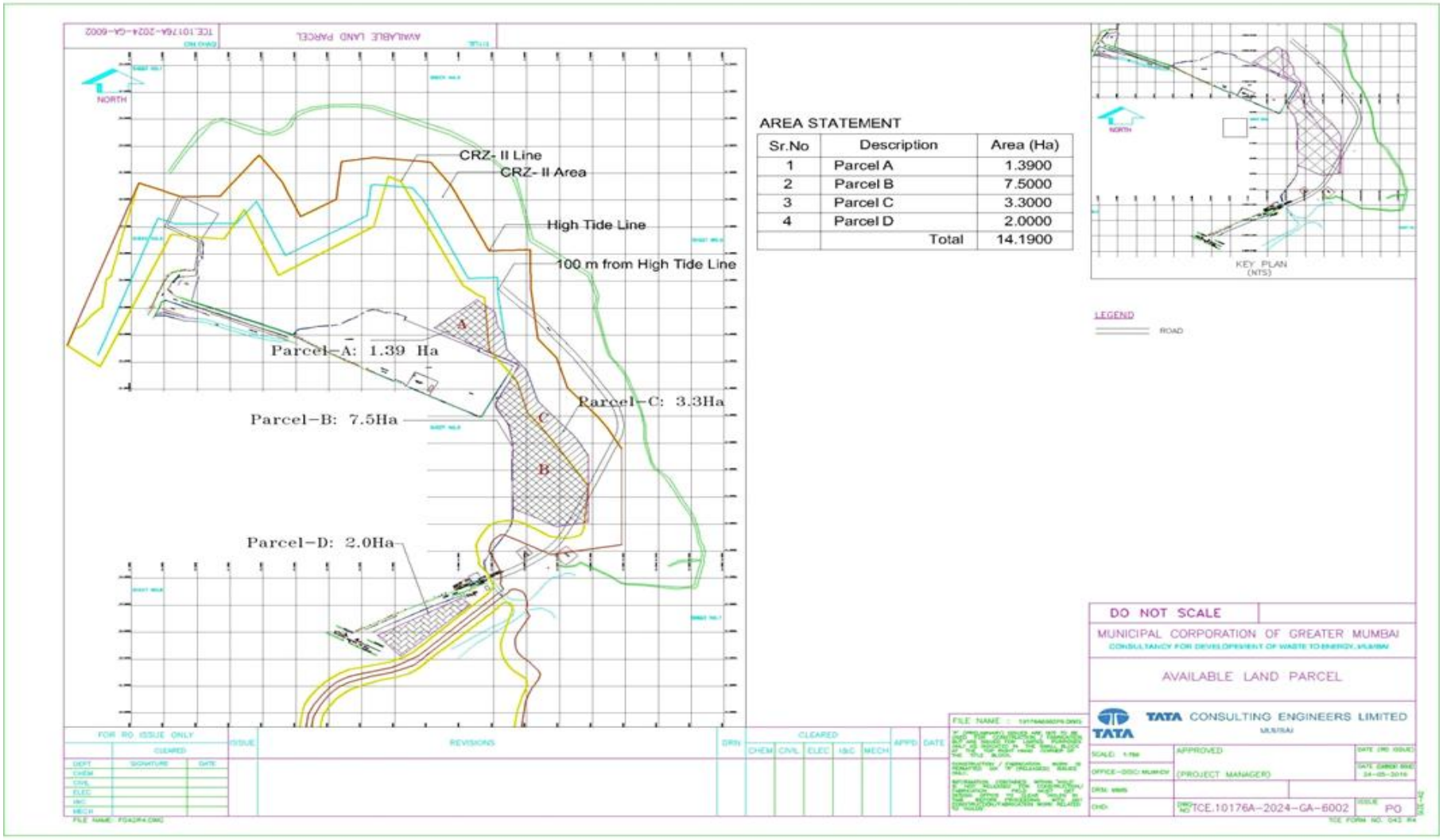
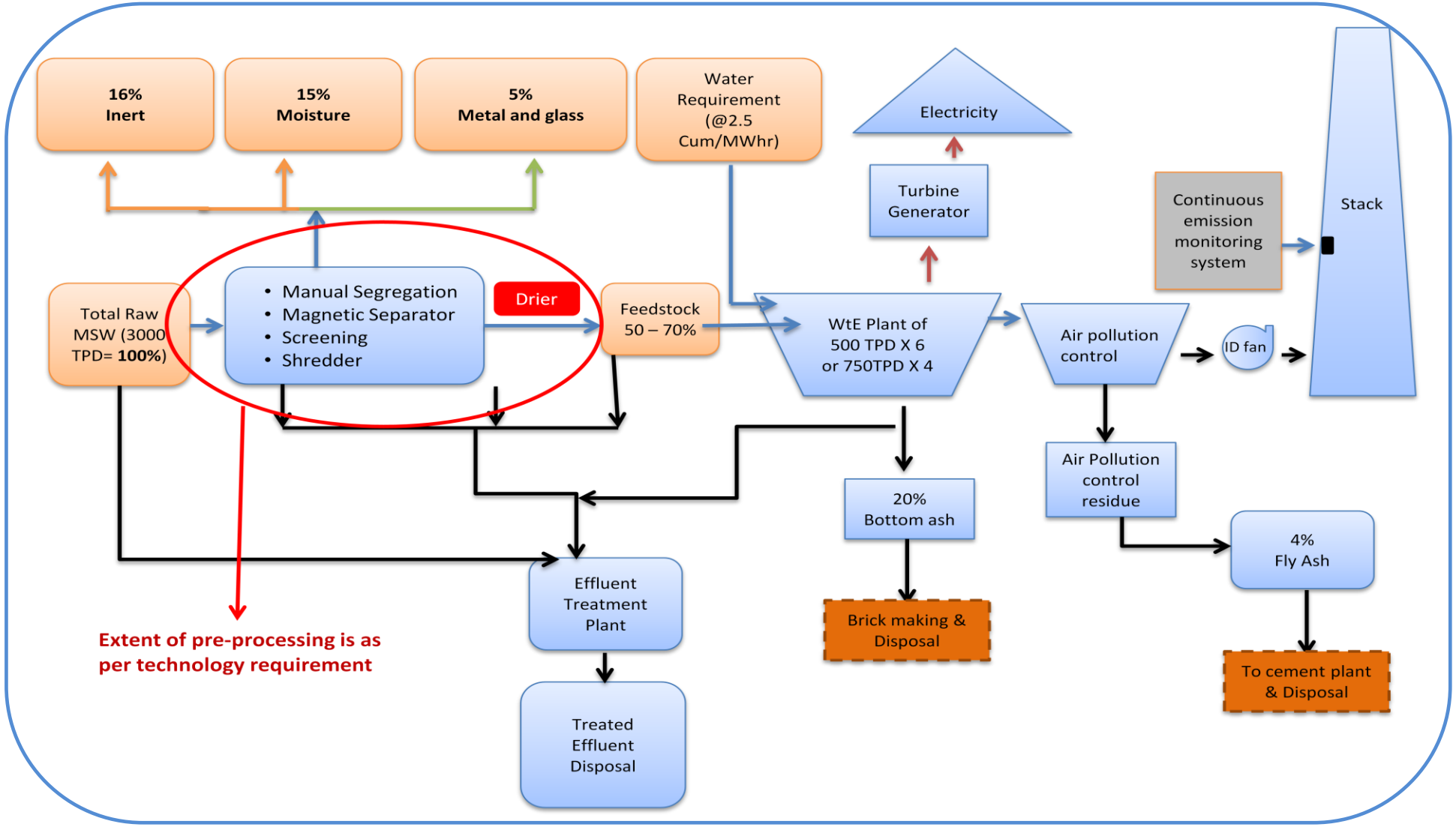


Figure E2: Flow Diagram for typical WtE



9. Funding Scenario and Financial Model

The WtE project for Mumbai is very important project for efficient waste management. This is also going to be the largest project (3000TPD) in India.

The important constraints for the project are land availability (carved out from existing dumpsite) and water (treated waste water from Ghatkopar STP). The project location has environmental and social sensitivities. Therefore, the project cost is very high comparing to the similar project elsewhere.

Considering the several constraints and objective of the project, DBO model is more feasible for project implementation. In this model, the project control would be in hand of MCGM and its close monitoring is possible. In another model, like PPP, there is a risk of shifting of objective from waste processing to energy generation. Also, in PPP mode, the Viability Gap Funding (VGF) would be in tune of about 50%.

Cost of Generation of Power

(i) With the project being financed by MCGM, considering 20 Years Operation Service period the levelized is arrived at considering:

a. Recovery of only capital investment during the project life
b. Operation Service charges considered @ 5% per annum of the Capex Cost with an annual escalation of 5.72% and
c. Asset Replacement Fund considered at 1% per annum of the Capex cost

The levelized tariff work out to **Rs. 7.42/ kWh**

(ii) Considering only Operation Service carried out by the Contractor for a period of 20 Years the levelized tariff is arrived at taking:

a. Operation Service charges considered @ 5% per annum of the Capex Cost with an annual escalation of 5.72% and
b. Asset Replacement Fund considered at 1% per annum of the Capex cost

The levelized tariff works out to Rs. 4.20/kWh.

10. Project Implementation Strategy

It is proposed to award a comprehensive contract to Commission Waste to Energy project and its Operation service, thereafter for a period of 20 years to a pre-qualified and competitively selected private operator through an International Competitive Bidding (ICB) process.

The project design and construction period is about 30 months, includes six months of commissioning. The project is new technology and of very large scale. The Asset replacement for the project is expected during 8^{th} to 10^{th} year. The project needs sufficient time for better yield. Considering all these factors, the Operation service period for the project is considered as 20 years.

11. Literature review

Several documents were reviewed for preparation of the DPR, this includes, IDECK Report for 1000TPD waste processing and related RFP and RFQ documents for year 2015.

The CPHEEO Manual 2016 and SWM Rules 2016 were also referred.

CHAPTER 1: Introduction

1.1 Background

A waste is viewed as a discarded material, which has no consumer value to the person abandoning it. According to World Health Organization (WHO), the term 'solid waste' is applied to unwanted and discarded materials from houses, street sweepings, commercial and agricultural operations arising out of mass activities. It is a mixture of vegetable and organic matter; inert matters, such as glass, metal, stones, ashes, cinders, textiles, wood, grass etc. Uncontrolled waste dumping or waste disposed in unscientific landfills can have serious environmental impacts: landfills consume land space, and cause air, water and soil pollution. Growing population, increased urbanization rates and economic growth are dramatically changing the landscape of domestic solid waste in terms of generation rates, waste composition and treatment technologies[4].

Without an effective and efficient solid-waste management program, the waste generated from various human activities, both industrial and domestic, can result in health hazards and have a negative impact on the environment. Understanding the waste generated, the availability of resources, and the environmental conditions of a particular society are important for developing an appropriate waste-management system.

Mumbai, the financial capital of India, and also its largest city, is currently facing a solid waste management crisis.

This is spread over an area of around 437.71 Sq km, located at 19°4.3698′ N 72°52.9566′ E. Total 12.5 million people as per the 2011 Census with floating population of about 5 million. The infrastructure has been unable to keep pace with economic development and population growth and resulted in insufficient collection of MSW and over-burdened dumps. Improper disposal of solid wastes over several decades and open burning of garbage have led to serious environmental pollution and health problems. Greater Mumbai is expected to generate about 11,000 tons of municipal solid waste in 2021. Accordingly, a total of 397 hectares of land-fill area would be needed to meet the demand. Given its increasing population, rapid expansion of urban areas, and scarcity of land as it is an island, Mumbai needs a solution to its burgeoning solid waste management problem that will be sustainable, cost effective, and minimizes public health, ecological, and climate change impacts.

In a typical city, about 60-70% of the budgeted amount for solid waste management works is spent on street sweeping of waste collection, 20% to 30% on transportation and less than 5% on final disposal of waste[5] .

The Municipal Corporation of Greater Mumbai currently generates above 8000 tonnes of Municipal Solid Waste per day, with an average per capita generation rate

4 World Energy Council 2013

5 Development of Solid Waste Management Project at Mumbai -Draft Project Report 2015 by IDECK

of about 540 grams/ capita/ day. Currently, the waste dumpsite at Deonar receives approximately 5100 TPD of waste from Mumbai which includes approximately 4100 tonnes of MSW and 1,000 TPD of construction and demolition (C&D) waste[6]. Entire waste is being dumped at Deonar dumpsite without any processing.

The present project is for processing of 3000TPD waste by way of Waste to Energy (WtE) project at Deonar. After processing of waste, only rejects (pre- and post processing) would be land filled.

1.1.1 **Waste Management Strategy for Mumbai**

The Municipal Corporation of Greater Mumbai (MCGM) a local authority for Brihanmumbai area formed under Mumbai Municipal Corporation Act, 1888 is responsible for providing municipal and civic services to the citizens of Greater Mumbai, including collection, transportation, and disposal of Municipal Solid Waste (MSW) generated within their jurisdiction. Waste processing is mandated under SWM Rule 2016. MCGM, as part of their endeavour, implementing several projects for MSW management in Mumbai, including, Waste-to-Energy (WtE) Project. The WtE project will have a capacity of approx. 3000 Tons per Day (the “Project”) and which is compliant with SWM Rules 2016 and all other applicable rules.

The present Detailed Project Report (DPR) is prepared for developing the Waste-to-Energy (WTE) Project for Mumbai. This is based on the applicable Rules and regulatory requirements for MSW management in India. Also taken into consideration various guidelines and best practices in this sector.

The integrated waste management approach discussed as the latest waste management philosophy advocates 5R principal emphasising on Refuse, Reduce, Reuse, Reform and Recycle. Minimization of wasteful usage and proper segregation of waste are the key areas of waste management.

Management of municipal solid waste and adoption of processing technologies are dependent on the quantity and characteristics of the total waste generated in a local authority, the financial resources available and in-house capability of local authorities to oversee project implementation.

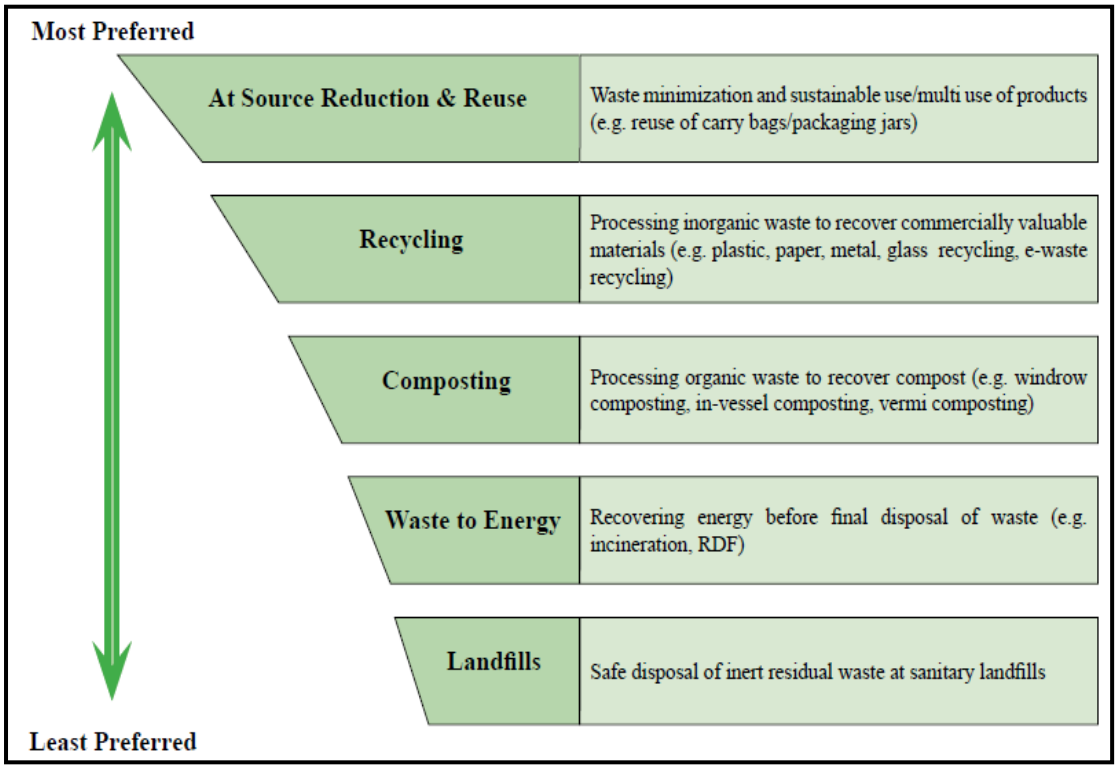
The Integrated Solid Waste Management Approach as discussed in the CPHEEO Manual and SWM Rule 2016 describes the preferability of various waste management options from at source reduction and reuse of waste to disposal of waste in landfill site. The hierarchy is shown in Figure 1.1.

At Source Reduction and Reuse: The most preferred option for waste management in the ISWM hierarchy is to prevent the generation of waste at various stages including the design of products, production, packaging, use and reuse of a product. Waste prevention helps to reduce handling, treatment, and disposal costs and reduces various environmental impacts such as leachate, air emissions and

6 Initial Environmental Examination Report for 1000 TPD Waste to Energy Project for MCGM at Deonar, Mumbai

generation of greenhouse gases. Minimization of waste generation at source and reuse of products are the most preferred waste prevention strategies.

Figure 1.1: Waste Hierarchy



Waste Recycling and composting: Environmentally suitable recycling of waste to recover material resources through a process of segregation, collection and re-processing to create new products is the next preferred alternative. In the waste management hierarchy composting is considered as an organic material recovery process and is often considered at the same hierarchical level as inorganic waste recycling.

Waste to Energy: Where material recovery from waste is not possible, energy recovery from waste through production of heat, electricity, or fuel is preferred. Biomethanation, waste incineration, production of refuse derived fuel (RDF) and co-processing of the sorted dry rejects from MSW in cement kilns are commonly adopted “Waste to Energy” technologies.

Considering the waste generation scenario in Mumbai city, where very large amount of waste is generated (above 8000 TPD), and very low availability of landfill site, WtE technology has the highest potential as this reduces the waste volume by 90% and by weight 80%[7].

WtE processing technology is also in line with Solid Waste Management Rules 2016. There are successful units for WtE worldwide as discussed in latter section of this chapter.

7 Report of the Task Force on Waste to Energy Volume I, 2014

Waste Disposal: Residual inert wastes at the end of the hierarchy are to be disposed in sanitary, lined landfills, which are constructed in accordance with stipulations prescribed in Solid Waste Management (SWM) Rules 2016. All over the world, landfills which integrate the capture and use of methane are preferred over landfills which flare landfill gas. The least preferred option is to dispose waste in landfills, where no landfill gas capture is planned.

While reduce, reuse and recycling are the most important principles for ISWM, WtE facility is preferred for metro city like Mumbai, where waste generation quality is very high.

Following strategies are recommended for ISWM in Mumbai:

- Treat waste to reduce volume to minimise land fill
- Generate energy
- Emissions (solid, liquid, gases) within norms
- Compliance to SWM Rules 2016
- Minimum land use
- Minimum lifecycle cost

WtE processing technology can meet all the above objectives as WtE plant will give high quality product like energy, saves on land, and other environmental benefits like lower emissions to air, water and soil (as less dumping area), health benefits to society and aesthetic of the city.

1.1.2 **Policy and Regulatory Requirement**

The Municipal Solid Waste Management (MSWM) is mainly governed by the SWM Rules 2016 and CPHEEO Manual. The respective municipal bodies need to formulate their own policies for successful implementation of SWM Rules 2016.

Mumbai city generates about 8000TPD waste and managing such quantity of waste requires integrated approach and technologies. Therefore, MCGM is in process of multiple processing facilities for treatment of waste at different locations.

There are many biological and thermal options available for treatment of MSW. These technologies are discussed in detail in Chapter 4.

The waste processing technologies are important for overall waste management life cycle, its success is very much dependent on pre-stream management, i.e. waste segregation at source, collection, transportation and pre-treatment at Transfer Station and at the processing site. These basic requirements for waste management are detailed in following sections.

Source Segregation:

Source segregation is pre-requisite for any waste management strategy. In Indian context, high moisture in waste is common phenomenon. In Mumbai, the moisture content goes up to 70-80%.

Segregated waste has advantage that it can be transported to the compatible processing facility like composting, bio-methanation, bio-reactor landfill or WtE facility. Implementation of this basic strategy will lead to saving of lots of energy in terms of transportation and drying of waste.

Transportation Strategy:

The waste transportation in Mumbai is mostly through compactor trucks and covered vehicles. Covered transportation not only help in preventing unhygienic condition during transportation, but also for preventing waste getting further moist due to its hygro-scoping nature and in rain.

The proper transportation strategy will also help in directing the source segregated waste to respective processing facilities. This will save in lots of transportation fuel and also save in energy for pre-processing of waste.

Secondary Segregation at Transfer Station (TS):

The TS facilities can be upgraded for secondary segregation of waste. This will ensure that some amount of recyclables and other materials can be segregated to be sent for recycling etc. Inert materials can also be segregated at TS and it can be disposed separately, therefore saving on landfill area and energy consumption for pre-processing of waste at WtE facility.

Decentralized Waste Processing Facility:

A large amount of segregated organic waste can be composted at society level itself. This will reduce the overall burden on landfill and save in transportation cost. Composting (including vermin-composting) at smaller level has better control and large amount of compost can be utilized within the society premises. Decentralized composting and Biomethanation plan (in scale of 100 – 200TPD) will help in processing the waste in shorter distance leading to saving in transportation fuel and combating pollution. Use of compost also ensures the nutrient replenishment in soil and saves on use of chemical fertilizer.

Above SWM Philosophy is in line with SWM Rules 2016 and other guidelines. It will help in reducing the overall burden on landfill and reducing the existing landfill volume (by way of using legacy waste in (WtE) plant.

The waste management philosophy as detailed above is very important for successful implementation of any waste processing technologies like WtE. These practices should be implemented parallel to WtE Plant.

1.2 Objectives of the Project:

The objectives of the proposed project are as follows:

- To process MSW as per SWM Rules 2016 and recovery of energy

- Provide environmentally safe and sustainable solution to implement an affordable system and technology for the WtE project that is easy to maintain and in-line with the global standards
- To reduce the MSW burden on landfill
- To improve environmental condition
- To embark on concept of 'zero landfill'

1.3 Project Benefit

The proposed WtE project is part of several initiative of MCGM towards sustainable solid waste management. There would be direct and indirect benefits of this project as given below:

Reduced burden on Landfill:

The land is one of the major constraint in Mumbai. It is estimated that for disposal of waste at the same pace, more than 80Ha of land would be required for 20 years disposal for 3000TPD waste. WtE plant reduces the waste volume by 90% and by weight 80%[8]. Implementation of WtE plant will save on huge amount of landfill requirement.

Control of emissions from fire of the dumpsite and other fugitive emissions:

Fire hazard is very common phenomenon for open dumping sites. Such incidents are happening at Deonar dumpsite as well causing pollution to environment and health hazard. In case of WtE plant, the emissions are controlled by efficient pollution control equipment.

Reduction in Green House Gas (GHG) Emissions:

If the MSW is landfilled instead of combusted, methane is released into the atmosphere. Methane is a far more potent GHG contributing 21 times more to global warming than carbon dioxide.

MSW incineration is a solution far more sustainable than coal with regard to CO_2 emissions. This is mainly due to substitution of landfilling, but also because combustion of biogenic waste is carbon neutral. The degree of CO_2 emissions of MSW incineration highly depends on the waste composition and plant technology[9].

Better Hygiene and Health Benefits:

Open waste dumping is one of the major health hazards as lots of fugitive emission emanates from the dumpsite, which causes several types of diseases to the people living in the vicinity. It also causes soil and water pollution. Many types of contaminants enter into the food chain through soil and water contamination. Many disease vectors also thrive on dumping sites causing several types of diseases.

Implementation of WtE plants will eliminate all such pollution to a large extent.

[8] K. Kasturirangan Report on WtE, 2014

9 ISWA guidelines WtE in low and middle income countries 2013

Prevention of surface and ground pollution:

Implementation of WtE plant will restrict the open dumping, therefore reducing the surface and ground water pollution.

Bird Menace:

The present dumping site at Deonar is by the side of flying zone of Mumbai Airport. Large birds' flying over the dumpsites poses grave danger to the flight. The bird menace can be reduced by project like WtE.

1.4 Report Structure

Based on the scope of work the present DPR for WtE project is developed into following chapters;

Executive summary: This gives overall summary of the project with cost estimates and timeline.

- **Chapter 1: Introduction**: This describes the project background and details of scope and objectives formulated.
- **Chapter 2: Waste characteristics & Project Site Information** The Site details and the relevant primary and secondary information about the site are presented.
- **Chapter 3: Regulatory Framework**. Regulatory requirement of the project, including International Regulations and Guidelines.
- **Chapter 4: Technology Screening:** Technology assessment and their respective feasibility with reference to the proposed project.
- **Chapter 5: Project Concept:** Project components, design basis, layouts/ general arrangements
- **Chapter 6: Social and Environmental Analysis:** Present social and environmental condition of the project vicinity
- **Chapter 7: Environmental Management Plan (EMP):** EMP is for mitigation of negative impacts for the project
- **Chapter 8: Project Risk Management:** Project risk, including environmental, social and financial risk are covered
- **Chapter 9: Quantity and Cost Estimates**: Detailed cost estimate for proposed plant with its ancillary facilities
- **Chapter 10: Funding Scenario and Financial Model:** The different mode of funding for the project
- **Chapter 11:** Project **Implementation Strategy:** Project schedule & time period
- **Chapter 12:** Literature Review

CHAPTER 2: Project Site Information & Waste Characteristics

2.1 Location

Deonar waste dumping ground is situated at the eastern suburb of the city of Mumbai (19.0671°N 72.9197°E) (**Figure 2.1**). The dumping ground extends over 132 hectares and receives about 5,500 metric tonnes of waste and 600 metric tonnes of silt daily. This dumping ground is located in M/East ward.

Joint site visits of MCGM and TCE officials were conducted at Deonar Dumping Ground and Ghatkopar STP Lagoon sites during April – May 2016. The objective of these site visits was to observe the infrastructure facilities like available land pockets, water availability & supply options and other necessary vital data for proposed WtE Plant. First hand observations on environmental and social aspects were also collected and presented in **Table 2.1**.

Table 2.1: Existing Scenario at Deonar

Sr. No.	Attributes	Detail
1.	Location	19.0671°N and 72.9197°E located at Eastern suburb of the city (M/ East Ward). The Site location and its surroundings are depicted in Figures 2.1 and 2.2, respectively.
2.	Area	About 120Ha
3.	Quantity of Disposal	About 5,500 TPD of waste
4.	Current Status of Dumping Site	Currently, the site is 60-70% saturated
5.	Health & Environmental Concern	About 5 km radius of the dumpsite is affected due to frequent fire and air emissions.
6.	Closure of dumping site	The dumpsite is partially closed by covering with C&D waste
7.	Height of waste dumping	Maximum waste height of about 37m (above-ground surface) in the Northern part of the Site. The dumpsite is very near to the landing funnel of Juhu Airport. Height of the waste dump and birds menace is one of the potential safety issues.
8.	CRZ Issue	The entire dumps yard is adjacent to CRZ areas and dumping is extended till CRZ II areas.
9.	Hazardous Waste disposal	The surroundings of the Deonar dump-yard has many recycling centres engaged in hazardous waste recycling and disposal.
10.	Leachate and Drainage system	There are numerous puddles of leachate in dump-yard. There is no drainage system existing

Figure 2.1: Location of the Project Site

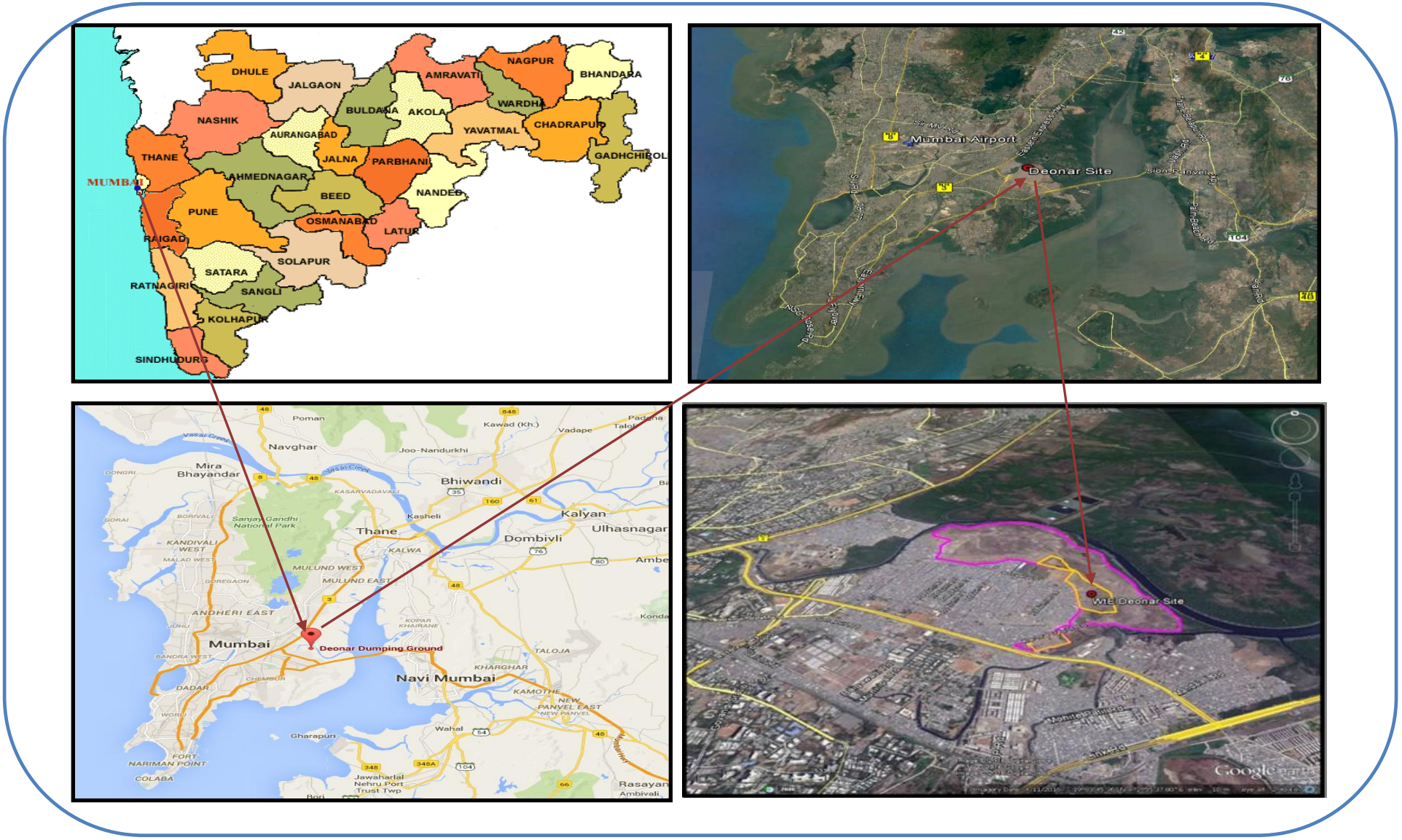
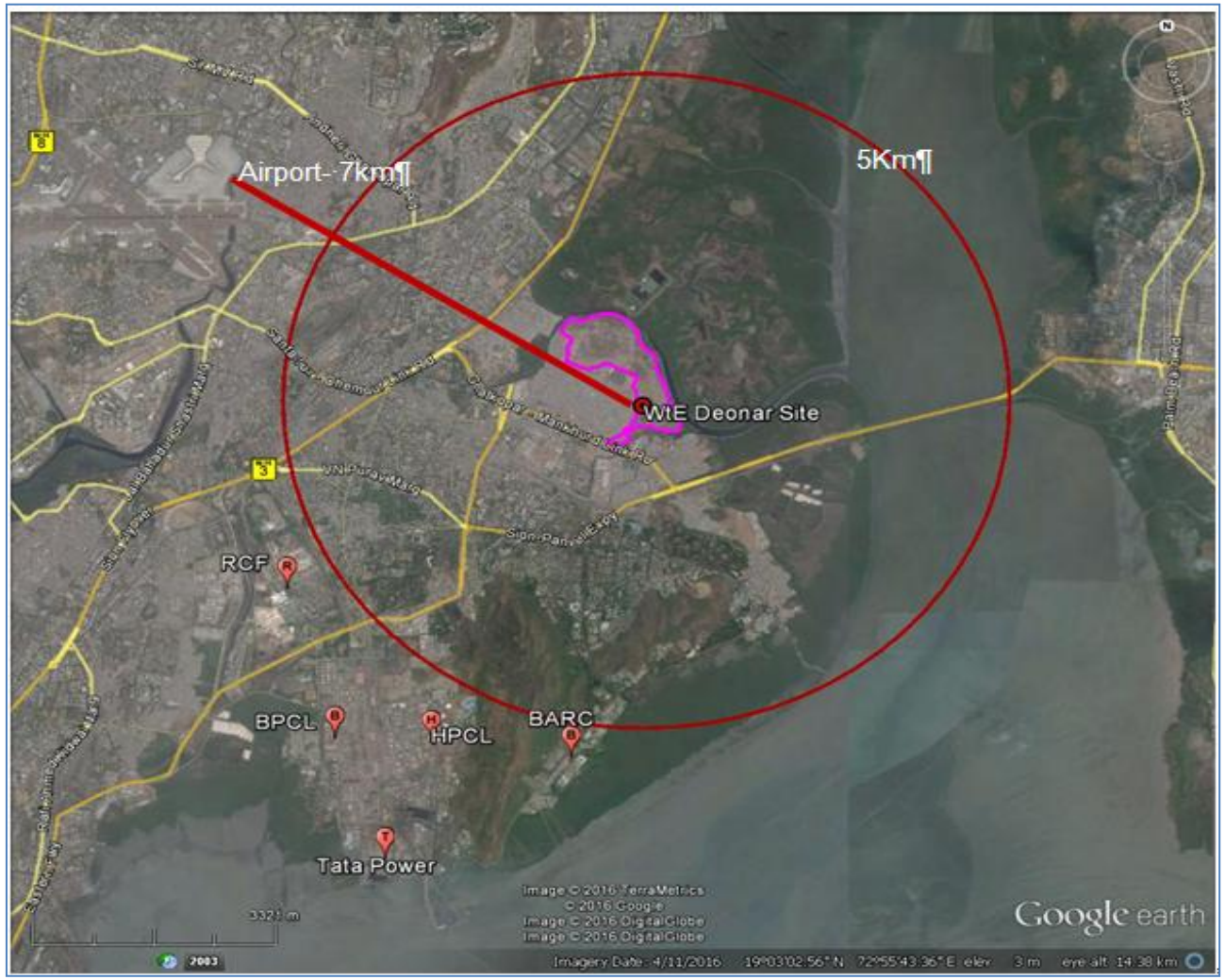


Figure 2.2: The project site and Surroundings



2.1.1 Project Site and Surroundings:

The project site and surroundings are given in **Figure 2.2**.

The proposed WtE site is the part of existing Deonar dumpsite. The area of 14.2Ha land is earmarked for developing the WtE plant. Detail of the available area and requirement are given in Chapter 5.

The North-east side of the site is surrounded by creek with mangrove vegetation, whereas, South-west side is habituated area, mostly slums.

Important organizations and industries, such as BARC, HPCL, BPCL, RCF and Tata Power are located beyond 5Km radius of the project, but within 10km. Mumbai airport is also located at about 7km from the site.

The WtE project at this location will help in reducing several environmental impacts in and adjoin areas including mangroves and creek water quality.

2.2 Baseline Environmental Data

Study of the existing (baseline) environment in a Project Area is important to assess prevailing quality of various environmental attributes such as air, water, noise, and socio-economic conditions in order to assess benefits of the proposed WtE Project on the environment, when implemented.

2.2.1 Geology and Geomorphology of the Region

The geological formations found in Mumbai include the Deccan Basalts and its acid variants, volcanic tuffs, intertrappean sediments, dykes, laterite and alluvium. The geology of Mumbai Island is rather unusual compared to that of the main Deccan flood basalt province, particularly the Western Ghats in several aspects.

The Mumbai Island has ridges along its western and eastern sides running north–south, with broad intervening lowlands between the ridges. The eastern ridge exposes amygdaloidal basalt which in places is albitized and shows pillow structures, red ash, breccia, trachyte, rhyolite and green, black or brown stratified ash. Red ash breccias are lateritized at some places. On the other hand, the western ridge mainly consists of stratified, coarse-grained acid tuff, stratified yellow–brown ash, massive lava flow of andesitic composition and columnar joints. Intertrappeans on Mumbai Island, especially at Worli Hill, have high yield of many fossil animals and plants. Most of the island consists of amygdaloidal basalts and mafic pyroclastic rocks dipping 7–12° W (Sethna 1999).

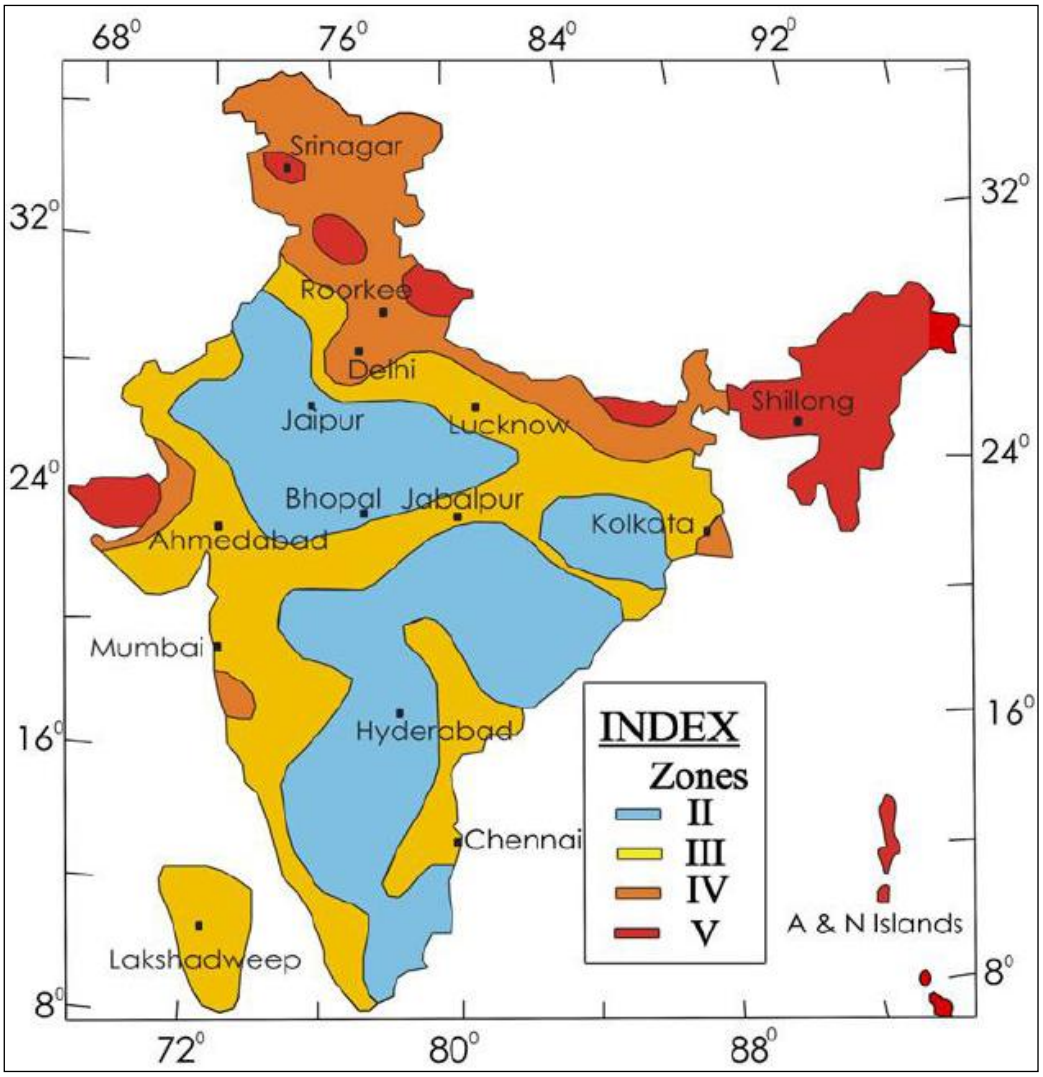
Structural features such as joints, shear zones and intrusions have also affected the morphological setup of the entire Mumbai region. These effects are clearly reflected in the coastal geomorphology and in the naturally distinct land units of the region. On the basis of different geomorphic features, the area has been divided into three distinct geomorphic land units and categorized as: (1) denudational, (2) fluvial and (3) coastal landform. Denudational landforms are formed as a result of active processes of weathering, mass wasting and erosion due to the action of exogenic agents upon the exposed rocks. During these processes, the rocks on the land surface are worn

away and the result is an overall lowering of the land surface. The geotechnical report is shown in Annexure 1.

2.2.2 **Seismic**

The country has been classified into different zones indicating the intensity of damage or frequency of earthquake occurrences by National Institute of Disaster Management (NIDM). These maps are based on subjective estimates of intensity from available information on earthquake occurrence, geology and tectonics of the country. Mumbai falls in Zone III as per the seismic hazard map classified as moderate risk zone. The Seismic map of India is shown in **Figure 2.3**.

Figure 2.3: Seismic map of India



Cyclones are one of the natural hazards that affect India almost every year causing large loss of lives and properties. Being a coastal city, Mumbai is prone to cyclones and gusty winds. Mumbai's vulnerability to extreme weather events was demonstrated on 26th July 2005 when more than 900mm of rainfall occurred in the suburban district in the 24-hour period.

2.2.3 **Ambient Air Quality**

Ambient Air Quality is an important parameter to asses existing level of air pollution due to harmful emissions from the Deonar dumping ground and also to understand its effects on the surrounding environment. The air quality levels at Deonar Dumping Ground from 11 January 2010 to 16 October 2015 are given in **Table 2.2**[10].

Table 2.2: Air Quality Levels from April 2010 to October 2015

Year of Sampling	SO_2	NO_2	SPM	CO	Methane	NH_3	H_2S
2010	9.5	70	388	0.2	10.4	58.5	23.0
2011	1.7	101	325	0.4	3.3	104.36	55.36
2012	3.8	80	523	0.7	5.9	65.9	68.0
2013	10.0	49	903	1.0	21.7	31.7	31.0
2014	17.0	33	529	0.9	-	64.0	49.8
2015	10.3	58	328	1.0	35.5	39.0	116.7

* All values in $\mu g/m^3$

The SPM levels are high throughout the year due to the unscientific practices at the site, there is no pollution control practice currently leading to generation of large amount of fugitive dust from the unloading of waste. The C&D waste is also coming with the Municipal waste in the main stream, due to the inherent nature of C&D waste dust generation is high. The values of SO_x and NO_x are well within permissible limits of ambient air quality, except few occasions, this may be attributed to the open mass burning activity at site.

The impact of different seasons on SPM level is winter > summer > rainy. In winter season, due to temperature inversion, dry condition and low humidity, the SPM levels are higher as compared to other seasons. In summer season, due to higher temperature and mixing height, the SPM levels were lower. The SO_x and Ammonia values were observed within the limit. The values are lowest in the rainy season due to removal of particulates due to precipitation.

2.2.4 Meteorology

Mumbai has a tropical wet and dry climate, and may be best described as moderate temperatures with high level of humidity. The region gets the rainfall from South West Monsoon, which commence usually in the first fortnight of June and last till the end of September. Pre-monsoon showers are received in May. Occasionally, north-east monsoon showers occur in October and November, but rarely more than twice in the entire rainy season.

The average annual rainfall of the District based on last 30 years data is 2457.0 mm. The District receives an average seasonal rainfall of 2363.0 mm during June-September. The data at IMD is usually measured twice a day viz., at 0830 and 1730hr. The nearest meteorological Sampling location of Indian Meteorological Department (IMD) is at Colaba, Mumbai located at 25 km from the site. The

[10] Brihanmumbai Mahanagarpalika Air Quality Monitoring & Research Laboratory Data

secondary data collected from IMD includes wind speed, wind direction, temperature, relative humidity, atmospheric pressure; rainfall and cloud cover over a period of 10 years. The monthly maximum, minimum and average values are collected for all the parameters. The collected data are tabulated in **Table 2.3**.

Table 2.3: Climatological Data-Station IMD, Colaba

S. No.	Month	Temperature (^{0}C)		Mean Relative Humidity (%)		Rainfall (mm)
		Mean Min	Mean Max	0830	1730	
1.	January	19.3	29.5	73	61	0.5
2.	February	20.1	29.8	73	61	1.0
3.	March	22.7	31.2	74	62	0.3
4.	April	25.1	32.4	74	66	1.9
5.	May	26.9	33.4	72	67	11.0
6.	June	26.2	31.9	81	76	583.6
7.	July	25.2	29.9	87	84	750.4
8.	August	24.9	29.5	87	83	460.9
9.	September	24.8	30.3	86	78	258.6
10.	October	24.7	32.3	81	73	64.9
11.	November	23.1	32.8	75	65	10.4
12.	December	21.0	31.4	74	64	3.1

On the basis of above table it is concluded that highest and lowest temperature (^{0}C) values are reported in May and January, respectively. The highest mean relative humidity (%) and rainfall values are reported in July, August and July, respectively, whereas, lowest are reported in January, February and March, respectively[11].

Wind Speed/ Direction

Generally, light to moderate winds prevail throughout the year. Based on IMD information of Colaba station for the past 30 years, winds were light and moderate particularly during the morning hours. During the afternoon hours the winds were stronger. The annual windrose based on 30 year data is shown in **Figure. 2.4** and presented in **Table. 2.4**. The detailed wind speed and direction results should be analysed for stack location and height design purpose.

The annual wind rose based on 30 Years data reveals that wind was blowing predominantly from the North West direction and wind speed was between 2.0 to 3.0m/s. The summary of wind pattern IMD Colaba is shown in **Table.2.4**.

[11] EIA Report for Modernization of Existing Unit #6 (500 MW) for Trombay Thermal Power Station (TTPS), Mumbai (Year 2013)

Figure 2.4: Annual Wind Rose Based on 30 Years Data

Table 2.4: Summary of wind pattern IMD Colaba

Season	First predominant winds		Second predominant winds		% Calm Condition	
	0830	1730	0830	1730	0830	1730
Pre-Monsoon	N	NW	NW	W	10.66	0.67
Monsoon	NW	NW	SW	SW	1	1
Post Monsoon	E	NW	NE	W	8.6	0.67
Winter	NE	NW	E	N	7.33	1.33

Local climatic conditions may be taken into account, such as the severity of the cold and the need for heating insofar as they influence the amounts of energy that can technically be used or produced in the form of electricity, heating, cooling or processing steam[12].

2.2.5 **Noise Level**

The site specific noise level data are not available. The WtE site is located well within the city limit and close to residential and commercial zone.

2.2.6 **Groundwater Quality**

Quality of groundwater depends on a numerous hydrological, physical, chemical and biological factors. Groundwater quality analysis will help to ascertain prevailing activities in the area. 'Status of Groundwater Quality In India - Part – I by CPCB, 2007' gives the details of the ground water quality of Chembur region. Chembur is

[12] Waste-to-Energy in Europe-Ella Stengler 2005

located at approximate aerial distance of 5 km from project site. In Chembur, groundwater quality was observed to be poor as most of the parameters exceeded the limits of Indian Drinking Water Standards BIS-IS 10500: 1991. The reported values of Total Dissolved Solids (TDS) in the groundwater were in the range of 252 mg/l and 1346mg/l. Results indicate contamination by the surface pollutants. The total hardness varied between 53 mg/l and 329 mg/l, Alkalinity varied between 102 mg/l and 970mg/l. The reason for high alkalinity in the Ground water may be due to the percolation of alkaline surface pollutants. The reported Chloride ranged between 23mg/l and 320mg/l. The reported values of Sulphate varied between 18mg/l and 239mg/l. The conductivity ranged between 310µmhos/cm and 1780µmhos/cm, indicating contamination from surface pollutants. The reported values of fluoride were within the limit of 1.0 mg/l. The counts of Total Coliforms and Fecal Coliforms were very high at open dug well during summer. The WtE plant will consider relevant factors to protect groundwater for further contamination.

2.2.7 **Surface Water Quality**

The nearest surface water body of the site is part of Thane creek. The visual observation of the creek water appears polluted, however, the mangroves around it is still in good health. This can be attributed to very high resilience of mangroves for pollution and contamination.

The source of pollution to the creek water is partly due to leachate from present dump as well as from discharge of oily and other contaminants of recycling activities across the creek.

2.3 Waste Characteristics

For the successful operation of WtE project on sustained basis, it is essential to know the physico-chemical quality of waste as well as different categories of the waste generated every day. Seasonal variations of MSW are an important aspect that needs to be considered during waste management. Solid waste generation differs from place to place to a great extent; but in general municipal solid waste includes the decomposable waste from household products during the preparation of meat, food, vegetable, and waste generated from shops, hotels, offices and other commercial units. With ongoing urbanization and change in lifestyle and food habits, the amount of municipal solid waste has been increasing rapidly and its composition is also changing. The characteristics of municipal solid waste collected from any area depend on a number of factors such as food habits, cultural traditions of inhabitants, life styles, climate etc. In order to plan, design and operate a solid waste management system, a thorough knowledge of the quantities generated and composition of wastes are essential.

The significant physical characterisation factors for consideration of technology for the waste processing are:

- Total Compostable waste (Organic fraction, food waste etc);

- Total Combustible waste (compostable waste, paper, plastic, leather, textile, rubber etc);
- Total Non Combustibles (Inerts, glass, metal etc).

The other characteristics of waste that plays a critical role in waste management technologies area:

- Moisture Content
- Calorific Value

MCGM has forwarded to TCE following documents as input for the proposed WtE project with regard to the information on waste characteristics for Mumbai and project site Deonar:

- NEERI Revised Final Report on Waste characterization of Mumbai- **2015** (Deonar Site- Freshly dumped waste values considered).
- MCGM Report on Waste characterization-**2007.**
- World Bank Report on Solid Waste in India, considering India as a Lower middle income country, **2012**.
- NEERI's study on "Assessment of Status of Municipal Solid Wastes Management in Metro Cities and State Capitals" in **2004-2005**.
- Status of solid waste generation, collection, treatment and disposal in metro cities, (CPCB, **2000**) for Mumbai.
- Waste composition for city more than 5 lakh population, Background material for Manual on SWM, NEERI **1996**.

The results of the various studies are varying in composition as well as characterization; hence it is very important to analyze the data applicable to Mumbai city and use probabilistic approach while sizing the various components of the WtE project. The Salient observations from the above table for individual components are:

1) MCGM waste is showing substantially high moisture content compared to other cities. The values are consistently high in the 2007 report and 2015 report. Also the moisture content is high in all samples presented in the report as well as checked at the dumped site. Hence the project needs to adequately factor the high moisture content while formulating the project concept.
2) The biodegradable component is also high compared to other cities.
3) Calorific value reported on dry basis when converted for waste with 50% moisture content, appears high compared to other cities. This high value of calorific value also appears inconsistent to some extent considering the high amount of biodegradable content in the waste. The data also varies significantly between 2007 report and 2016 report.

TCE has brought the inconsistency to the notice of MCGM, and same was communicated to NEERI. In reply from NEERI, they confirmed that the given data in the report is accurate. TCE has used the data presented in 2016 report as base for

further work of DPR which is presented in this report. Any change in the waste characteristic data will have significant impact on the project concept and basis.

2.4 Statistical Analysis of Solid Waste Report

MCGM had carried out a comprehensive study for solid waste for its characteristics through National Environmental Engineering Research (NEERI) in year 2014-15. The revised final report for this study was submitted in May 2016.

This study was carried out for all the wards of Mumbai and its active dumping sites. This is the most relevant study out of all the data sources with reference to the proposed project, as it is recently done and covers entire Mumbai Municipal Corporation waste characterization. The study is conducted for an entire year covering three seasons- pre-monsoon, monsoon and post monsoon. Waste from all 24 wards and old and fresh waste from two existing waste dumpsites- Mulund and Deonar were collected and analyzed for their composition as well as physico-chemical characterization.

Waste characterization is one of the salient factors for designing of a Waste to Energy based project, and firm values are required for all important parameters like waste composition, moisture content, calorific value etc. Considering NEERI study report 2016 as the basis of waste characterization following limitations are encountered:

- The number of seasons of sampling and number of samples are inadequate for interpretation of results for design purpose.
- Waste composition data for monsoon is not available.
- The organic content and moisture content of all the samples is considerably high, as compared to other data sources.
- There is no correlation of parameters like moisture content, inert/ non combustibles, and total solid values with the calorific value. Hence, no trends could be established for waste characterization.
- The calorific value and moisture content for post-monsoon season is similar to monsoon season. This could be due to extended monsoon period in that year. Such detail is not available in the report.

However, in the absence of other detailed and site specific data source, the NEERI report is further analysed to arrive at the range of critical waste characterization parameters for the proposed project.

Table 2.5: Physical Composition and Chemical Characterization of Waste in Indian Cities

Waste category	HEEO/NEERI 1996[a]	CPCB 2000[b]	NEERI 2004-2005[c]	World Bank 2012[d]	World Bank 2025[d]	MCGM 2007[e]	NEERI 2015[f]
Physical Composition (%)							
Paper	6.43	10	–	6	10	–	4
Rubber, leather and synthetic	0.28	Textile-3.6 Leather-0.2	–	–	–	–	–
Glass	0.94	0.2	–	3	4	–	2
Metal	0.80	–	–	2	3	–	2
Total Compostable matter	30.84	40	40-60	59	55	52	79
Inert	53.90	–	-	15	15	15.37	12
Recyclables	–		10-25			19.94	
Plastic	–	2.0		12	13		3
Dry Organic	–					13.6	–
Ash, fine earth and others	–	44	–	–	–	–	–
Other Characteristics (%)							
Moisture Content (%)	38.72	–	30-60	–	–	66	70 - 80
Calorific value Kcal/kg	800	–	–	–	–	905	500 - 1200

Calorific Value:

The key criteria for MSW incineration, as defined in the Draft CPHEEO Guidelines is that, "MSW incineration projects are appropriate only if, the lower calorific value (LCV) of waste must be at least 1450kcal/kg throughout all seasons and the annual average LCV must not be less than 1700kcal/kg.

As per the NEERI report, out of the 78 values the minimum calorific value is 1458 kcal/kg (observed in monsoon) and the average value is 3587kcal/kg. Hence, both the criteria as per CPHEEO are met.

An analysis to understand the trend of calorific value of the waste collected across the 24 wards was performed using bell curve method; the results show that for 71% of the time the values are in the range of 3200 to 4400kcal/kg. The table and the graph showing the results are presented below:

Table 2.6: Calorific value range and the relative occurrence percentage

CV Range	Occurrence	% Occurrence
1400-1700	2	3
1700-2000	2	3
2000-2300	4	5
2300-2600	4	5
2600-2900	5	6
2900-3200	4	5
3200-3500	8	10
3500-3800	19	24
3800-4100	22	28
4100-4400	7	9
4400-4700	1	1

Feedstock for WtE:

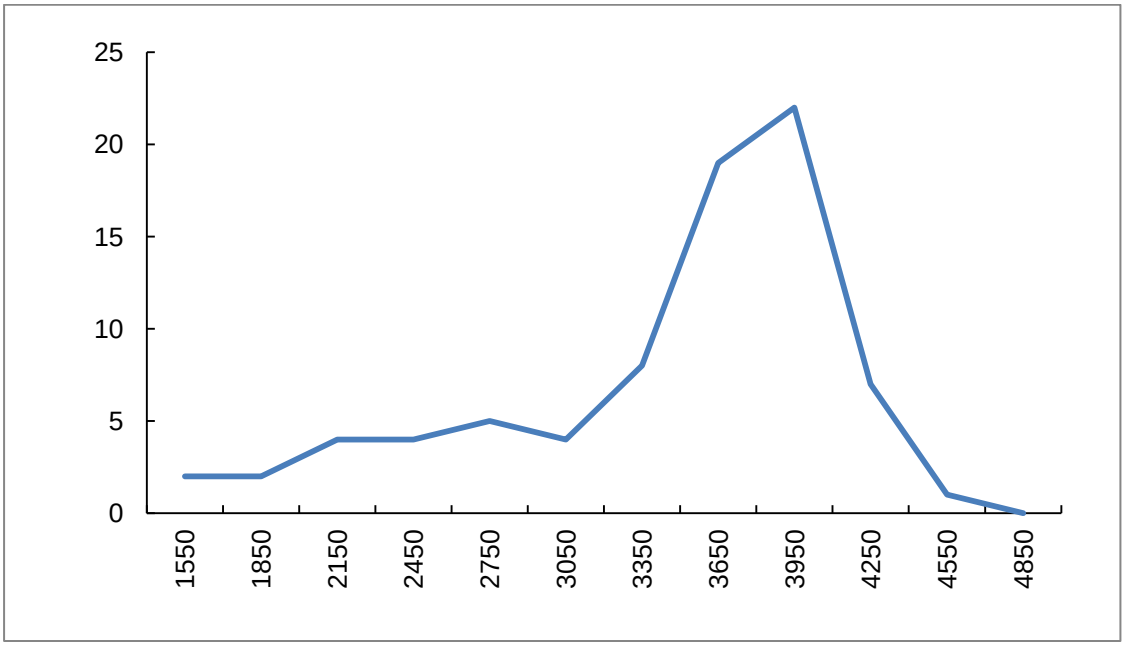
The power generation is the factor of feedstock and its calorific value. Based on the NEERI Report for waste characteristics and requirement as per SWM Rules 2016 as well as CPHEEO Manual for SWM, basic assumptions for calculating variation in power generation of the proposed plant are considered as below:

1. Total waste to be treated is 3000TPD
2. Minimum calorific value for feedstock to be maintained is 1200Kcal/ Kg
3. Maximum moisture content to be maintained at 50%

Therefore, at any given time the feedstock quality should have GCV >1200Kcal/ Kg and moisture content below 50%. This can be achieved by following strategies:

- Pre-processing: The project has mandatory provision of pre-processing of waste not only to maintain the minimum quality requirement (i.e. 1200 Kcal/ Kg and less than 50% moisture), but also to maintain uniform feedstock quality throughout the year.

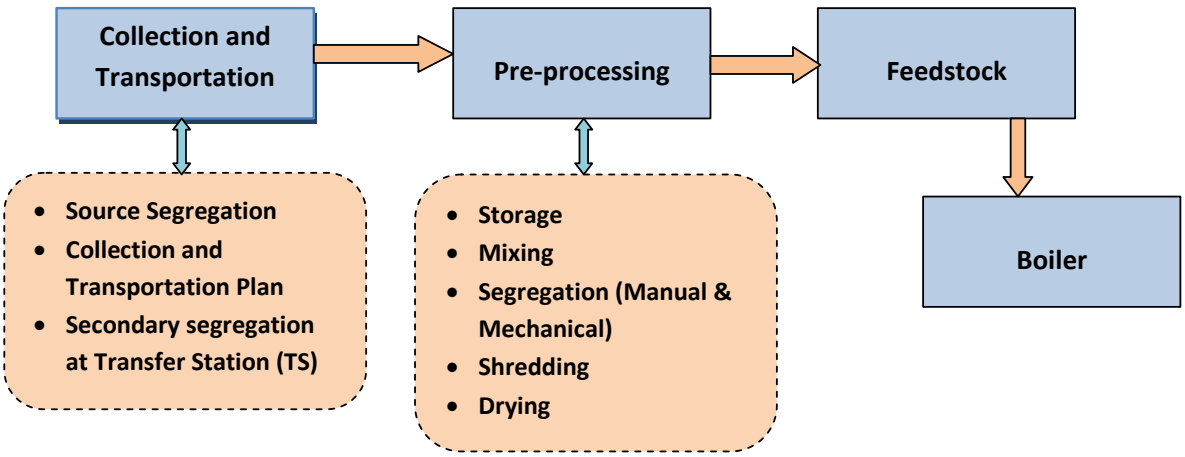
Figure 2.5: Bell curve showing calorific value in kcal/kg vs. occurrence percentage



- Pre-Stream Management: Proper management of waste collection like source segregation of waste, its transportation (segregated waste to be transported separately etc.) will help in maintaining the good quality of feedstock. This will also save in energy required for pre-processing of the waste.
- Mixing of waste: Another way of maintaining uniform quality of feedstock is to mix the waste from different parts of the city, mixing waste of different days and mixing waste with stock of pre-processed waste.

Implementation of above strategies will meet the requirement of minimum quality of waste feedstock.

Figure 2.6: Municipal Solid Waste Flow Diagram in WtE Plant



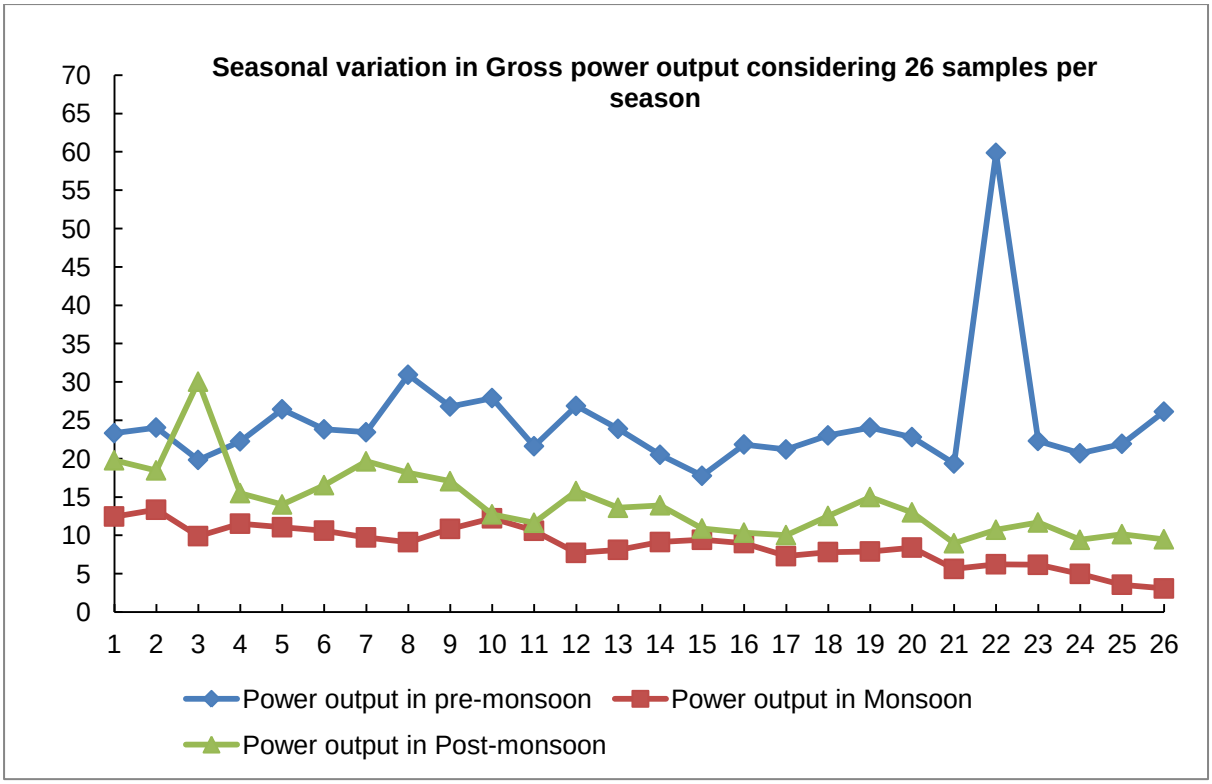
2.4.1 **Power Plant Capacity:**

A detailed sensitivity analysis) to arrive at the range of power generation output of the proposed plant considering incineration technology for calculation is performed, the various assumptions for the study are:

- Power generation depends on calorific value of feedstock, the turbine/ generator capacity and the boiler capacity.
- The sample data of NEERI Report is considered for the sensitivity analysis, assuming that the seasonal variation and ward wise variation in waste characterization is considered. The same results are used for the analysis.
- Other significant parameters of waste characterization like inert, recyclables and calorific value are considered constant from primary collection to waste processing site.
- The plant gross power generation capacity is calculated considering calorific value at 50% moisture.

The seasonal variation in gross power generation potential is given in Figure 2.7.

Figure 2.7: Seasonal variation in Gross Power output as per waste characteristics[13]



There are two results, one in pre-monsoon season and another one in post-monsoon season as shown in Figure 2.7 are abnormally high, therefore, excluded for the calculation of Gross power generation.

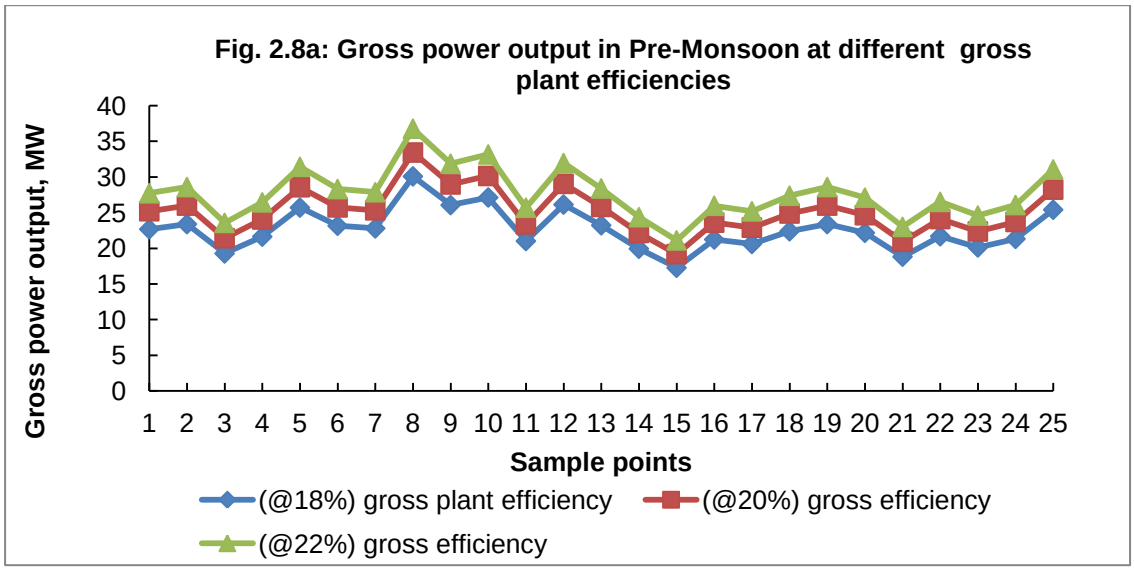
Analysis of above Figure depicts following points:

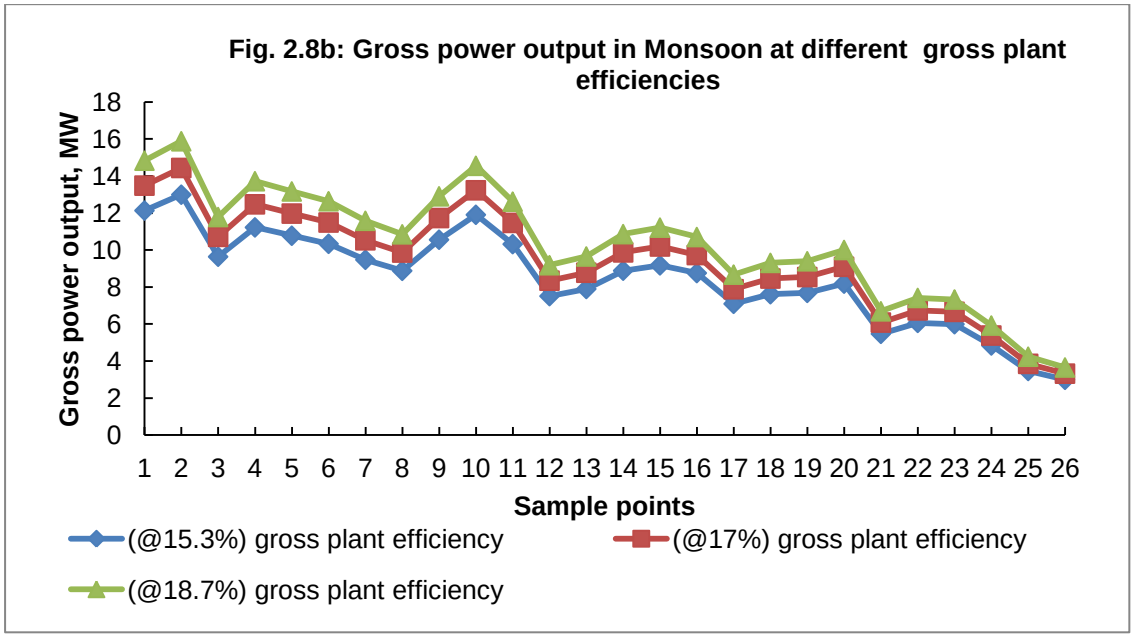
[13] NEERI Report 2016

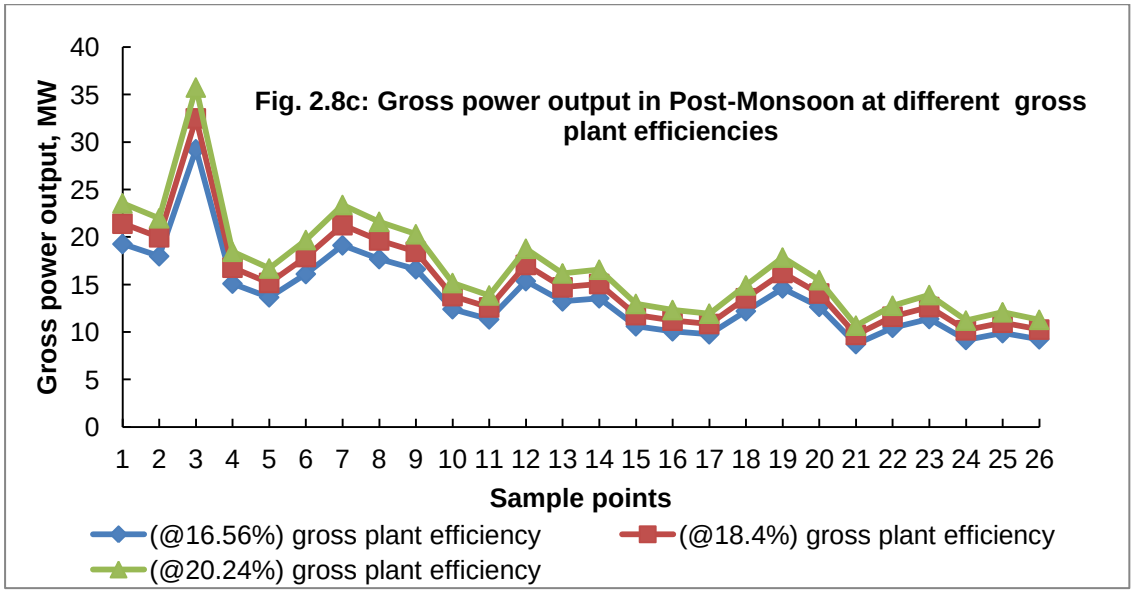
1. Maximum power generation is possible in Pre-monsoon season, followed by post monsoon. In monsoon season, the power generation would be very low.
2. Comparing to all the data values, for 90% of time, the power generation would be less than 25MW.
3. Minimum acceptable plant capacity should be 25MW. This will have sufficient margin to handle better quality of MSW, if available, in future.
4. Further increase in plant capacity (say, 35MW), would reduce plant efficiency in the order of 1%, which will lead to lower power generation

The seasonal variation in plant efficiency is given in Figure 2.8.

Figure 2.8: Seasonal Variation in Plant Efficiency







It is evident from the above Figures that for given waste quality, the WtE plant capacity should be 25MW. Plant capacity higher than 25MW will always be under loaded, and therefore, will perform at lower efficiency and its power generation would also be lower.

Performance of Steam turbine at different plant capacity is shown in Figure 2.9 and overall plant efficiency is shown in Figure 2.10.

Figure 2.9: Steam turbine/ Plant performance vis-à-vis Plant capacity

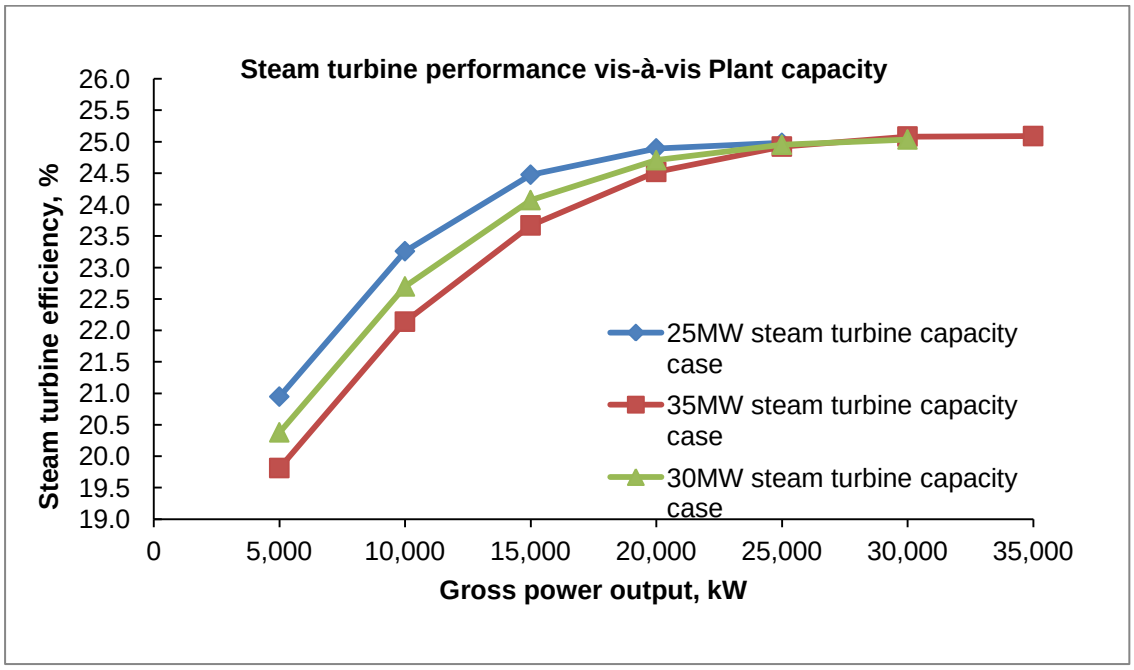
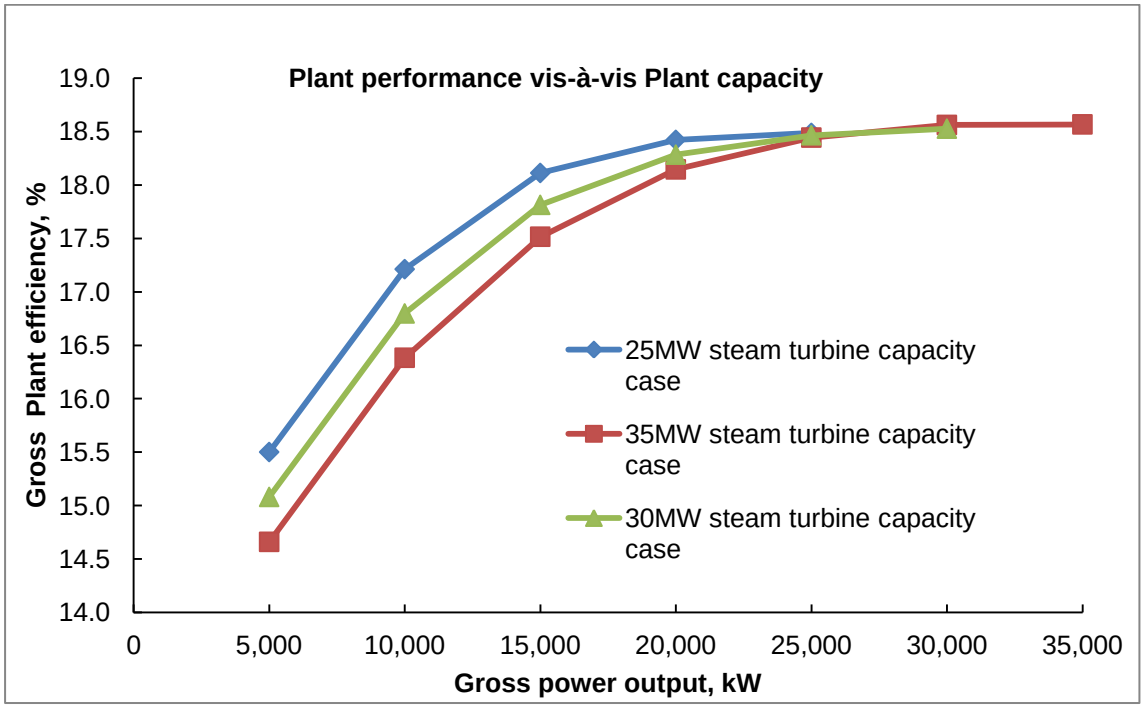


Figure 2.10: Steam turbine/ Plant performance vis-à-vis Plant capacity



2.4.2 **Power Generation**

The power generation from the proposed plant is calculated based on the NEERI Report. The expected power generation from the power plant is given in Table 2.7.

Table 2.7: Expected Power Generation

Parameter	Unit	Range of Values		
		Pre-Monsoon	Monsoon	Post Monsoon
Calorific value of MSW (@50% moisture)*[1]	kcal/kg	1899 - 2018	729 - 2291	944 - 2244
Average Calorific value	kcal/kg	1965.5	1721.6	1786.2
Gross plant efficiency expected *[2]	%	18.5	15.7	17.0
Gross Power Generation expected	**MW**	**17.8 - 30.9**	**3.07-13.33**	**9.0 - 25.0**

Notes:

- 50% moisture is considered in feed stock. Excess moisture to be removed in pre-processing unit
- *[2] Gross plant efficiency variation is due to part load operation of the plant

The above comments are valid and needs to be considered. The actual power generation is estimated based on the given plant capacity and with seasonal variation. The estimated power generation is given in Table 2.8.

Table 2.8: Annual Net Power Generation (Estimated)

Parameter	Values	Unit
Total number of hours in a year	8760	Hrs
Hours in different seasons		
Pre-monsoon	2920	hrs
Monsoon	2920	hrs
Post-Monsoon	2920	hrs
Gross power generation range	86996 – 216929	MWh
Average Gross Power generation expected (*)	134836	MWh
Auxiliary Power	15	%
Average net Power generation expected	114611	MWh
Say	**115**	**Million Units (MU)**
Note: ➢ MSW quality as per NEERI report. ➢ Weighted average quality of MSW considered is equal to arithmetic average of MSW quality in that season.		

The expected power generation (Net power output) from the WtE Plant is about 115MU. However, this power output is dependent on the quality of waste, particularly, in monsoon and post monsoon seasons.

2.4.3 **Optimization of Power Generation**

It is evident from the above analysis that WtE plant output during monsoon would be less than 50% and <30% during post monsoon comparing to the pre-monsoon period. Maintaining optimum plant efficiency and output during monsoon and post monsoon will yield higher power output, therefore, higher revenue.

This is important that proposed WtE Plant to be utilized to its maximum potential. MCGM should make strategies to provide better quality waste in terms of higher GCV. This can be achieved by waste segregation at source and its transportation in closed vehicles during monsoon. MCGM can also mine the existing waste of the dump site (legacy waste) for combustible material and send that to WtE plant. This will give better power output and also help in reducing the waste volume in existing dump.

MCGM can also get RDF from adjoining municipalities for blending the low calorific waste during monsoon and post monsoon period. Revenue generated by such venture should be suitably shared with operator.

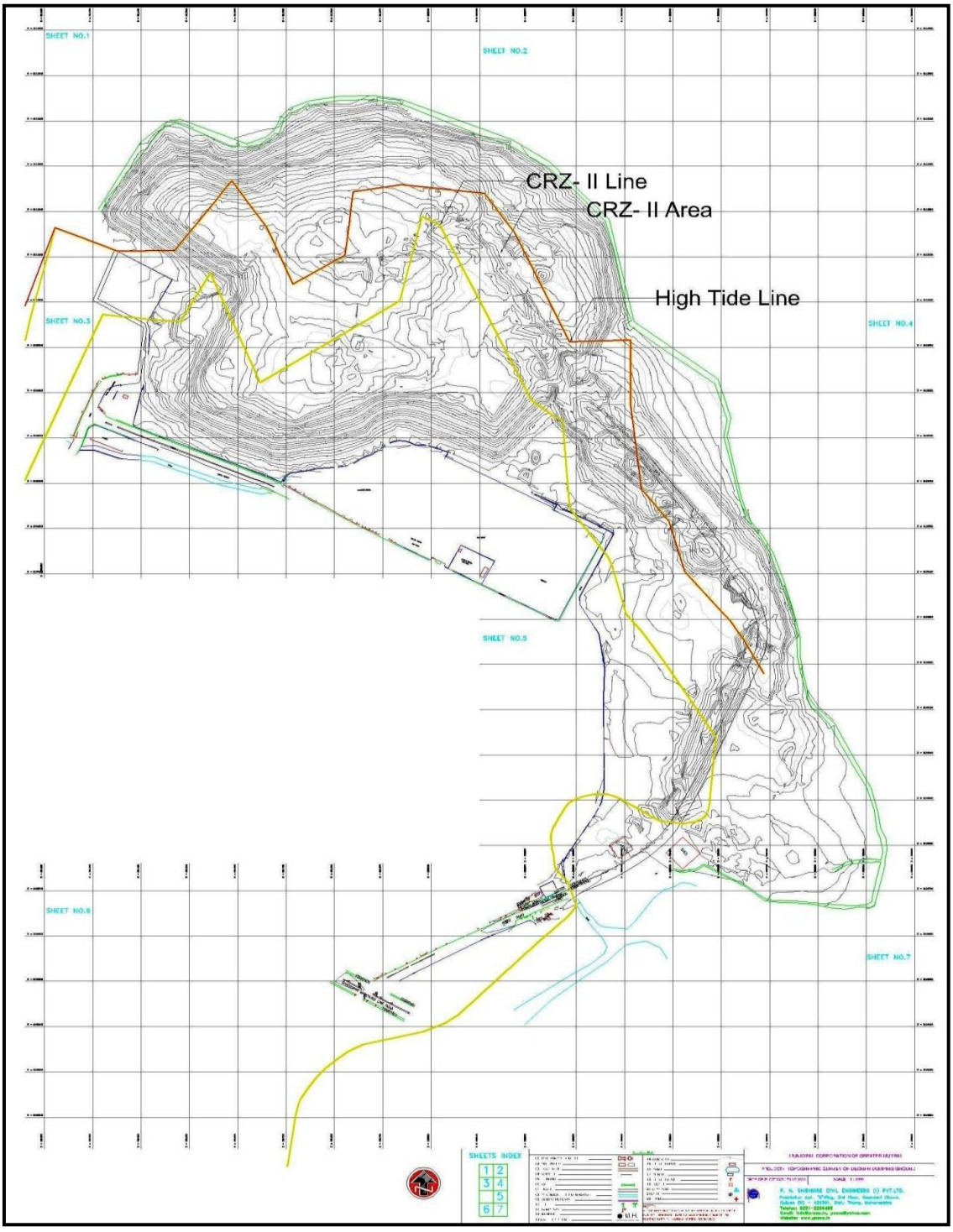
The WtE plant at all time should maintain its emission level as mandated by the regulatory requirement.

2.5 Review of available data

2.5.1 **Topographical details of the Site**

Topographic survey map (Dec-2014) prepared using Total Station Equipment with overlay of CRZ lines, which was provided by MCGM, is used for studying topographic and location features of the site and selection of land parcels for proposed Waste to Energy project. It is presented in **Figure 2.11**.

Figure 2.11: Topographic Map of the Deonar Site



The key outcomes for the topographic survey are given in **Table 2.9**.

Existing features such as Ghatkopar Mankhurd Road, approach road to site, footpath, internal road, streetlights, peripheral storm water drain, structures, weighbridge, surrounding area of the site are presented in this map. Contours were generated at 1.0m interval and presented on 100m x 100m map Grid.

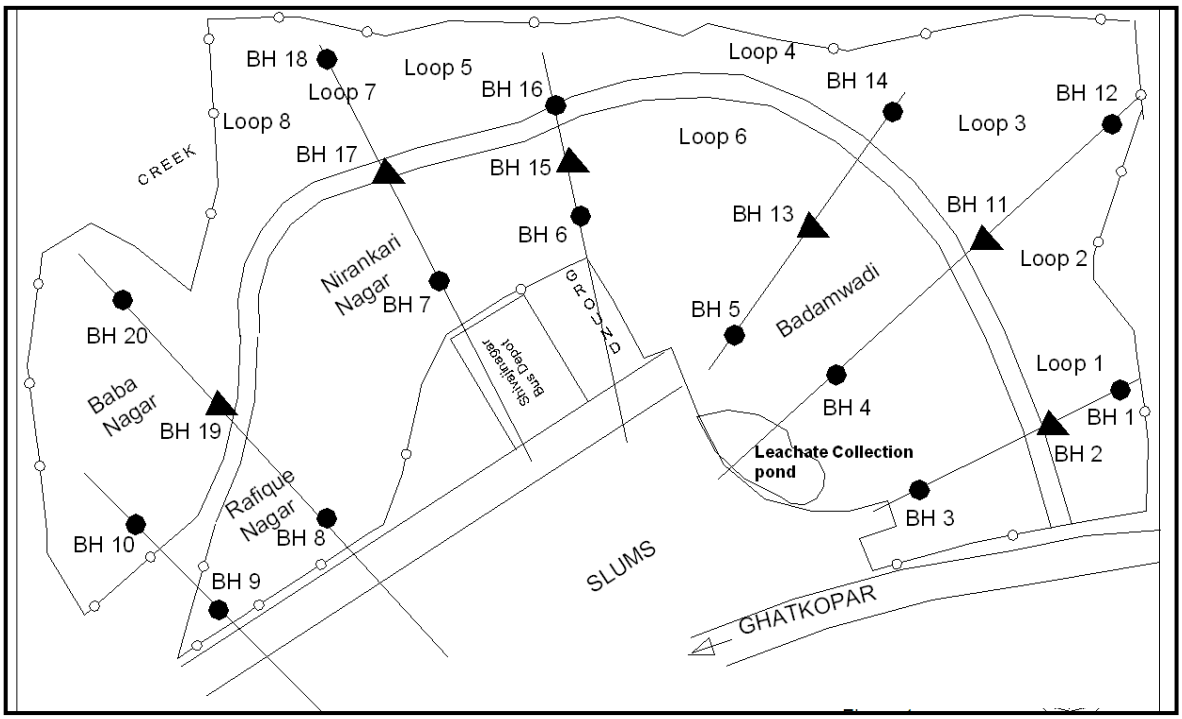
Table 2.9: Key outcomes of the Topographic Map

Sr. No.	Particular
1	The reduced level at the approach road at Ghatkopar to Mankhurd Highway is 7m while highest contour level of the dumpsite is at 40m. Maximum height of the Dump above average ground is 34m.
2	Large portion of the Deonar dumpsite with high contour picks is located in the CRZ area

2.5.2 **Geotechnical details of the Site**

The report of Geotechnical investigation survey conducted in 2005 by MCGM is studied to understand the subsurface features of the site.

Figure 2.12: Borehole Locations



The investigation report and Borehole details are presented in the **Annexure-1.** Sub-soil conditions and generalized sub-soil profile for the area investigated based on drilling and sampling in a total of twenty boreholes is presented in **Figure 2.12.**

Table 2.10 Key details of the Geotechnical Investigation Report

Sr. No.	Particular
1.	**Layer – I: DUMPED MATERIAL** This layer was encountered from ground surface existing at the time investigation up to depth varying from 4 m (BH18) to 13.80 m (BH6). In BH19 boulders with sand and clay was encountered up to 5.2m depth.
2.	**Layer – II: SAND SILTY ORGANIC CLAY (CLAYEY MURRUM)/ MURRUM WITH BOULDERS** This layer was encountered below layer I in boreholes BH1, BH2 up to depth varying from 10.7 m (BH19) to 13.5 m (BH2) and below layer IIA in BH4 from 15.4 m to 18 m depth. Standard Penetration Tests were performed in this stratum and SPT N varied from 14 to 20.
3.	**Layer – IIA: GRAYISH / YELLOWISH SILTY ORGANIC CLAY / SILTY ORGANIC CLAY WITH BOULDERS, PEBBLES** This layer was encountered below layer I in boreholes BH3 to BH20 up to depth varying from 11.9 m (BH19) to 20 m (BH6). Standard Penetration Tests were performed in this stratum and SPT N varied from 10 to 23.
4.	**Layer – III: FRACTURED, WEATHERED, AMYGDALOIDAL BASALT (SOFT ROCK)** This layer was encountered below layer II up to 22.6 m that is the maximum depth reached. Recovery (Rec.) in this stratum varies from 15% to 85% and Rock Quality Designation (RQD) varies from 0% to 64%. Based on RQD quality of rock can be considered as very poor to fair. Soaked unconfined compressive strength vary from 174 to 635Kg/cm^2. Based on unconfined compressive strength rock can be considered as moderately strong to strong.

Table 2.11: Key inference of the Geotechnical Investigation Report

Sr. No.	Particular
a.	Ground profile is highly varying
b.	From Bore logs it appears that the preliminary purpose of investigation was to access the dump thickness. Most of the bore holes were terminated in organic clay. Out of 20 bore holes 13 bore holes were terminated in organic clay. 7 Bore holes stuck the natural ground out of which 4 bore holes reached to amygdaloidal basalt at level varying between 10.5 m to 13.5 m below ground level. Field and laboratory tests results are missing
c.	Bore logs indicates that at most of the locations the average thickness of dump is more than 10.5m except bore hole 19 where thickness of dump is 1.4 m
d.	The construction in this area will require cast in situ piles (with 6 mm thick MS linear) embedded in rock. The average length of pile is envisaged as 18m with maximum as 28 m. The pile will be designed considering extreme exposure

Sr. No.	Particular
	condition. Pile socketing rock shall be obtained by considering realistic parameters and overall design requirements.
e.	In absence of field and laboratory tests results the pile capacity have to be estimated by assuming crushing strength of bed rock or considering the capacity available in the report.
f.	Piles will be poor in lateral capacity. Piles will be designed as free standing above the embedment length in natural ground level.

It is recommended to carryout detailed geotechnical Investigation in the proposed area of development during the detailed design phase for obtaining the realistic design parameters of the substrata.

2.5.3 **Development of Solid Waste Management (SWM) Project at Mumbai**

MCGM as part of their endeavour to implement Integrated Solid Waste Management (ISWM) in Mumbai had initiated a WtE project for 1000TPD in year 2015. The project feasibility and DPR as well as RFP and RFQ were prepared. MCGM had also short listed four contractors for implementation for this project. However, due to certain administrative and other issues, the project was shelved.

The DPR for the project was prepared by consortium of three consultants, i.e. (1) Infrastructure Development Finance Company, Bangalore (IDFC), (2) Infrastructure Development Corporation (Karnataka) Limited, Bangalore (iDeCK) and (3) SENES Consultants India Pvt. Ltd., Noida. This report was submitted to the Asian Development Bank (ADB).

The important points as extracted from this report are as below:

A. Government (Centre, State/ MCGM) to
   - Provide capital grants for the Project

B. MCGM to:
   - Provide Right of Way to the Project Site
   - Obtain Environment Clearance for the Project Site
   - Supply Assured Qty of 1000 TPD (±20%) and make payments accordingly
   - Environment User Charge to be paid on actual quantity supplied, which shall in no case shall be lower than 800 Tons (bi-monthly average)
   - In case of supply over 1200 tons, Concessionaire may accept the additional waste. However, in no case shall the payment be made for a quantity of >1200 TPD
   - Supply upto 1MLD water to the Project Site. In case water requirement exceeds 1MLD, Concessionaire shall make its own arrangements to meet the same
   - Make timely payments to the Concessionaire
   - Undertake landfill post-closure activities after handback of Project Facilities

C. Concessionaire shall

- Process waste and generate energy
- Landfill no more than 150 TPD (bi-monthly average) of inerts
- Maintain SLF and Plant as per norms and standards prescribed in the Concession Agreement and in line with applicable laws
- EU norms are proposed to be followed for emission standards
- Have the right to reject MSW supplied over and above 1200 tons. However, in case the Concessionaire accepts waste over and above 1200 tons, no additional payment would be made for the same
- Obtain all clearances for the Project
- Design, construction, and operation of a processing plant using suitable technology and a scientific landfill facility at one or more of Deonar, Kanjur and Mulund for a 1000 Tonnes per day Capacity per package; and
- Management of the products of processing, and usage of inerts and disposal of hazardous waste in the sanitary landfill site with objective of minimizing the land fill requirement.

It can be inferred from the IDECK report and further RFQ and RFP documents for 1000TPD project of 2015 that WtE is a feasible concept for Mumbai. This also indicates that there are competent organizations who can implement such project in Mumbai.

The report had given the list of successful projects worldwide as given in **Table 2.12**.

2.5.4 **Initial Environmental Examination (IEE) Report**

Initial Environmental Examination (IEE) was prepared for Waste to Energy (WTE) project proposed at Deonar dumpsite in Mumbai in year 2015 for 1000TPD.

The project covers (i) construction of a Processing facility with energy recovery, Ash utilization plant, Sanitary landfill (ii) Other infrastructure facilities including roads, storm water management system, green belt, parking & vehicle shed, small repair workshop, administration unit and weighbridges and utilities like water supply and sanitation, lighting, etc.

An Environmental Management Plan (EMP) is also proposed as part of this IEE which includes mitigation measures for significant environmental impacts during implementation of the Project, environmental monitoring program, and the responsible entities for mitigation and monitoring. The proposed project was categorized under ADB's environmental Category B2 projects. Therefore, it had small scale, localized impacts on the environment, and can be mitigated.

The summary of the IEE report is as below:

- The proposed processing facility may generate reject of approximately 20%.
- Considering the limited land availability at Deonar site for development of waste to energy facility, an ash/ reject utilisation plant has been proposed to further processing the reject and minimise the rejects going to the SLF.

Following assumptions were made for design of waste processing system:

- Solid waste provided by MCGM: 1000 (±200 TPD)
- The calorific value of waste delivered for the project is assumed as 1100-1200 kcal/kg
- Water to be supplied by MCGM – 800 KLD at project boundary at Rs.70/m^3.
- The plant availability was assumed for 7680 hours (320 days).
- Evacuation is assumed at 33 kV to nearby grid, assumed within 5 km
- Flue Gas Treatment System as per International norms (EU norms)

Table 2.12: WtE Plant Reference List from IDECK Report

Components	AEB, Amsterdam, The Netherlands	Lakeside, London, UK	Spittelau, Vienna, Austria	Allington, Kent, UK	Issy les Moulineaux, Paris, France	Reno Nord, Aalborg, Denmark	Energos, Sarpsborg, Norway	Zabalgarbi, Bilbao, Spain
Technology	AfvalEnergieBedrijf	Combustor and horizontal boiler	Incineration (two lines)	Rotating fluidized bed technology (ROWITEC) & CIRCOCLEAN technology	Two-line water-cooled grate incinerator with horizontal boilers	Reno-Nord line 4	Energos technology with two identical gasification lines	Conventional grate incinerator with an advanced energy recovery system [Combined Cycle Gas Turbine (CCGT)process]
Developer	Widmer & Enrst	Viridor and Grundon Waste Management	Spittelau and Maishima Osaka Plant (MOP)	Kent Enviro power Limited	Syctom Paris	Interessentskabet Reno-Nord	Borregaard Industries bio refinery	
Technology Provider	Widmer & Enrst	Takuma of Japan		LurgiLentjes	Hitachi Zosen	B+V Industrietechnik GmbH.	Energos	Martin GmbH
Plant Capacity (tonnes per annum)	5,12,000	4,10,000	2,50,000	5,00,000	4,60,000	1,60,000	1,56,000	2,50,000
Plant Capacity (TPD)	1600	1300	800	1600	1500	500	500	800
Conversion in INR (Crores)	2072	1120	752	1155	3382.4		216	862.4
Power capacity (MW)	93.6	37	40	43	222	18	16	56
Capital Cost INR Cr/100 TPD	130	86	94	72	225		43	108
Capital Cost INR Cr/MW	22	30	19	27	15		14	15

CHAPTER 3: Technology Screening and Design Basis for WtE

3.1 Approach and Methodology of Technology Screening

As a general trend, the higher the economic development, higher the amount of MSW generated. Nowadays more than 50% of the entire world's population lives in urban areas. The high rate of population growth, the rapid pace of global urbanisation and economic expansion of developing countries are leading to increased and accelerating rates of municipal solid waste production[14]. With proper MSW management and the right control of its polluting effects on the environment and climate change, municipal solid waste has the opportunity to become a precious resource and fuel for the urban sustainable energy mix of tomorrow: only between 2011 and 2012, the increase of venture capital and private equity business investment in the sector of waste-to-energy - together with biomass - has registered an increase of 186%, summing up to a total investment of USD 1 billion[15].

Energy recovery in the form of electricity, heat and fuel from the waste using different technologies is possible through a variety of processes, including anaerobic digestion, incineration, gasification and pyrolysis. These processes are often grouped under "W to E technologies".

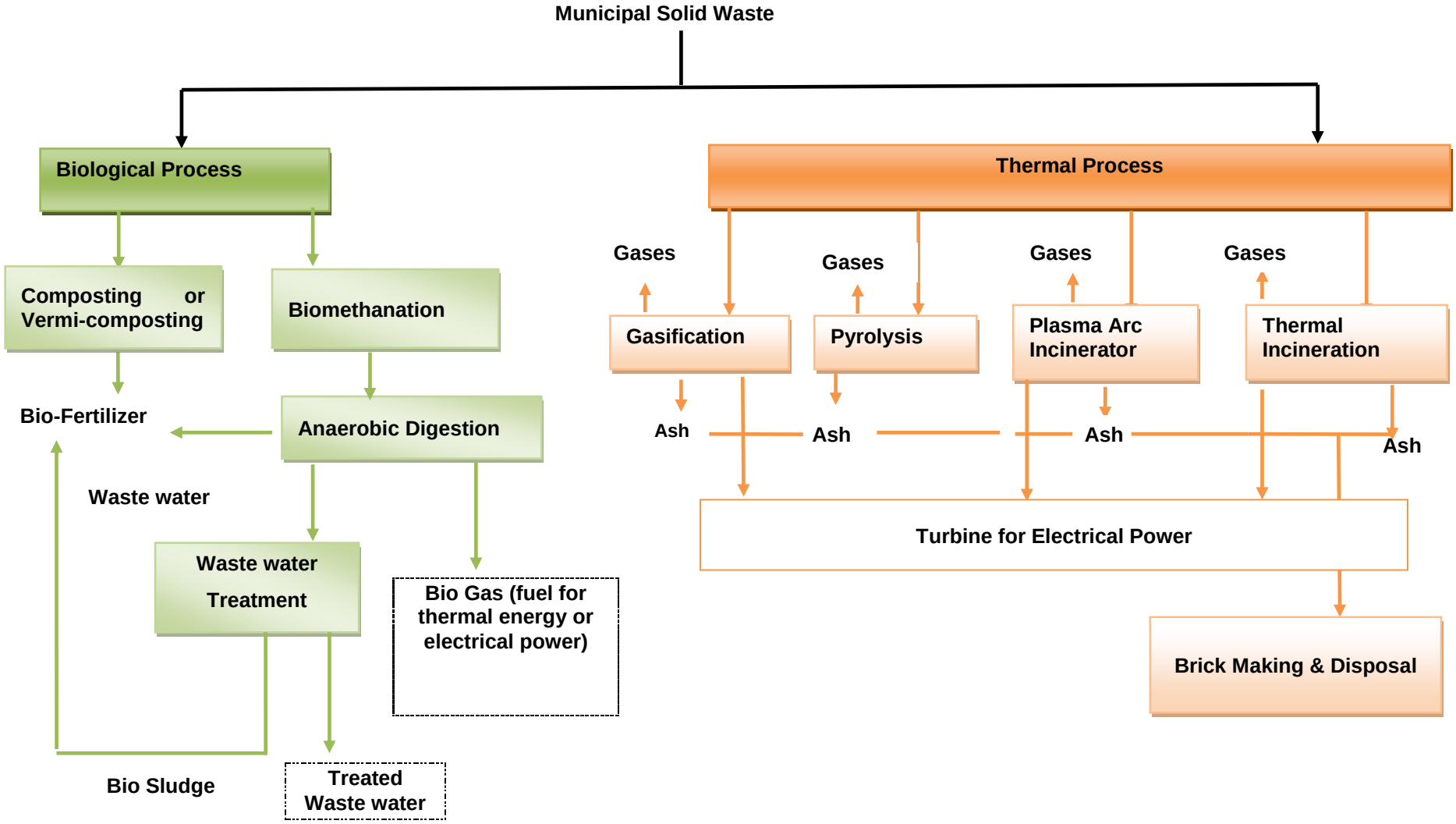
Appropriate waste treatment technology should be selected based on the characteristics of the waste generated. Biological or thermal treatment of waste can result in recovery of useful products such as compost, biogas or heat energy. Municipal Solid Waste (MSW) contains organic as well as inorganic matter. Factors that influence the selection the waste treatment technology are follows:

- Applicable regulations;
- Health & safety aspects;
- Available supporting Infrastructure i.e. land, electricity, water supply etc.;
- Capital investment and economic viability of the technology;
- O&M costs; and
- Saleability and management of the by-products.

The selection of technologies is also based on the factors like the desired form of the energy, quantity and characteristics of feedstock, end-use requirements and environmental standards (Kalyani et al. 2014).The options available for MSW treatment and utilization are discussed in **Figure 3.1**.

14 World Bank, 2012
15 UNEP/ Bloomberg NEF, 2012

Figure 3.1: Options available for MSW Management treatment



3.2 Biological and Thermal Technologies for Waste Management

3.2.1 Biological Technology

3.2.1.1 Composting

Composting is a microbial based aerobic and anaerobic process which is now consider as an environmentally sound way to reduce organic waste and produce organic fertilizer or soil conditioner. The organic material present in Municipal Waste can be converted into a stable mass by aerobic decomposition.

Biological treatment involves using micro-organisms to decompose the biodegradable components of waste. Two types of processes are used, namely:

a) Aerobic processes: Windrow composting, aerated static pile composting and in-vessel composting; vermi-culture etc.

b) Anaerobic processes: Low-solids anaerobic digestion (wet process), high solids anaerobic digestion (dry process) and combined processes.

There are several factors which affects the composting process such as organism, Use of culture, Moisture, temperature, aeration etc. This technique is not considered for WtE process because no energy is produced during the composting process[16].

3.2.1.2 Biomethanation/ Anaerobic Digestion Technology

The organic fraction of waste is segregated and fed to a closed container (biogas-digester) under anaerobic conditions; the organic wastes undergo biodegradation producing methane-rich biogas and effluent/ sludge. The process involves the anaerobic (without air) decomposition of wet organic wastes to produce a methane-rich biogas fuel and a small amount of residual sludge that can be used for making compost. Typically 100-200 m^3 of gas is produced per ton of organic MSW that is digested. The biogas can be utilized for either for generating steam or electricity.

Table 3.1: Advantages and Disadvantages of Biomethanation Technology

Advantages	Disadvantages
• Makes landfills easier to manage by removing problematic organic waste material which is responsible for gaseous and liquid emissions. • The feedstock for biomethanation plant is a renewable source. Energy generated through this process can help reducing the demand for fossil fuel. • The technology reduces the emission of Green House Gases to	• Suitable only for organic matter and cannot used for mixed waste • Nature of organic waste may vary according to location and time of year. This may lead to a variation in the C/N ratio and affect the rate of gas production. • The detention time in the plant is around 30-50 days. The space required for the process is significantly high.

16 By Organic Recycling of Agricultural Waste Today: Composting and Anaerobic Digestion 2016)

Advantages	Disadvantages
atmosphere. • The use of digestate also participates to this reduction by decreasing synthetic fuel uses in fertilizer manufacturing, which is an energy intensive process. • An end product can be used as a soil conditioner • Clean Technology • Acceptable by Public • Environmentally Sound • Best suitable to Indian conditions if proper biodegradable feed is provided for the plant • Proper designing of the plants initially can be easily scalable as per the need	• Relatively expensive and requires a major capital investment. • Wastewater from the process may contain a high concentration of metals, nitrogen and organic materials. • Because of the complex association of different types of bacteria, digesters have a higher risk of breakdown and may be difficult to control. • Blockage of pipes can be caused if large pieces of waste enter the system; this causes problems, particularly in continuous systems. This can be avoided with appropriate measures • Non utilization of End Product in nearby area lead to plant installation unviable

3.2.2 **Bioreactor landfill (BLF)**

In this technique aerobic as well as anaerobic digestion take place and it takes around 7 years for complete decomposing. It also required huge land area and time. Bio mining of the BLF materials does not assure quality of end product, which may not be suitable as soil conditioner or manure due to contamination of the incoming waste. BLF is not a WtE technology hence not considered further.

Biomethanation process treats only organic matter hence will also require a separate treatment system for the management of non-biodegradable waste including recyclables. Considering significant requirement of land for the process & need for separate treatment system for non-biodegradable waste. Technology of biomethanation is considered unfeasible and not considered for further discussion in this report.

3.2.3 **Thermal Techniques**

Thermal waste to energy technologies are as given below;

1. Gasification
2. Pyrolysis
3. Plasma arc process
4. Incineration

3.2.3.1 **Gasification**

Gasification involves thermal decomposition of organic matter at high temperatures in presence of limited amounts of air/ oxygen, producing mainly a mixture of combustible and non-combustible gas (carbon Monoxide, Hydrogen and Carbon Dioxide). It involves the partial oxidation of a substance which implies that oxygen is added but the amounts are not sufficient to allow the fuel to be completely oxidized and full combustion to occur. The process is largely exothermic but some heat may be required to initialize and sustain the gasification process. This process is similar to Pyrolysis, involving some secondary/ different high temperature (>1000^{o}C) chemistry which improves the heating value of gaseous output and increases the gaseous yield (mainly combustible gases CO+H_2) and lesser quantity of other residues. The gas can be cooled, cleaned and then utilized in IC engines to generate electricity.

Gasification facilities produce gas-primarily carbon monoxide and hydrogen (85%) - plus hydrocarbon oils, char and ash. Gasification plants' air emissions also include nitrogen oxides, sulfur dioxide, particulate matter, carbon monoxide, carbon dioxide, methane, hydrogen chloride, hydrogen fluoride, ammonia, heavy metals mercury and cadmium, dioxins and furans. The ash which remains after gasification, 8% to 15% of the original volume, is toxic and presents special problems because of the acidic or low pH, conditions in landfills. Gasification shares many characteristics with incineration.

Apart from the high energy needs, the possible impacts to the environment are emissions to the atmosphere, noise pollution, soil protection, waste generation and possible waste water discharges[17]. During the processing of biomass in gasification plant and the production of gases also several unwanted by-products will be produced. The most significant impurities, such as tars and particulates are separated from the final product. Conventional separation processes for tar and particulate removal are usually cyclones, filters, electrostatic precipitators and scrubbers. The advantages and disadvantages of the gasification technology are given in the **Table 3.2**.

Table 3.2: Advantages and Disadvantages of Gasification Technology

Advantages	Disadvantages
• It takes place in a low oxygen environment that limits the formation of dioxins and of large quantities of SO_x and NO_x. • Furthermore, it requires just a fraction of the stoichiometric amount of oxygen necessary for combustion. As a result, the volume of process gas is low, requiring	• During gasification, tars, heavy metals, halogens and alkaline compounds are released within the product gas and can cause environmental and operational problems as below: ○ Tars are high molecular weight organic gases that ruin reforming catalysts, sulfur removal systems,

17 Gasification guide 2009

Advantages	Disadvantages
smaller and less expensive gas cleaning equipment. • The lower gas volume also means a higher partial pressure of contaminants in the off-gas, which favors more complete adsorption and particulate capture. • Finally, gasification generates a fuel gas that can be integrated with combined cycle turbines, reciprocating engines and, potentially, with fuel cells that convert fuel energy to electricity more efficiently than conventional steam boilers.	ceramic filters and increase the occurrence of slagging in boilers and on other metal and refractory surfaces. ○ Alkalis can increase agglomeration in fluidized beds that are used in some gasification systems and also can ruin gas turbines during combustion. ○ Heavy metals are toxic and accumulate if released into the environment. ○ Halogens are corrosive and are a cause of acid rain if emitted to the environment.

At high temperatures used in gasification, toxic metals including cadmium and mercury, acid gases including hydrochloric acid, and ozone-forming nitrogen oxides are released. Also, dioxins and furans are created in the cooling process following the burning of ordinary paper and plastic. These poisons are dangerous at extremely low levels and modern pollution control devices do a poor job of reducing these emissions into the atmosphere. Some including mercury and dioxin are persistent and bio accumulative; they resist breakdown in the environment and are concentrated in the food chain.

While evaluating gasification, the degree of pre-processing required in conversion of MSW into a suitable feed material is a major criterion. Unsorted MSW is not suitable for gasification because of its varying composition and size of some of its constituent materials. It may also contain undesirable materials which can play havoc with the process or emission control systems.

Though full-scale and pilot scale units have shown reliable results, mass fired gasifiers have not success. Therefore except for the modular combustion unit gasification systems has limited proneness to consider as commercial technology.

3.2.3.2 **Pyrolysis**

Pyrolysis is also referred to as destructive distillation or carbonization. It is the process of thermal decomposition of organic matter at high temperature (about 900^0C – 1700^0C) in an inert (oxygen deficient) atmosphere or vacuum, producing a mixture of combustible Carbon Monoxide, Methane, Hydrogen, Ethane [CO, CH_4, H_2, C_2H_6] and non-combustible Carbon Dioxide, water, Nitrogen [CO_2, H_2O, N_2] gases, pyroligenous liquid, chemicals and charcoal. The pyroligenous liquid has high heat value and is a feasible substitute of industrial fuel oil.

The main product pyrolysis is syngas, which is composed mainly of carbon monoxide and hydrogen (85%), with smaller quantities of carbon dioxide, nitrogen, methane and various other hydrocarbon gases. Syngas has a good calorific value, so it can be used as a fuel to generate electricity or steam or as a basic chemical feedstock in the petrochemical industries and refineries. It can also undergo treatment to produce a hydrogen stream for use in fuel cells. The calorific value of this syngas will depend upon the composition of the input waste to the gasifier. Most gasification and pyrolysis processes have four stages: Preparation of the waste feedstock, Heating the waste in a low-oxygen atmosphere to produce a gas, oils and char (ash), Scrubbing' (cleaning) the gas, generate electricity. The advantages and disadvantages of the pyrolysis technology are given in the **Table 3.3**.

Table 3.3: Advantages and Disadvantages of Pyrolysis Technology

Advantages	Disadvantages
• By using less oxygen, fewer air emissions may be produced. • Emissions are easier to control because they are scrubbed to remove contaminants. • The plants are modular and flexible • They are quicker to build. • The processes produce a more useful product than standard incineration – gases, oils and solid char can be used as a fuel, or purified and used as a feedstock for petro-chemicals and other applications. • The syngas can be used to generate energy more efficiently via a gas engine (and potentially fuel cell), whilst incineration generates energy less efficiently via steam turbines • If the economics associated with production of synthetic liquid fuels change, pyrolysis may be an economically viable process for thermal processing of solid waste	• Net energy recovery may suffer in case of wastes with excessive moisture. • High viscosity of pyrolysis oil may be problematic for its transportation may lead to burning • Inherent complexity of the system and lack of appreciation by system designer of the difficulties of producing a consistent feedstock were the causes for failure • Other disadvantages are same as mass burn incineration

Safety issues are one of the fundamentals of the pyrolysis plant because of several fire and explosion hazards. The main disadvantages of pyrolysis technique are they required pre-sorted or processed waste as feedstock and low moisture content. Pyrolysis technology is newer and there are just a few demonstration projects and not much of pyrolysis reactors (Roos 2010). Although the possibility to meet regulation will depend on technology providers experience.

3.2.3.3 **Plasma Arc process**

An emerging technology utilizing thermal decomposition of organic wastes for energy/ resource recovery. The system basically uses a Plasma Reactor which houses one or more Plasma Arc Torches which generate, by application of high voltage between two electrodes, a high voltage discharge and consequently an extremely high temperature environment (between 5000 - 14,000^{o}C). The gas output after scrubbing comprises mainly of CO and H_2. The liquefied produce is mainly methanol. It has the advantage that the NO_X (oxides of Nitrogen) and SO_X (Oxides of Sulphur) gases emissions do not occur in normal operation due to the lack of oxygen in the system. The advantages and disadvantages of the plasma arc technology are given in **Table 3.4**.

Table 3.4: Advantages and Disadvantages of Plasma Arc Technology

Advantages	Disadvantages
• Compared to combustion/ incineration technology, it creates much less atmospheric pollution • In techno-economic terms, oxides of nitrogen and sulphur are not emitted during normal operations because the system works in absence of oxygen • Toxic materials become encapsulated and are therefore much safer to handle than the toxic ash left by combustion/ gasifier processes • Clean Technology • Less amount of residue	• Plasma arc technology is extremely costly • Plasma torches are very costly and need to be replaced frequently • No of shutdowns due to frequent replacement of plasma torches increases downtime.

The main disadvantage of this technology is that it has not been tried and tested on large scale for MSW. The plasma arc technology is not considered for the proposed project at Deonar due to limitation in application on large scale, which is a primary objective of technology selection.

3.2.3.4 **Incineration process:**

Incineration is a waste treatment technology that involves the combustion of organic materials and/ or substances. Sufficient quantity of oxygen is required to fully oxidize the fuel for combustion. Incineration plant combustion temperatures are in excess of 850^{o}C and calorific value of the waste should be more than 1200 kcal/kg.

The waste is mostly converted into carbon dioxide and water and any noncombustible materials (e.g. metals, glass, stones) remain as a solid, known as Incinerator Bottom Ash (IBA) that always contains a small amount of residual carbon. Bottom ash can be treated to recover ferrous (iron, steel) and non-ferrous metals and inert materials (to be utilized as a sustainable building material). Air Pollution Control

residues are generally treated and disposed as industrial waste.The advantages and disadvantages of the plasma arc technology are given in **Table 3.5**.

Table 3.5: Advantages and Disadvantages of Incineration Technology

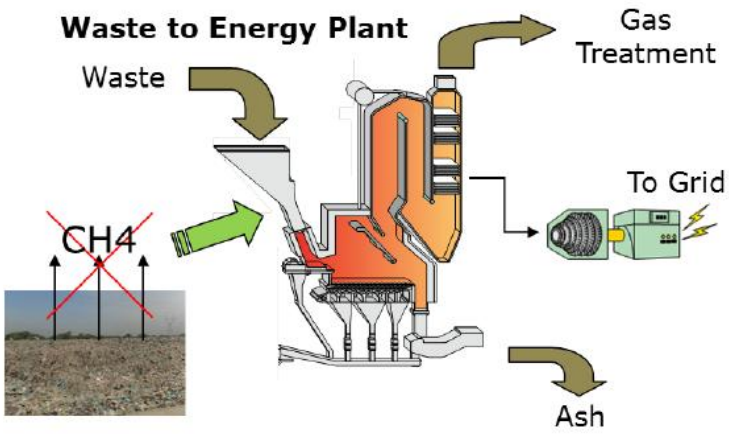
Advantages	Disadvantages
• The main residue from incineration is a volume-reduced inorganic ash, which has virtually no capacity to produce methane when disposed of in landfills. • Minimum of land is needed as compared to the other waste disposal technologies (minimum land requirement) • The incineration of waste produces process steam for heating, and power generation, (Waste to Energy) • Ashes can be used for making construction bricks, and thus the need for landfill capacity is reduced. • The produced residues, ash and slag as well as the developed flue gases, are odour-free. • As the raw material needed for waste incineration is municipal waste, helps to reduce the use of fossil fuels. • If appropriate pollution control measures are taken, incineration can act as clean technological option for MSW treatment	• The air pollution control equipments required in incineration plants are relatively expensive. • Effective and timely maintenance of the plant and equipments is required for smooth operation of plant. This results into high O & M costs. • The plants require skilled workers/ staff, which leads to higher wages • The residues from the flue gas cleaning can contaminate the environment if not handled properly.

The Task Force Report of K. Kasturirangan and SWM Rule 2016 considers incineration as a feasible option for waste management. This is proven technology in Indian as well as Global context. More than 72 incinerators are successfully operating in EU nations of varied capacity.

3.3 Climate Change Impact

The thermal processes like Incineration, Pyrolysis and gasification releases fossil-fuel derived CO_2 from plastics, synthetic textiles etc. They may also release biologically derived CO_2 from biological materials. Diverting solid waste to a Waste-To-Energy (WtE) facility or a diversion facility such as a composting operation or anaerobic digester avoids the methane that would have been generated if the waste were sent to a landfill.

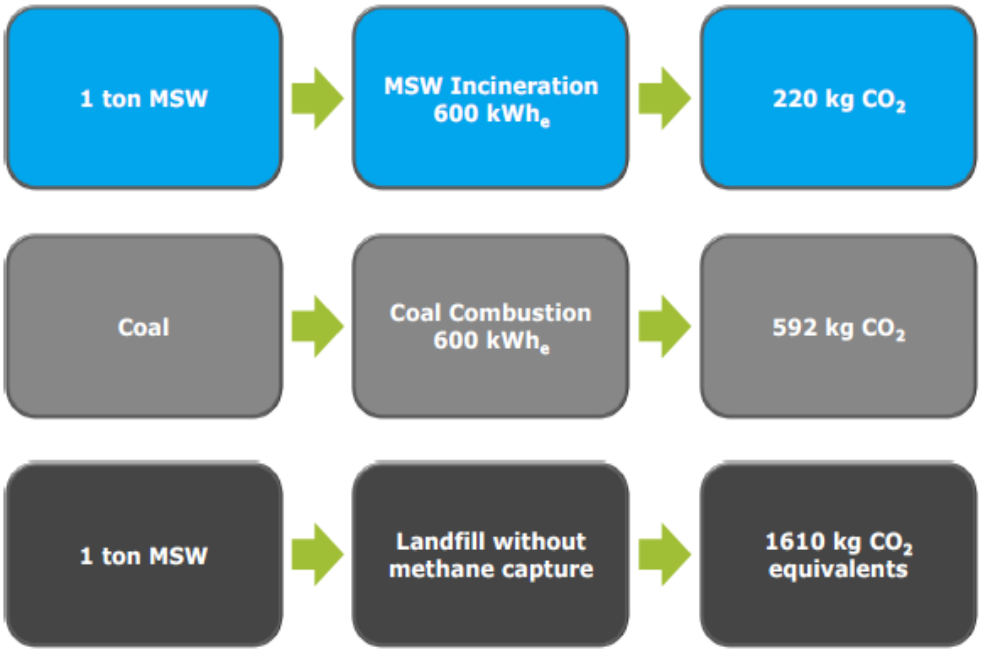
Figure 3.2: Comparison between landfill and WtE plant



If the MSW is landfilled instead of combusted, methane is released into the atmosphere. Methane is a far more potent GHG contributing 21 times more to global warming than carbon dioxide. The CO_2 balance of MSW compared to a condensing coal power plant is shown in above figure- 3.2, taking the alternative of landfilling into account.

The comparison of CO_2 emission from Coal and MSW incineration and landfill gas is compared in Figure 3.3, below:

Figure 3.3 Net CO_2 reduction of MSW incineration when replacing coal combustion



It is evident from Figure 3.3, that MSW incineration is a solution far more sustainable than coal with regard to CO_2 emissions. This is mainly due to substitution of landfilling, but also because combustion of biogenic waste is carbon neutral. The

degree of CO_2 emissions of MSW incineration highly depends on the waste composition and plant technology[18].

It is estimated that implementation of WtE plant for Mumbai will save more than 8 million tons of CO_2 equivalent GHGs in 20 years period.

3.4 Scenario of Different WtE Plants in National and International

The objective of WtE combustion is treating MSW to reduce its volume and generating energy and electricity during this process. In India, installation of various WtE plants has been witnessed in the recent past and several projects are known to be under pipeline. The status of different WtE plants in India is discussed in **Table 3.6**.

Table 3.6: Status of Different WtE Plants in India[19]

Sr. No.	Units	Plant details	Observation/ Status	Remarks
1.	Bio Gas plant at Delhi Secretariat	- Pilot plant based on BARC, Nisagruna Technology - 0.5 tonnes of wet waste into 30 m^3 of gas - Sludge used for gardening	- The plant is in operation. - It is outsourced to a private entrepreneur.	- Decentralized biogas plant should be the part of cities/ town plan - Gas generated can be used various purposes
2.	Okhla WTE Plant	- 16MW WTE on BOOT basis - M/s Jindal is operating the plant - Operational in 2012 and generates 15-16 MW of electricity from 1100MT of MSW - Emission problem	- Presence of C&D Waste in MSW is major problem - Bag house filter needs to be upgraded	- Problems of emissions like Dioxin and Furan, which needs to be monitored - Viability gap funding should be extended. - Better monitoring of emissions by CPCB
3.	A 2 Z Kanpur	- Collection, transportation, processing and disposal by A 2 Z Infrastructure - 46 Acres of land to process 1500 tonnes waste/ day	- RDF and composting not working due to fund problem - SLF was not built as per standards - WTE plant is not yet commissioned	- Continued operation should be ensured - The plant is not operating due to non-supply of requisite amount of waste and

18 ISWA guidelines WtE in low and middle income countries 2013
19 Planning commission report (WTE) under the chairmanship of Dr. K Kasturi Rangan (Vol – I & II)

Sr. No.	Units	Plant details	Observation/ Status	Remarks
		- Total project cost 85 crores - The plant is not operational		quality
4.	M/s SELCO International Ltd. MSW Plant, Hyderabad	- Initiated in 1999 with help of DST - 6.6MW energy production started in 2003 - The plant was operational for 11 years	- Closed due to non-availability of required quantity and quality of waste - Gaps in agreement signed with the company (No tipping fee)	- Policies for extending financial support to promote new technologies should be based on careful scrutiny of the viability of the project
5	Bio-Gas Plant Aundh ward, Pune	- 5MT biomethanation plant based on hotel wet waste- operational last 5 years	- Gas is being used for street lighting	- Initiatives of ward officials enabled successful operation of the bio-gas plant
6.	Roechem WTE plant, Ramtekadi, Hadapser	- 250MT plant based on German Technology - The plant could convert syn gas to power and ethanol	- Initial stage of operation - Pune Municipal Corporation is supplying segregated waste to the plant	- Initial stage of operation
7.	Plastic waste to Fuel plant, Katraj, Pune	- Pilot plant processing 50kg plastic to liquid fuel with indigenous catalytic conversion technology	-Conversion efficiency was 50kg plastic to 47 litres fuel oil -Trails is being carried out to convert metalized plastic waste	-This innovative technology should be promoted for managing plastic waste.

The international status of different WtE plants is discussed in **Table 3.7**.

Table 3.7: International Status of Mass burning Plants

S. No	Technology and Expenses	Lakeside Waste to Energy, London, UK/ 2010	Allington Waste to Energy Plant, Kent, UK/ 2008	Afval Energie Bedrijf (AEB) Waste to Energy Plant, The Netherlands	Syctom Paris Issy Les moulineaux Waste to Energy Plant, Paris, France/2007
1.	MSW Processing (TPD)	1123	1370	1612	1260
2.	Calorific Value (Kcal/kg)	2199	2199	2390	
3.	Power Generation (MW)	37	43	186.6	52
4.	Capital Investment (Cr.)	1520	1425	3515	3624

The above table clearly depicts that there are many successful projects for WtE. However, this can also be inferred from the above table that most of these projects are in developed countries, where life style is different from India and also other waste management practices like segregation at source etc are well established.

Mumbai is one of the largest city of India and is known as economical capital of the country. The population density of the city is very high and waste generation is also above 8000 tons/ day. Considering the waste management in similar cities worldwide, WtE projects is one of the most feasible option for waste management in city like Mumbai.

The status of International projects list for WtE is given in Chapter 2.

3.5 Lesson learn from WtE Projects in India

The lesson learns from WtE projects in India are shown in **Table 3.8.**

Table 3.8 Lesson learns from WtE projects in India

S. No.	Limitations/ Constraints of WTE Projects	Solutions
1.	Waste-to-Energy is still a new concept	It is the only solution considering lack of space and massive quantum of MSW in Larger ULBs.
2.	Proven and commercial technologies are required to be imported	Contractual condition has to be fair and financially viable enough to attract good Operators on board
3.	High cost of project	Cost has to be compared with the intangible

S. No.	Limitations/ Constraints of WTE Projects	Solutions
		benefits to Environment, People, Health and Human Society at large while doing Cost benefit analysis.
4.	Non-availability of segregated and continuous supply of waste	Pre-processing facility is mandatory to get uniformity in feedstock. Supply of waste is not an issue in Large ULBs. Plant has to serve the surrounding towns and smaller ULBs to get more waste.
5.	Lack of financial resources with ULBs.	MNRE Grants, low interest rate loans, Government funding and revival funds is important.
6.	Lack of conducive Policy Guidelines from State Govts. in respect of allotment of land, power purchase/ evacuation facilities and pollution standards.	It can be tackled by good intergovernmental Coordination.

3.6 Selection of Technologies

There are several thermal technologies available for the processing of MSW, however considering the critical factors applicable for technology selection for Deonar site, such as land availability, Capital investment, Waste characterization, Power Potential, Scale of operation etc. three technologies seem suitable, they are:

- Pyrolysis
- Gasification
- Incineration (with or without pre-processing)

The details of these technologies are given in **Table 3.9**.

Table 3.9: Details of WtE Technology Options

Parameters	Gasification	Pyrolysis	Incineration
Method	Thermochemical	Thermochemical	Thermal
End-Products	Producer gas Syngas, Biochar	Biooil, Biochar, Pyrolytic gas	Heat , Ash
Process principle	Partial oxidative Conversion	Reductive transformation	Complete oxidative conversion
Feedstock Requirements	Dry wastes of synthetic and biological origin	Dry wastes of synthetic and biological origin	Dry wastes of synthetic and biological origin

Parameters	Gasification	Pyrolysis	Incineration
Temperature Requirements (°C)	500-1800	250-900	800-1450
Cost (Capital & O&M)	High	High	Medium-high
Prominence in India	Emerging	Not proven	Prominent
Future Potential	High Potential	Moderate	Moderate
Operation Efficiency (%)	70-80	70-80	50-60
Environmental issues	Concerns with toxic gases, organic compounds emissions and char generation.	Constraints remain as tar depositions, char and volatile organics emissions	Ash discharges and evolution of toxic gases from partial combustion as limitations. **Note**: SWM Rules 2016 stipulates emission standards
Feedstock Preprocessing Method	Shredding and drying	Drying	Drying
Permitted moisture content of feedstock	<15%	<15%	50%
Sub-types of process	Fixed bed, Fluidized bed and entrained flow gasifiers	Fast and slow pyrolysis	Mass burn, Modular and RDF incineration systems
Application of fuel products	Heat and power applications. Transport fuels.	Electricity and heat generation. Feedstock for chemical derivatives synthesis	Heat and power applications
Start up energy (kWh/T)	339	339	77.8
Energy generated(kWh/T)	685	685	544
Solid residue (Kg/T)	120	120	180

There are several reports and expert committee views available on technology selection for WtE. Some of the important reports in Indian context published i.e. the decision support matrix of Kasturirangan Expert Committee for selection of centralized approaches and NEERI are of relevance in technology selection for the project at Deonar.

The Kasturirangan Report of Task Force for Waste to Energy in the context of waste management has given relative scoring to several WtE technology options available. The scoring has been given in the range of 1 to 10 (1 being the least beneficial) to address suitability of centralized and decentralized systems for each unit operation. The experts were made aware of the rationale behind suggesting scores for each unit operations in MSW management. The scores are based on attributes such as technical feasibility, managerial, social acceptance, operation and maintenance advantage, capital cost and recycling potential[20]. The Technology selection matrix is given in **Table 3.10**.

Table 3.10: Decision Support Matrix for Selection of Centralized Approaches based on Experts' Valuation[21]

S. NO.	Technology	Technical Feasibility	Managerial Feasibility	Social Acceptability	Low Capital Cost Advantage	Low O & M Cost Advantage	Recycling Potential	Average	Total Score
1.	Biomethanation	7	7	7	6	6	7	6.7	40
2.	Conventional Composting	6	6	7	5	6	6	6.0	36
3.	RDF Production	7	7	8	6	6	6	6.7	40
4	Pyrolysis/ Gasification	8	7	6	5	6	6	6.3	38
5	Plasma Arc Gasification	6	5	7	4	4	6	5.3	32
6	Incineration	9	8	6	6	7	6	**7.0**	**42**

Based on the above table, Incineration is rated as the best suitable option amongst all the studies technologies for waste to energy.

Incineration is also given as best processing option amongst incineration, Pyrolysis/ gasification for waste in Mumbai region as given in NEERI report. Same is indicated in the Matrix in **Table 3.11.**

20 A Billion Reasons for Waste to Energy in India 2011

21 Report of the Task Force on Waste to Energy Volume I, 2014

Table 3.11: WtE Relative Ranking

Sr. No.	Options Available	Individual Preferred Values (Xpref)	Ideal Treatment Option Value (Xideal)	Standard Treatment Options Value (Xstd)	Reasons	Rank
1.	Incineration	0.80	0.90	0.75	Most Preferred	2
2.	Pyrolysis	0.70	0.75	0.60	Least Preferred	5
3.	Anaerobic Digestion	0.90	1.00	0.65	Most Preferred	1
4.	Sanitary Landfilling	0.55	0.60	0.30	Least Preferred	6
5.	Composting	0.70	0.75	0.62	Preferred	4
6.	Recycling Options	0.80	0.90	0.70	Preferred	3
Xpref –Fraction preferred by individual based on their intuition (Xstd < Xpref ≤ Xideal)						
Xideal –Fraction collectable for the particular treatment option						
Xstd –Fraction of waste suitable for particular treatment option						

On the basis of above discussion, the incineration technology with appropriate pre processing involving waste segregation and inert removal as well as moisture reduction to achieve the desired characteristic of waste for incineration purpose is recommended as the WtE option for the proposed project.

CHAPTER 4: Regulatory Framework and Clearances

4.1 Regulatory Framework

Growing concerns regarding unsuitable waste management resulted in numerous public interest litigations (PILs) prompting the Supreme Court of India, in 1996, to order the Ministry of Environment and Forests (MoEF), Government of India, to issue rules regarding MSW management and handling, initially only for all class I cities. Four years later, in 2000, the MoEF notified the Municipal Solid Waste (Management and Handling) [MSW (M&H)] rules for all Indian cities (Dube, Nandan, & Dua, 2014). The rules contained directives for all ULBs to establish a systematic approach for waste management including installation by end of 2003. The revised SWM Rules 2016 focuses on the various technologies and processes like Waste to Energy, apart from the conventional system of waste management. It also speaks about the duties and responsibilities of various agencies for catering the MSWM issues. The highlights of the SWM rules 2016 will be discussed in the below sections in detail. While planning it is also important to take into account the types of consents and obligations as mandate for processing MSW.

The right to live in a healthy environment is also a basic human right. At present, the solid waste management practices are to comply with the following sets of regulations:

- Environment protection Act (Umbrella act), 1986.
- Air (Prevention and control of pollution) Act 1981- amended in 1987,
- Environment (Protection) Rules 1986- amended in 2003.
- **Municipal Waste (Management and Handling Rules) 2000, [25.9.2000], S.O. 908(E) and SWM Rules 2016.**
- Batteries (Management and handling) Rules 2001
- **Bio-Medical Waste (Management and Handling) Rules 2016, S.O.1069 (E)**
- **Hazardous Wastes (Management, Handling and Trans boundary Movements) Rules 2016,**
- **Plastics Waste Management Rules 2016**
- **E-waste (Management) Rules 2016[22].**
- **Construction and Demolition Waste Rules 2016.**

The significant regulatory requirements applicable to the project during construction and operation stage are described herewith.

4.1.1 Solid Waste Management (SWM) Rules, 2016

Ministry of Environment and Forests under the provisions of the Environmental Protection Act, 1986 issued the Solid Waste Management (SWM) Rule, 2016 on 8th April 2016. Some of the key functions to ensure adherence include:

- Provide infrastructure and services for collection, storage, segregation, transportation, treatment and disposal of MSW

22 Implementation from 01 October 2016

- Obtain authorization/ technical clearance from the state pollution control board to set up waste processing and disposal facilities
- Criteria are for setting up processing and treatment facility & actions for hilly areas and waste to energy process.
- Publish annual reports of compliance to conditions laid down in the SWM Rules, 2016.
- Reporting of any accidents at the site during managing of MSW as per Form VI in SWM Rules 2016.

The SWM Rules 2016 have focused on the Waste to Energy treatment system and have adopted the necessary framework for developing it in India. Being a source of energy generation from waste, WtE plants are looked upon as subsidiary sources of energy to the ULBs or respective developer. The rules discuss about the standards and criteria's for developing the Waste to Energy Plants in India. SWM Rules 2016 have also defined and refurbished the list of agencies and their respective duties for MSWM.

Following are brief points from the SWM Rules 2016 relevant to WtE Plants,

- Promoting waste treatment technologies such WtE for processing of waste
- Air emission standards for the Incineration of waste (type of WtE Plant)
- Criteria for WtE Process, thus utilizing waste of higher calorific value in systematic manner.
- Mandate for purchase of energy generated through WtE plants.

As per the SWM Rules 2016, the criteria for waste to energy process are as follows-

- Non recyclable waste having calorific value of 1500 Kcal/kg or more shall not be disposed of on landfills and shall only be utilized for generating energy either or through refuse derived fuel or by giving away as feed stock for preparing refuse derived fuel.
- High calorific wastes shall be used for co-processing in cement or thermal power plants.
- The local body or an operator of facility or an agency designated by them proposing to set up waste to energy plant of more than five tons per day processing capacity shall submit an application in Form-I to the State Pollution Control Board or Pollution Control Committee, as the case may be, for authorization.
- The State Pollution Control Board or Pollution Control Committee, on receiving such application for setting up waste to energy facility, shall examine the same and grant permission within sixty days.

The Schedules of SWM Rules 2016 are discussed in Annexure 2.

Time frame for implementation.-Necessary infrastructure for implementation of these rules shall be created by the Urban Local Bodies and Prescribed Authorities, as the case may be, on their own directly or by engaging agencies within the time.

4.1.2 EIA Notification 2006, and Amendments

As per the EIA notification 2006 the proposed WtE Plant falls under the 7 (i) projects of Physical Infrastructure including Environmental Services of Category 'B' type with General Conditions.

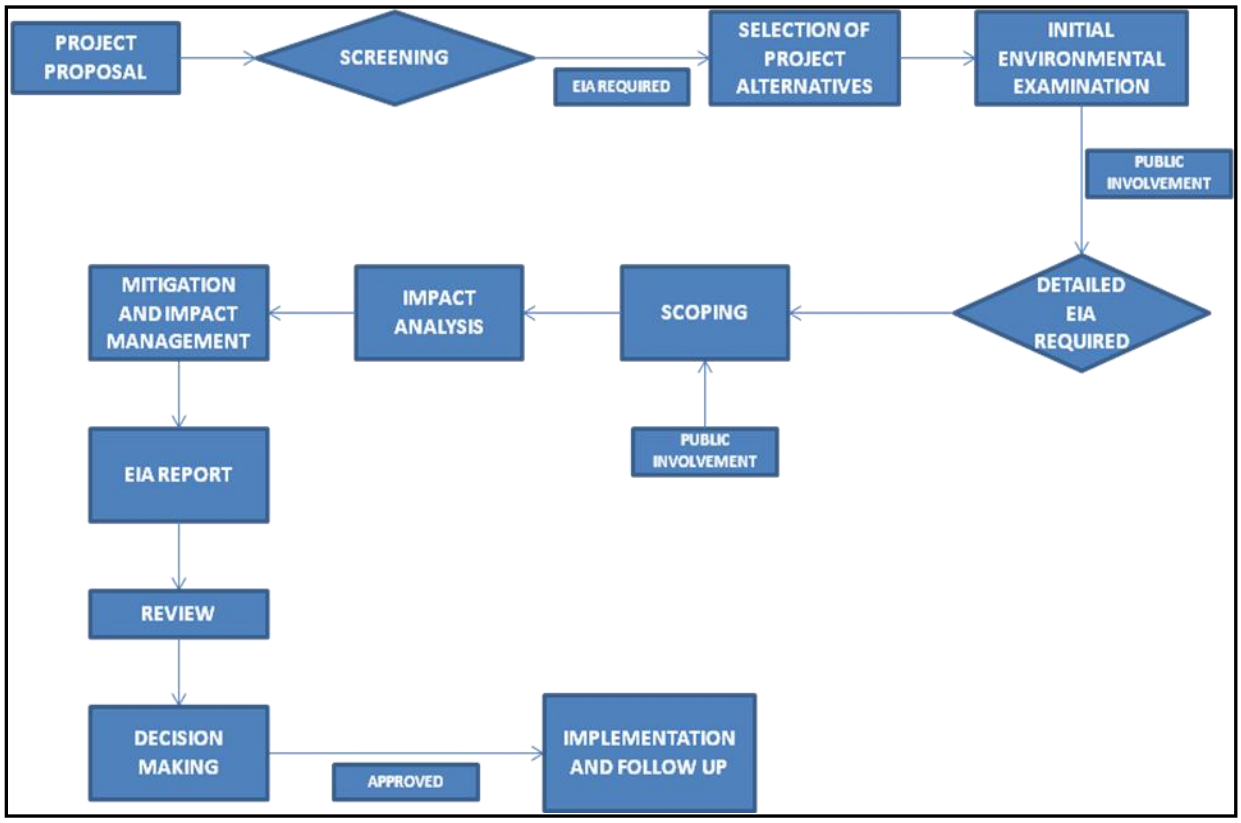
The WtE project with electricity generation is also categorized under thermal power category of 1(d). The power generation from this project is expected above 25 MW, therefore, it will be apprised from Expert Appraisal Committee (EAC) of Ministry of Environment & Forest (MoEF), New Delhi. The project category as EIA Notification 2006 and amendment thereof is given in **Table 4.1**.

Table 4.1: Environmental Clearance requirement for Thermal Power Project (SO 1533, modified 25th June 2014)

Project or Activity		Category with threshold limit		Conditions if any
		A	B	
(1)	(2)	(3)	(4)	(5)
1(d)	Thermal Power Plants	≥500 MW (coal/lignite/ naphta & gas based); ≥50 MW (Pet coke diesel and all other fuels including refinery residual oil waste except biomass). >20 MW (based on biomass or non-hazardous municipal solid waste as fuel).	<500 MW (coal/ lignite/ naphtha and gas based); <50 MW≥ 5MW (Petcock diesel and all other fuels including refinery residual oil waste except biomass) <20 MW>15 MW (based on biomass or non-hazardous municipal solid waste as fuel).	General Condition shall apply Note: (i) Power plants upto 15 MW based on biomass and using auxiliary fuel such as coal, lignite, petroleum products upto 15% are exempt (ii) Power plants upto 15 MW, based on non-hazardous municipal waste and using auxiliary fuel such as coal/ lignite/ petroleum products upto 15% are exempt. (iii) Power plants using waste heat boiler without any auxiliary fuel are exempt.
7(i)	Common Municipal Solid Waste Management Facility (CMSWMF)		All projects	General Condition shall apply

An EIA framework comprising of the activities is been presented in the figure below. A detailed Environment Management Plan (EMP) needs to be prepared in order to overcome the impacts predicted in the EIA for the locations.

Figure 4.1: General EIA Framework



4.1.3 **Coastal Regulation Zone Notification 2011, and amendments**

With reference to the initial section of this chapter, conducting CRZ study and obtaining Clearance will be a mandate in order to develop the WtE plant at Deonar. The present Deonar Dumping site is located within CRZ notified areas, mostly in CRZ II areas, and also spilling over to CRZ I as per the CRZ Map as available with MCGM for 1991.

The revised CZMP of the area is under approval and is not yet available. It is important to establish the revised HTL and LTL falling at the project site to establish the land available for development. The areas & activities under CRZ Zones is shown in Annexure 3. The Map demarcating the CRZ I & CRZ II is shown in **Figure 4.2.**

Figure 4.2: CRZ Demarcation Map (1991)

4.2 Statutory Clearances

In India, under the provisions of air and Water Act, for running or establishing any industry or process and discharging effluent/ emitting pollutants into any water resource or on land/ air and polluting thereby the environmental water/ air is required to obtain Consent to Establish (CtE) and Consent to Operate (CtO) from the concerned Pollution Control Board. The Maharashtra Pollution Control Board (MPCB) shall be the governing agency to release the consents. The prerequisite documents to be considered for the WtE plant are as follows,

- License for manufacturing and trading of compost
- Pollution control boards NOC for manufacturing and trading of refuse derived fuel
- DIC (District Industries Centre) registration.
- NOC from PCB (Pollution Control Board).
- NOC from Labor Commissioner

The various project stages and the required compliances/ requirements to be attained concerned agencies for the proposed WtE plant at Deonar are shown in Annexure 4 and **Table 4.2.**

Table 4.2: Project stages and respective Compliances

Sr. No.	Project Stage	Compliances/ Requirements	Remarks	Agency
1.	Project Development Stage	Environmental Clearance (EC) from State Pollution Control Board under Environment Protection Act 1986	Statutory	SEAC/ SEIAA
2.	Pre Construction	Consent to Establish (CTE) from State Pollution Control Board under Water Act 1974 & Air Act 1981	Statutory	MPCB
3.	Construction	Registration under The Contract Labour (Regulation & Abolition) Act, 1970 as Principal Employer	Statutory	State Labour Departme nt
4.	Pre Construction	Central Ground Water Board NOC for ground water extraction	Statutory	CGWB
5.	Pre Construction	Airport Authority of India (AAI) Clearance/NOC	Statutory	AAI
6.	Pre Construction	Building Plan Approval from ULB	Statutory	MCGM
7.	Pre Construction	Other Site/Location Specific Clearances Required: 1. Forest Dept. Clearance 2. CRZ Clearance	Statutory	SEAC/ SEIAA
8.	Operational Phase	Consent to Operate from State Pollution Control Board under Water Act 1974 & Air Act 1981	Statutory	MPCB
9.	Pre Construction	Authorization under SWM Rules 2016 (State Pollution Control Board)	Statutory	MPCB
10.	Operational Phase	Value Added Tax (VAT & CST) Registration	Statutory	
11.	Operational Phase	Service Tax Registration	Statutory	Income Tax Dept.
12.	Operational Phase	Registration under Employees Provident Fund Act	Statutory	EPFO
13.	Operational Phase	Registration under Employees State Insurance Act	Statutory	EPFO

4.3 Regulatory Standards

4.3.1 Air Quality Standards

With the processing of MSW at proposed WtE plant will release considerable quantities of air emissions, both particulate and gaseous in nature. The release of air

emission from the operation shall be in adherence to the emission standards stipulated by the regulatory agency. As per the SWM Rules 2016, emission standards for incineration facility of MSW are presented in **Table 4.3**.

Table 4.3: Air Emission Standards or Incineration Facility of MSW (SWM Rules 2016)

Sr. No.	Type	Emission Standards (mg/Nm^3)	Sampling Duration (in minutes) unless
1.	Particulate matter	50	30
2.	HCl	50	30
3.	SO_2	200	30
4.	CO	100	30
		50	24 hrs.
5.	Total Organic Carbon	20	30
6.	HF	4	30
7.	NO_X	400	30
8.	Total Dioxins and Furans	0.1 ng TEQ/Nm^3	8 hrs.
9.	Cd + Th + their compounds	0.05	2 hrs.
10.	Hg and its compounds	0.05	3 hrs.
11.	Sb + Pb + As + Co + Cr + Cu + Mn + Ni + V + their compounds	0.5	2 hrs.

International emission standards for processing of MSW through WtE technologies were reviewed like International standards by Environmental Protection Agency (USEPA) and European Commission (EU) for incineration and combustible waste processing and compared with SWM Rules 2016. The emission standards given in SWM Rules, is comparable to International Standards and therefore, its compliance will meet the environmental requirements for the WtE project.

Considering the air emission to be employed with WtE Plant, following control methods needs to be considered in the planning stage (Jain et al. 2014),

1. Suspended Particulate Matter: High efficiency Bag filters to be provided to remove dust and discharge clean flue gas with maintaining the level at 30mg/ Nm^3.
2. Oxides of Sulphur: According to the CPCB norms the Chimney height of the boiler is calculated using the formula Height = 14 X $Q^{1/3}$, where Q= Qty. of Sulphur Dioxide in kg/hr. By neutralization with lime, the acidity of the gas is reduced thus ranging the height of stack between 50-60m.
3. Oxides of Nitrogen: Thermal DeNOx method can be installed under which, urea solution will be injected in controlled manner into the furnace in a region having optimum gas temperature to achieve optimum reduction. Waste to Energy plants equipped with SNCR has achieved NOx reductions of about 45%.

4. Carbon Monoxide: By efficient combustion with proper distribution of primary and secondary air and continuous agitation of fuel on the grate with minimum excess air, CO concentration can be minimized. The Boiler must have a Gas recirculation system to re-circulate the flue gas thus enabling the reduction in unburnt carbon. Thus, provision of a gas recirculation system will increase the Boiler efficiency.
5. Dioxin and Furans: The dioxin and furans emission can be controlled by,
    - Extensive segregation chlorinated plastics such as PVC, rubber, etc.
    - Furnace design with 2 sec retention and higher temperature after secondary air injection will ensure destruction of any Dioxin formed.
    - Controlling the SPM levels to further control any potential emission of dioxins and furans.
    - Powdered activated carbon to be injected into flue gases before entrainment into bag filters to enable adsorption of any dioxins/ furans.

Deonar dumping site is well located within the city boundary and very close to residential, commercial and Natural Zones, thus it is also necessary to maintain high standards to emissions. A Continuous Emission Monitoring System (CEMS) for stack emission and regular ambient air quality monitoring is suggested to ensure the air quality as well as to take corrective and preventive actions as and when required.

4.3.2 **Water Quality Standards**

Water requirement for the project will be of two categories- potable water requirement as well as process water requirement. The water requirement of approximate 4.5 MLD for the proposed WtE plant will be met by the nearby Ghatkopar Treatment Lagoon.

The potable water requirement shall be calculated as 45 litre per person per day (lpcd) as per CPHEEO requirement for staff. The potable water should meet the IS: 10050 standards for drinking water quality.

Water shall be required at various treatment processes. The quantity utilized should reach the quality standards for smooth functioning of plant especially for boilers and cooling systems.

4.3.3 **Leachate Quality Standards**

There will be waste water discharge from the project as leachate from waste collection, storage and processing areas, effluent from the power generation process and sewage generation. It is mandatory to treat all these waste water streams before discharge or reuse. The individual discharge norms are discussed below:

Leachate management is very critical and needs immediate action for collection and treatment. As per SWM Rules 2016, a systematic approach for treatment and disposal of leachate is a mandate. The rule also provides the mode of disposal standards for leachate. The Standards for Leachate disposal as per SWM Rule 2016 is shown in **Table 4.4**.

Table 4.4: Standards for Leachate disposal as per SWM Rule 2016

Sr. No.	Parameters	Inland Surface Water	Public Sewers	Land Disposal
1.	Suspended solid (mg/l)	100	600	200
2.	Dissolved solid (inorganic) (mg/l)	2100	2100	2100
3.	pH value	5.5 to 9.0	5.5 to 9.0	5.5 to 9.0
4.	Ammonical Nitrogen (as N) (mg/l)	50	50	-
5.	Total Kjeldal Nitrogen (mg/l)	100	-	-
6.	Biochemical Oxygen Demand (BOD) 3 days @ 27^0C (mg/l)	30	350	100
7.	Chemical Oxygen Demand (COD) mg/l	250	-	-
8.	Arsenic (as As) mg/l	0.2	0.2	0.2
9.	Mercury (as Mg) (mg/l)	0.01	0.01	-
10.	Lead (as Pb) (mg/l)	0.1	1	-
11.	Cadmium (as Cd) (mg/l)	2	1	-
12.	Total Chromium (as Cr) (mg/l)	2	2	-
13.	Copper (Cu) (mg/l)	3	3	-
14.	Zinc (Zn) (mg/l)	5	15	-
15.	Nickel (as Ni) (mg/l)	3	3	-
16.	Cyanide (as CN) (mg/l)	0.2	2	0.2
17.	Chloride (as Cl) (mg/l)	1000	1000	600
18.	Fluoride (as F) (mg/l)	2	1.5	-
19.	Phenolic Compounds(as C_6H_5OH) (mg/l)	1	5	-

Table 4.5: Waste Water Discharge Standards by CPCB (Environment Protection Rule 1986, Schedule IV)

Sr. No.	Parameter	Standards			
		Inland Surface water	Public sewers	Land for irrigation	Marine coastal areas
1.	Colour & Odour	agreeable		agreeable	agreeable
2.	Suspended solids mg/l, max.	100	600	200	(a) For process waste water- 100
					(b) For cooling water effluent 10 percent above total suspended matter of influent.
3.	Particulate size of suspended solids	Shall pass 850 micron IS Sieve	–	–	(a) Floatable solids max. 3 mm.
					(b) Settleable solids max. 850 microns.
4.	pH value	5.5 to 9.0	5.5 to 9.0	5.5 to 9.0	5.5 to 9.0
5.	Temperature	shall not exceed 5°C above the receiving water	–	–	shall not exceed 5°C above the receiving water
6.	Oil & Grease mg/l Max.	10	20	10	20
7.	Total Residual Chlorine mg/l Max	1	–	–	1
8.	Ammonical nitrogen (as N) mg/l Max	50	50	–	100
9.	Total Kjeldahl Nitrogen (as NH_3) mg/l, Max	100	–	–	100
10.	Free Ammonia (NH_3) mg/l Max	5	–	–	5
11.	Biochemical Oxygen Demand (3 days at 27°C) mg/l max	30	350	100	100
12.	Chemical Oxygen Demand, mg/l, max	250	–	–	250
13.	Arsenic (as As), mg/l max	0.2	0.2	0.2	0.2
14.	Mercury (as Hg), mg/l max	0.01	0.01	–	2
15.	Lead (as Pb) mg/l, max	0.1	1	–	2

Sr. No.	Parameter	Standards			
		Inland Surface water	Public sewers	Land for irrigation	Marine coastal areas
16.	Cadmium (as Cd) mg/l, max	2	1	–	2
17.	Hexavalent Chromium (as Cr + 6) mg/l, max	0.1	2	–	1
18.	Total Chromiun (as Cr.) mg/l, max	2	2	–	2
19.	Copper (as Cu) mg/l, max	3	3	–	3
20.	Zinc (as Zn) mg/l max	5	15	–	15
21.	Selenium (as Se) mg/l max	0.05	0.05	–	0.05
22.	Nickel (as Ni) mg/l max	3	3	–	5
23.	Cyanide (as CN) mg/l Max.	0.2	2	0.2	0.2
24.	Fluoride (as F) mg/l Max	2	15	–	15
25.	Dissolved Phosphates (as P), mg/l Max	5	–	–	–
26.	Sulphide (as S) mg/l Max	2	–	–	5
27.	Phenol compounds (as C_6H_5OH) mg/l,	1	5	–	5
28.	Radioactive materials :				
29.	(a) Alpha emitter micro curie/ml.	10^{-7}	10^{-7}	10^{-8}	10^{-7}
30.	(b) Beta emitter micro curie/ml.	10^{-5}	10^{-6}	10^{-7}	10^{-6}
31.	Bio-assay test	90% survival of fish after 96 hours in 100% effluent	90% survival of fish after 96 hours in 100% effluent	90% survival of fish after 96 hours in 100% effluent	90% survival of fish after 96 hours in 100% effluent
32.	Manganese (as Mn)	2 mg/l	2 mg/l	–	2 mg/l
33.	Iron (as Fe)	3 mg/l	3 mg/l	–	3 mg/l
34.	Vanadium (as V)	0.2 mg/l	0.2 mg/l	–	0.2 mg/l
35.	Nitrate Nitrogen	10 mg/l	–	–	20 mg/l

4.3.3.1 **Treated Effluent Water**

An Effluent Treatment Plant (ETP) and STP respectively will be developed to treat the waste water generated at the site. The same will be discussed in detail in infrastructure section of the report. The treated discharge from the ETP shall be reused in the process (if applicable), and for dust suppression of the roads and unloading areas, landscaping requirement etc. The surplus treated water (if any) will be discharged as per the CPCB norms as enumerated in **Table 4.5**.

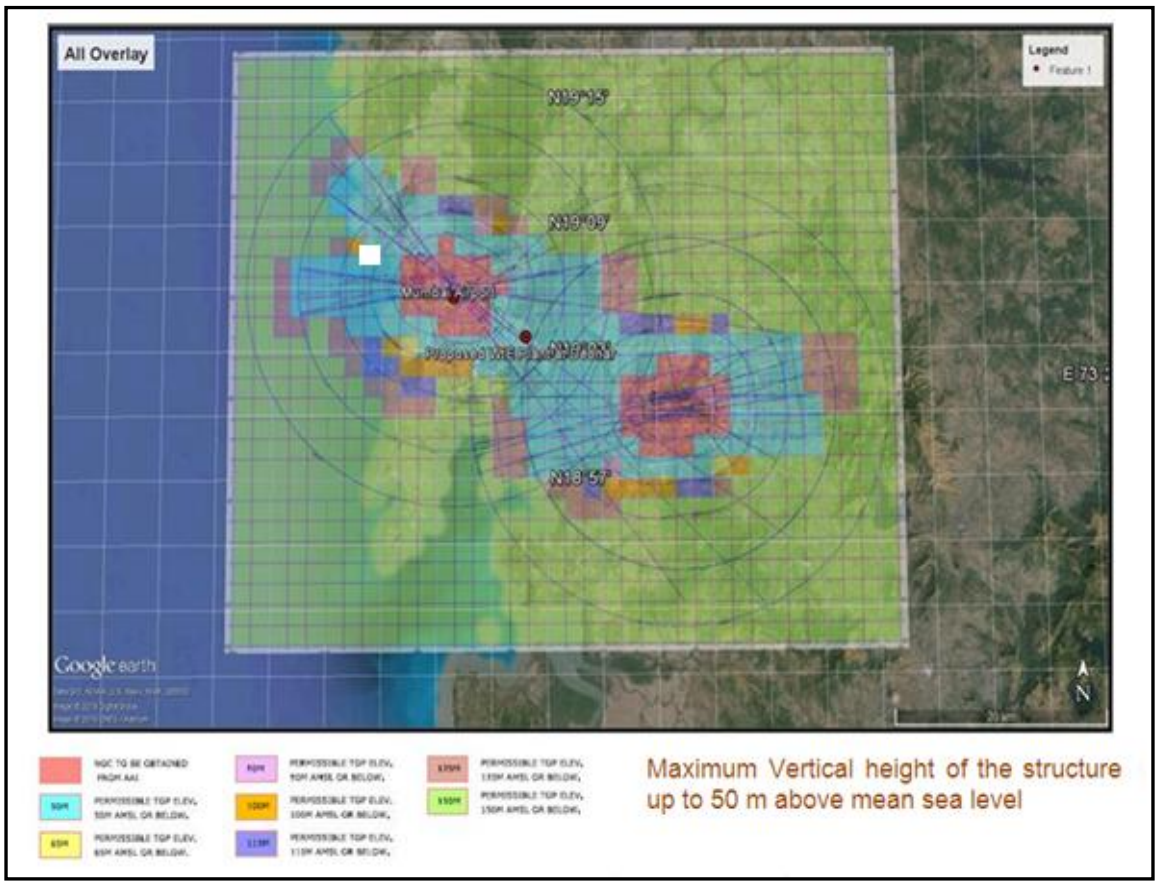
4.3.3.2 **Storm Water Quality**

It is required to design a robust storm water collection network as the runoff water may contain impurities due to the nature of the project. The collected storm water shall be treated as per the National Building Code (NBC) Best Practices for storm water management. Any discharge of storm water to nearby surface water body shall be monitored for its quality.

4.4 Consent from Airport Authority of India

As per the guidelines specified by the Airport Authority of India (AAI), restriction for vertical development is been limited within the funnel zone. Below map is been generated overlaying the coordinates of the CCZM map and the Mumbai Airport. As per the CCZM map, the proposed WtE Plant falls in the blue zone. This allows development of vertical structures limiting to 50m above mean sea level (MSL).

Figure 4.3: Overlay of AAI Colour Coding Zoning Map over Deonar Dumping ground



AAI have identified the various permissible heights within the funnel zone from Mean Sea Level (MSL) and has developed the Colour Coding Zoning Map (CCZM).

The height limitation is very vital while planning the vertical structures for the proposed WtE plant such as Stack for emission dispersion. While designing the stack it is thus important to take account this limitation.

4.4.1 **Noise Quality Standards**

The site is located well within the city limit and close to residential and commercial zone. With the proposed WtE Plant, the noise during pre construction and post construction shall be varying thus affecting the nearby areas. The Ambient Noise Standards are shown in **Table 4.6.**

Table 4.6: Ambient Air Quality Standards with respect to Noise

Area Code	Category of area/ zone	limits in dB (A) Leq*	
		Day Time	Night Time
(A)	Industrial	75	70
(B)	Commercial	65	55
(C)	Residential	55	45
(D)	Silence	50	40

*****dB(A) Leq denotes the time weighted average of the level of sound in decibels on scale A which is relatable to human hearing.

Note

- Day time shall mean from 6.00am to 10.00pm
- Night time shall mean from 10.00pm to 6.00am
- Silence zone is defined as an area comprising not less than 100 metres around hospitals, educational institutions and courts. The silence zones are zones which are declared as such by the competent authority.

The monitoring of the various noise levels during the construction and operation phases and also while processing waste is the primary requirement and should adhere to the levels specified by Noise Pollution (Regulation and Control) (Amendment) Rules, 2010 and Industrial standards

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CHAPTER 5: Project Design Concept

5.1 Technology Description:

There are several Waste to Energy (WtE) technologies as discussed under Chapter 3. The overall objectives are:

(i) Reduce the volume of waste to the dumping site
(ii) Meet the criteria under SWM Rules 2016
(iii) Meeting the environmental criteria and emission standards as laid down under Environmental Protection Acts 1986, and
(iv) Sustainable waste management for the city

The technology or combination of technologies, which can achieve the above objectives considering the factors like waste quality, quantity (i.e. 3000 TPD), location, environmental and social scenario of the city are given below:

- Incineration
- Pyrolysis
- Gasification

Although, above mentioned WtE technologies and there possible combination are available for processing MSW, technical details of incineration based WtE technology is presented in this chapter to understand overall scale of project, which includes required specific and common allied infrastructure.

The common facilities and infrastructure for the project considering waste quality and quantity, (independent of WtE technology, which to be selected by Agency/ developer) is given in **Table 5.1**.

Table 5.1: Common facilities/ resources for technologies

Sr. No.	Requirements
1.	Land (Project area for handling, storing, pre-processing of waste, plant facility etc.)
2.	Water
3.	Auxiliary Power
4.	Emission Control
5.	Continuous Emission Monitoring
6.	Reject Disposal
7.	Allied infrastructure (i.e. Effluent/ Leachate Treatment Plant (LTP), Internal Roads, Compound Wall, Storm Water Drain Fire fighting system, and Pre-treatment of waste.

5.2 Case Study: Incineration based WtE

5.2.1 **Project requirement**

The major requirements are as follows:

- Process 3000 TPD MSW to generate electric power
- Comply statutory requirements
- Design to suit various operational scenarios based on variations in waste characteristics and maximise efficiency and power generation
- MSW Pre-processing
- Manage rejects in environmental friendly manner and assess revenue potential
- Efficient Utilities and allied Infrastructure

A typical flow diagram for WtE plant is given at **Figure 5.1**.

5.2.2 **Approach**

Following approach is adopted for planning, design and implementation of Waste to Energy (WTE) project to achieve above mentioned objective.

- Assessment of Land availability and requirement
- Assessment of Water availability and requirement
- Assessment of Power availability and requirement
- Demarcation of land on the proposed site
- Layout Planning
- Site preparation
- MSW Pre-processing plant
- Waste to Energy Plant
- Power generation and evacuation system
- Auxiliary Power Supply System
- Process water conveyance pipeline
- Raw Water Treatment Plant
- Management of rejects – Inert material, Glass and Metals, Bottom ash and fly ash etc.
- Leachate, Effluent and Sewage Management
- Emission Control and Monitoring
- Green Belt
- Provision of required allied infrastructure

5.2.3 **Assessment of Land availability and requirement**

5.2.3.1 **Land Availability**

Based on Topographical survey map (Contour map) and Coastal Regulation Zone (CRZ) map provided by SWM and DP department of MCGM and joint site visit conducted by MCGM officials and TCE representatives, two land parcels (A and B) as mentioned in land availability map) were shown to TCE by MCGM. Based on the

said documents and applicable regulatory guidelines, land availability at site is analysed. It is found that both land parcels are adjacent to CRZ-II area. Land parcel-C from CRZ-II, which is 100m away from High tide line, also considered to be included in the proposed project area for allied infrastructures such as Green belt, internal road, compound wall, utility lines, ETP, LTP, WTP facilities. The area statement of available land parcels is presented in **Table 5.2**. The available Land parcel is also presented in the Figure 5.2.

The detailed of the land parcel is given at **Drawing No: TCE. 10176A-2024-GA-6002**. It is evident from the below mentioned table that 8.89 Ha (i.e. Land parcel A+B) is available in non-CRZ area for the plant and 3.3 Ha (i.e. Land parcel C) in CRZ-II areas.

Apart from A, B, C, Parcel, there is another parcel of 2 Ha is available at the entrance of the project as parcel – D. This is non-contagious land parcel.

Here after, land parcel (A+B+C+D) will be addressed as proposed land parcel.

Table 5.2: Land Availability and Depth of existing MSW

Land Availability and Depth of Existing MSW					
Land Parcels	**Area**	**Unit**	**Located in**	**MSW above Avg. Ground Level**	**Remark**
A	1.39	Ha.	Non-CRZ	3-4 m	Small Land Parcel near partial Closure toe
B	7.5	Ha.	Non-CRZ	3-11 m	Main Land Parcel
C	3.3	Ha.	In CRZ-II & 100 m away from HT Line	3-11 m	Add on for Land Parcel B
D	2.0	Ha.	Non-CRZ at the Southern side (near Entrance)	Not available	Separate land parcel
Total	**14.19**	**Ha.**			
Note: RL of the Average Ground level is 7m. As per Geotechnical Survey (July-2005), average depth of MSW below average GL is minimum 10 m. As per Contour map (December-2014), Average depth of MSW above average GL is undulating from 3m to 11 m range.					

Apart from the above proposed land parcel, there are two vacant plot on the right side of approach road to Site near Mankhurd-Ghatkopar Highway. The size of plot is 2.2 Ha and 0.85 Ha beside Biomedical Facility of MCGM.

Figure 5.1: Flow Diagram for Typical WtE

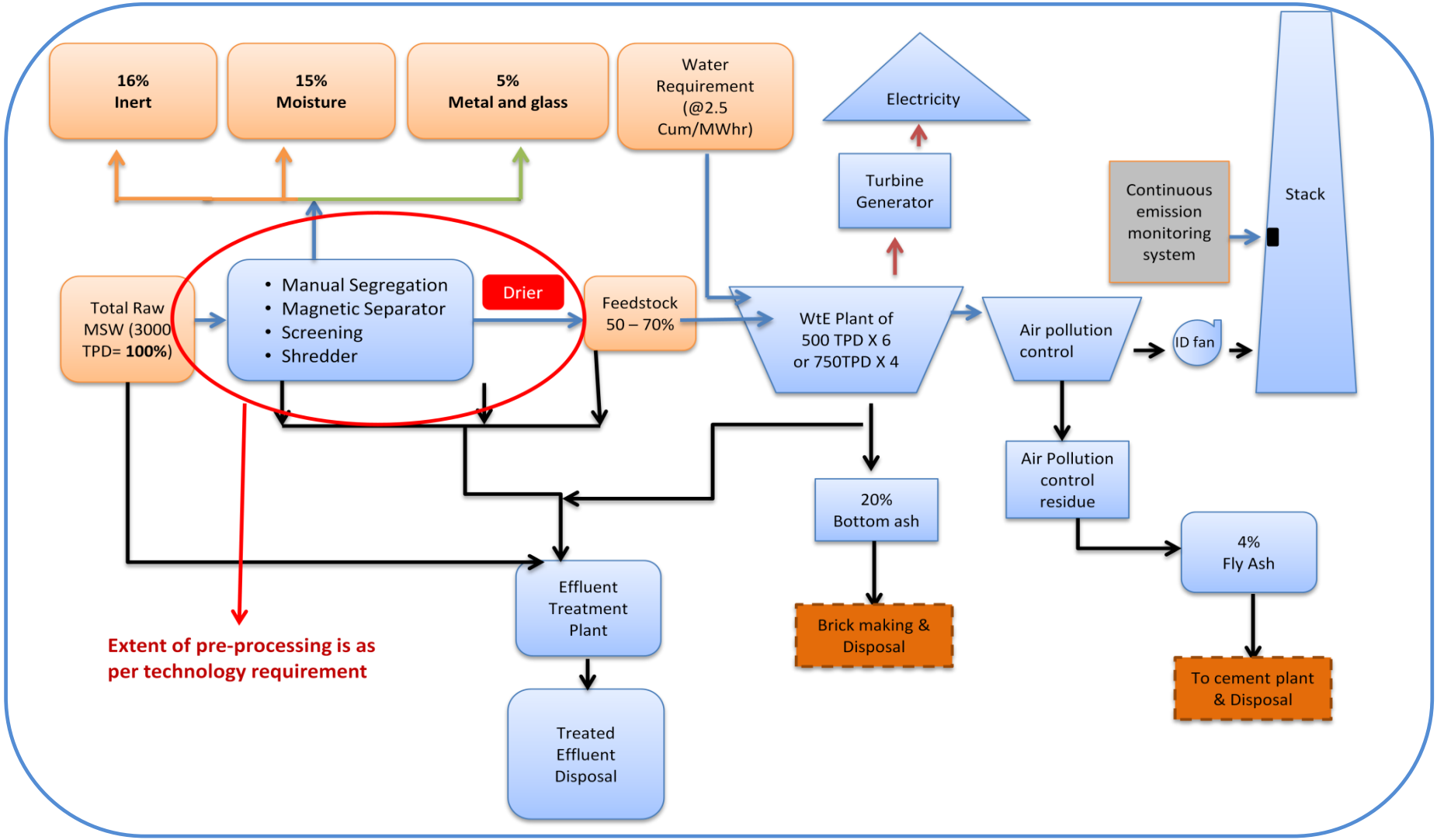
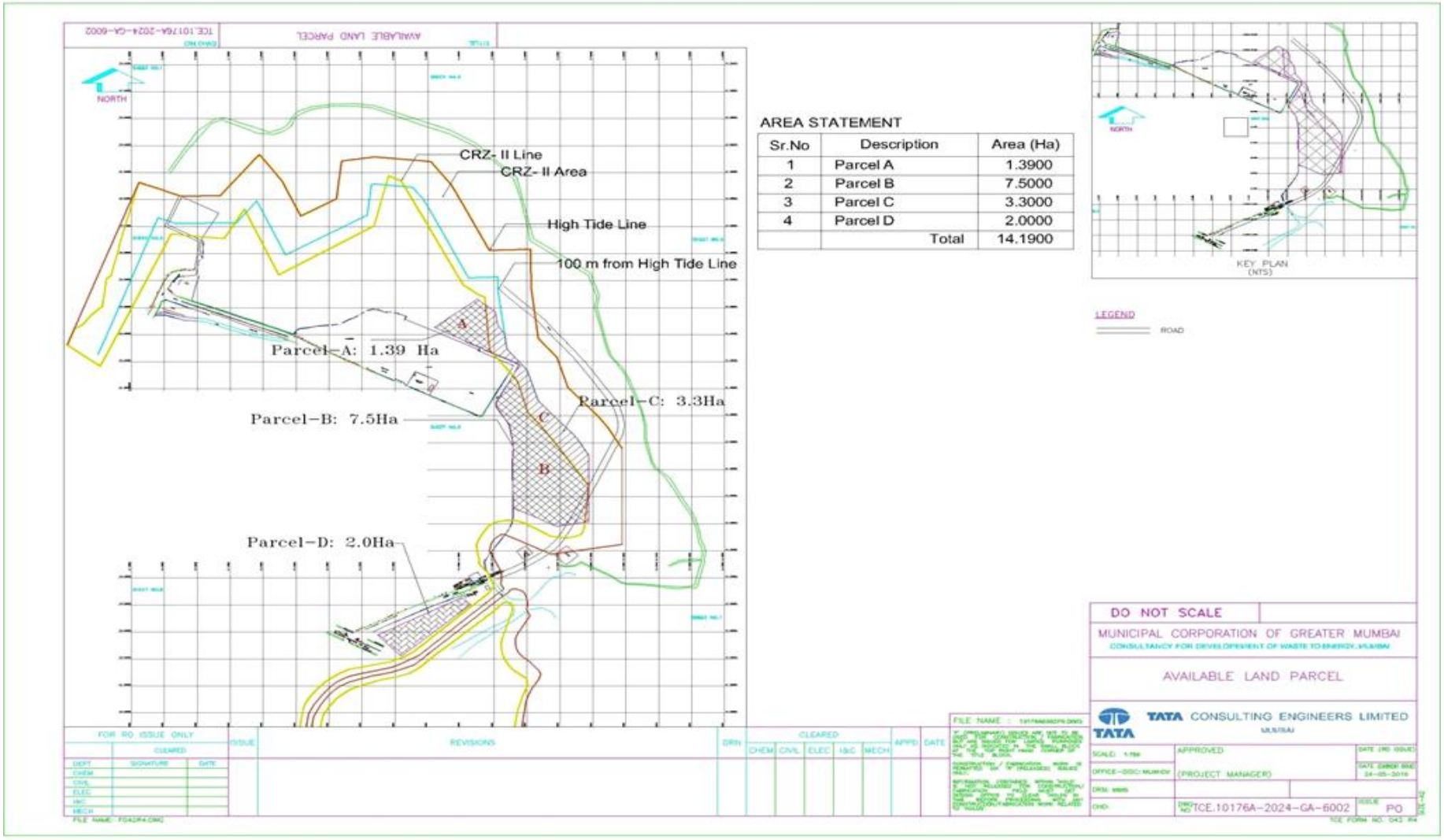


Figure 5.2: Available land parcel at proposed site



5.2.3.2 **Land Requirement**

The land requirement for the project is considered for three main components:

1. **Plant area:** This includes waste receiving area, pre-processing, processing area (including Incineration, power island and stack), emission control facility, Water Treatment Plan (WTP), Leachate Treatment Plan (LTP), Parking lot, open and Green areas.etc.
2. **Ash Pond and SLF:** This is for disposal of fly ash and bottom ash. SLF is required for disposal of pre-processing rejects.
3. **Reject Management Facility:** This area is required for facilities like brick making and storage of inerts (for use for construction or filling material).

Considering the above components, the land area requirement for the project is given in **Table 5.3**:

Table 5.3: Land area Requirement

Sr. No.	Components	Land area Reqmnt. (Ha)	Remarks
1.	Plant Area	9.5	The plant area is for processing of 3000TPD
2.	Ash Pond and SLF	23.5	(Ash pond 9 Ha + SLF 14.5 Ha = 23.5 Ha) for 20 years disposal
3.	Reject Management Facility	2.0	For Brick making etc.
	Total	**35.0**	

Notes:

1. Height of disposal for waste and pre-processing rejects are considered as 30.5 m
2. Height for Ash disposal is considered as 23.5m
3. Side slope for SLF is taken as 1V : 4H
4. Density:
   - For Waste disposal: 1.4 Ton/ CUM
   - For Pre-processing waste: 1.8 Ton/ CUM
   - For Ash disposal: 1.2 Ton/ CUM

It is evident from above table that sufficient area is not available for disposal of inerts and ash from processing of 3000TPD waste at Deonar. Considering the above scenario, following two options are considered for the project:

1. **Option 1:** Presently about 15 Ha land (14.2Ha + some miscellaneous adjacent pockets) is available. Additional 15Ha land should be identified in the vicinity or to be developed within the Deonar dumpsite.
2. **Option 2:** Process rejects, i.e. ash (Fly ash and bottom ash) to be utilized 100%. Other rejects (pre-processing and misc rejects) should also be utilized to the maximum possible.

In the second option, the land requirement for reject disposal would reduce to about 10Ha for 20 years period. This land can be developed from the existing dumpsite by way of using the waste in WtE plant and also by transporting it to other landfill site.

5.2.3.3 **Site Preparation**

Available data of Geotechnical report and contour map is reviewed to assess the quantum of waste (MSW) dumped within the proposed land parcel. Considering RL-7m at proposed site as average ground level, it is found that MSW is present 10 to 12m below and 3 to 11m above average ground level. In the view of above site scenario, it is recommended to excavate entire waste upto 12m depth and refilling the excavated ground up to required average RL: 7m with good soil and/ or construction and demotion material (C&D) and get compacted as per directions of the Geotechnical expert in order to avoid any settlement. Considering this site preparation scheme, estimated excavation quantity is 1,680,705 cubic meter and filling quantity is 1,506,852 cum. It is recommended that before detailed design and development, all primary investigations such as Site survey, Geotechnical Investigation, Baseline environmental monitoring and any other in-situ or laboratory test and analysis in order to have best use of land ensuring stability of proposed structures to be carried out. Accordingly, ground improvement plan and design foundations for all the proposed structures should be carried out.

5.2.3.4 **Legacy Waste:**

The waste lying at the site (fresh and old waste) is termed as legacy waste. As stated in the above section that it constitutes about 16 million cubic meter. Excavation of such quantity and re-filling constitutes huge expenses in terms of waste transportation and bringing good quality earth from outside. Procuring of good earth material for re-filling is one of the major constraint to the project vis-a-vis removal of legacy waste and its disposal. Removal of entire waste and its re-filling will also incur huge cost to the project.

The study conducted by Central Road Research Institute (CRRI), Delhi for National Highway Authority of India (NHAI) recommends that about 60 - 70% of municipal waste is actually soil and can be used for the purpose of constructing embankment and roads[23].

Based on the detailed geotechnical study, topographical survey and as per the requirement of site grading, the methodology of site development shall be prepared. It shall include the depth of excavation, calculations and quantum of excavation, philosophy of segregation (for Soil, C&D, RDF etc.), stacking & storing of the segregated RDF material as feedstock for the WtE Plant. Reuse of good quality segregated material such as Soil, C&D and inert materials to be considered for backfilling in order to reduce the disposal quantity of excavated legacy waste.

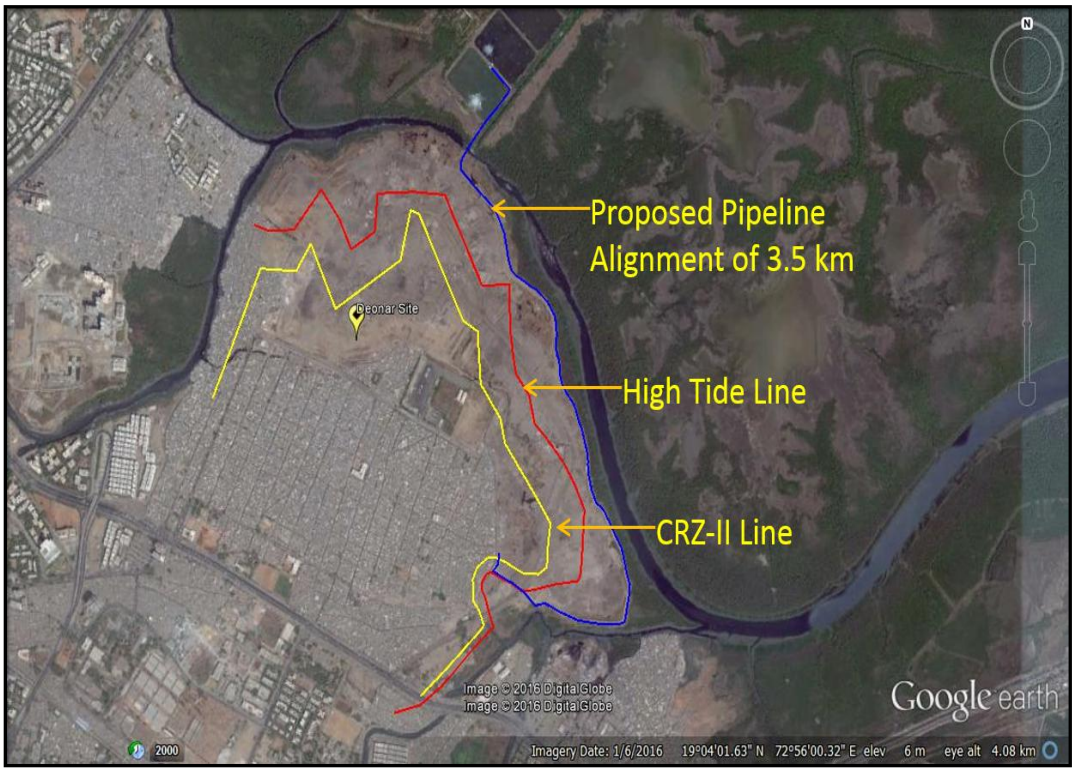
[23] NHAI to use Municipal solid waste for construction of highways By Express News Service, Published: 24th June 2016

5.2.4 **Assessment of Water availability and requirement**

Presently water requirement at the Deonar site is met through tanker water and there is no permanent water supply at the site. WtE project requires water for boilers, turbine steam and other allied activities. As per the MoEF&CC notification dated 7th December, 2015, New plants to be installed after 1st January, 2017 shall have to meet specific water consumption up to maximum of 2.5 m^3/MWh and achieve zero waste water discharged", accordingly water requirement of the proposed WtE plant of 30 MW would require 1.8MLD water[24]. Considering the fire fighting water requirement at the Deonar dumpsite which is presently being met through drinking water tankers, it is proposed to have supply capacity of 4.5MLD of raw water from Ghatkopar STP lagoon. The analytical raw water samples analyses are shown in Annexure 5. The proposed Alignment of Water Conveyance Pipeline from Ghatkopar STP is shown in **Figure 5.3.**

These requirements were discussed during joint site visit at Ghatkopar Lagoon dated 19 April 2016 by MCGM officials and TCE, and it was proposed to have 3.5 km long pipeline (the pipeline route is taken by the side of waste dumping) to convey 4.5 MLD of pre-treated water from Lagoon (as raw water) to the proposed WTE site location and have a WTP of same capacity at the proposed site.

Figure: 5.3 Proposed Alignment of Water Conveyance Pipeline from Ghatkopar STP



The route of the pipeline is shown along the side of the dumpsite as straight route is not feasible considering huge waste dumping of about 30m. Accordingly, probable

24 There is no specific regulation for Waste to energy Plant, therefore, standard for Thermal Power Plant is considered for present project.

alignment of the pipeline is proposed along the periphery of the site as presented in **Figure 5.3**. However, after detailed survey and geotechnical investigation, the possibility of micro-tunnelling can be explored.

5.2.5 **Assessment of Power Availability and Requirement**

Presently, there is power supply available at site for the Weighbridge. Operator will have to make arrangement for supply of power from DISCOM located in the vicinity of the WTE plant.

5.2.6 **Components of Waste to Energy Plant**

Components of WtE plant for processing 3000 TPD are shown in **Table 5.4**.

Table 5.4: Components of the proposed plant

Sr. No.	Plant Components
1.	MSW Processing Plant (Power House)
	Common Infrastructure
2.	MSW Pre-Processing Unit
3.	Weighbridge
4.	Internal/ Service Road
5.	Storm Water Drainage System
6.	Boundary Wall
7.	Power Evacuation System
8.	Auxiliary Power Supply System
9.	Control Panel and Instrumentation
10.	Process Water Conveyance Pipeline
11.	Raw Water Treatment Plant
12.	Emission Control System
13.	Continuous Emission Monitoring System
14.	Leachate Collection and Management System
15.	Effluent Treatment Plant
16.	Reject Management System
17.	Landscape Works/Greenbelt
18.	Administration office, Workers area, Canteen and Security Cabin

5.2.7 **Layout Planning**

Based on the requirement of specific and common infrastructure for the proposed plant, a layout for the same is planned within the available land parcels and it is presented in the Drawing No. TCE.10176A-2024-GA-6001.

5.2.8 **Demarcation of land on the proposed site**

The land area for WtE plant and allied infrastructure as indicated in layout, should be marked by MCGM to stop further dumping in this site. The plot area can be marked by putting pillars and fencing.

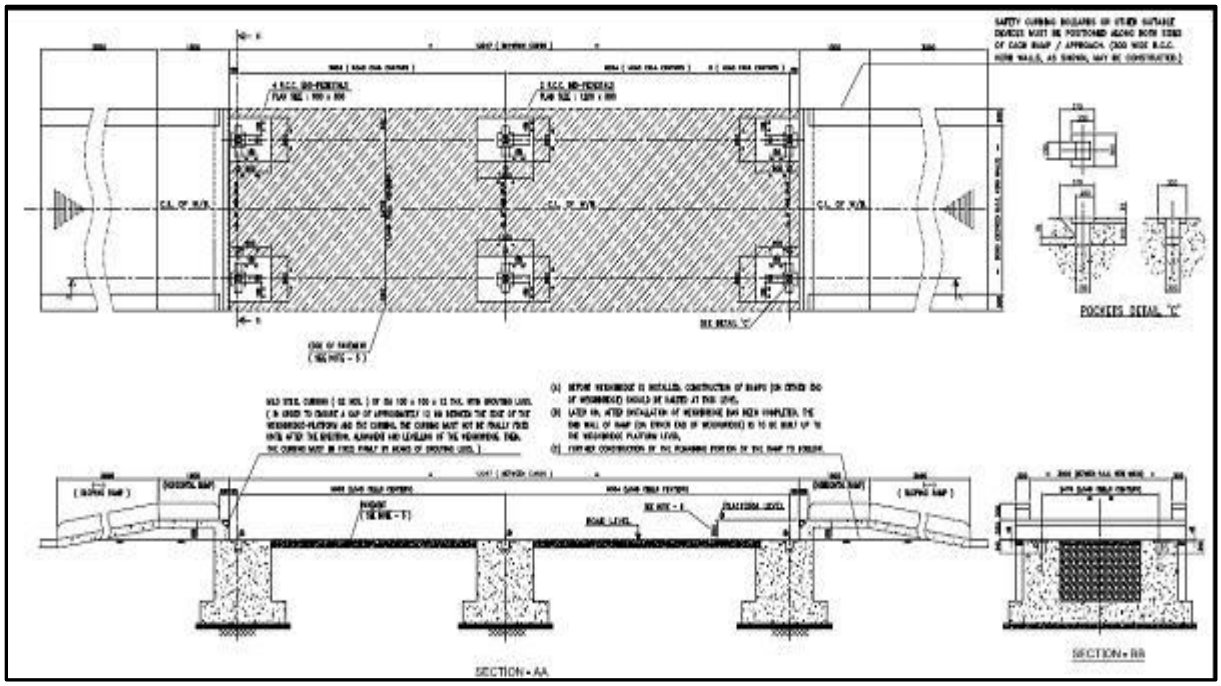
5.2.9 **Weighbridge**

Presently, there are two old weighbridges of 40 Ton capacity in operation at Site weighing daily MSW vehicles towards existing Dumpsite. Still it is envisaged to have two new dedicated weighbridges of 40 Ton capacity within the premises of proposed Waste to Energy plant considering weighing of incoming MSW, pre-processing inert material, Bottom ash, Fly Ash, etc. The weigh bridges would be equipped with digital recording with related software for recording of all the incoming waste and outgoing empty vehicles as well as recyclables etc.

5.2.9.1 **Selection Rationale**

The maximum weight of the MSW Vehicle has been considered while selecting 40 Ton capacity Weighbridge. It is proposed to have surface mounted weighbridge due to short maintenance time and requires minimum civil work which help faster commissioning process.

5.2.9.2 **Weighbridge Conceptual Drawing**



5.2.9.3 **Weighbridge Specification**

Type	Surface Mounted
Qty.	2 Nos
Capacity	40 MT
Platform sz.	12 x 3 m
Load cells:	
Type of load cell	ANALOGUE
No. of load cells	6 Nos.
Capacity of each load cell	45 MT.
Password	Multiple protection levels

5.2.9.4 **Weighbridge Standards**

IS: 1436-1991	Specification for weighbridge
IS: 2062 – 2006	Hot rolled low medium and high tensile structural steel
IS: 9281 Part 1-1979, Part III-1981,Part IV 1983	Electronics weighing System
IS: 800-2000	Code of practice for general construction in steel
IRC: 3-1983	Dimension and weights of road design vehicles
IRC: 5-1985	Standard specification and codes of practice for road bridges section 01
IRC: 24-1967	Standard specification and codes of practice for road bridges section 05 steel road Bridges
IRC: 6-2000	Load and Stress
IS: 875-1985	for live load
WEIGHTS & MEASURES RULES – 1987	Compliance to Standard of Weights & Measure

5.2.10 **MSW Receiving Pit/ Platform**

It is proposed to construct a RCC Platform for receiving the waste by transporting vehicles (Refuse compactor, Trucks etc.). The first level manual screening needs to be done at the platform itself to avoid any large or unacceptable waste like large wood planks, metal objects of large size etc to go in the pre-processing system. This firsts level spotting would be manual.

After waste is manually screened, it will be collected in a pit for further pre-processing, which includes pre-drying, screening through trommel, magnetic, eddy current, vibrator and then final drying for desired level of moisture for boiler feed. Shredder is optional, in case it is required for a particular technology. The receiving pit is proposed to have holding capacity of 3 to 4 days MSW.

As there is very high moisture content in waste as per the Revised Final NEERI report-May-2016, it is proposed to have efficient leachate collection and conveyance system (LCCS) which will collect leachate from receiving area as well as from the pre-processing area and collect in leachate sump. Leachate from the sump shall be pumped to the proposed effluent treatment plant (ETP).

5.3 MSW Handling and Pre-processing Plant (MHP)

The Pre-processing of MSW is necessary as it improves the Calorific value of the input fuel. The extent and requirement of pre-processing depends on the characteristics of waste and type of technology. There are many advantages of pre-processing like:

- Removal of inert and non-combustible fraction gives better calorific value
- Redundancy of the WtE plant is reduced

- Removal of inert and other non-combustible materials before processing also reduces the emission
- Segregation of high quality recyclables helps in resource conservation

The MSW pre-processing plant may consist of Screening, Magnetic Separation, Eddy Current Separation, Shredder to reduce the size of the material and Grab Cranes. In case of high moisture content, drier is also an essential pre-processing stage.

5.3.1 **Pre-Processing Stages**

The material fed into the Slat Conveyor by the grab crane will be conveyed to the Trommel Screen. This Screen separates the total input feed into 3 fractions i.e. Fines, Medium Size and Oversize. The fines which will mainly consist of sand and dust will be separated by the screen and dumped on the ground. This will be cleared with front end loaders and loaded into the trucks for further transportation outside the plant. The oversize will be fed to a conveyor where large Inert particles like Glass, Construction debris, stones etc. are removed manually. This conveyor operating in the manual separation zone will be designed for a low speed to facilitate easy removal of the rejects. These inerts will be transported out of the plant.

Both medium size and oversize will then be mixed and sent to Cross belt Magnetic separation which will remove the ferrous metals.

An eddy current separator will be mounted above conveyor. This will facilitate removal of Non-ferrous metallic parts from the MSW material. The ferrous and non ferrous metallic parts recovered from the above conveyor will be transported out of the plant.

The balance Non-Metallic portion of the MSW from the above conveyor will be fed to the shredder. The shredder will reduce the particle size as per the requirements of the boiler. Thus processed material will be conveyed to the storage shed. This storage shed will be open type with short walls around. The material stored will be further dried to bring down the moisture to desired level. The low energy intensive technology for drying would be adopted.

The better waste management during collection and transportation can ensure that comparative drier waste reached to the WtE plant. This will reduce the energy cost for drying and will also enhance the calorific vale of the waste.

5.3.1.1 **Major equipment in the pre-processing plant:**

Screens

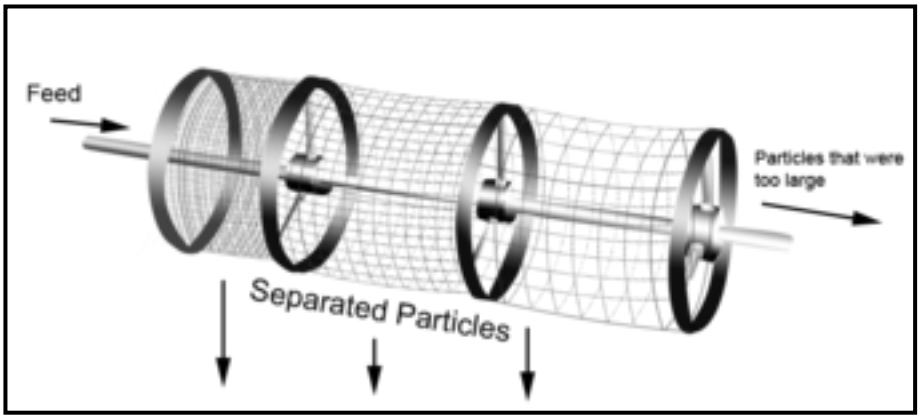
The Screen separates waste, or a fraction of waste according to particle size. These screens may be either flat or rotary (trommel) type, which are usually fitted with a mechanical device to vibrate the screen or to move the material on the screen surface. The rotary or other mechanical motion is important to avoid blockages and achieve a high degree of separation during the short time for which the material is on the screen.

The barrel is mounted such that it can be slowly rotated, and is often set with its long axis tilted with respect to horizontal. Material is fed in the high end, progresses down the barrel as it is rotated. Trommel screens with 2 or 3 discharge is available. The undersize material passes first through the screen surface, medium sized next and oversized material is discharged from the lower end. Trommel screens have a lower throughput capacity than that of equivalent flat screens. However, their great advantage for waste processing is that they do not “blind” from plate like items e.g. paper sheets, cardboard etc. adhering to the screen surface. They also come with fitted Jaw like structures which rip the bag open and act like Bag openers. In this project Trommel Screens (1W+1S) with 3 discharge points are considered. The schematic representation of a trommel screen shown in **Figure 5.4.**

Magnetic Separators

The MSW contains ferromagnetic materials such as iron and steel, which can be easily removed by a magnetic separator. As a general rule, magnetic separation is performed on processed MSW (either after homogenising or after shredding). The overhead belt type magnetic separator is suspended over a feed conveyor carrying MSW. The magnet itself is stationary and the rubber belt is set to travel faster than the feed conveyor for effectively removing the magnetic materials from the MSW.

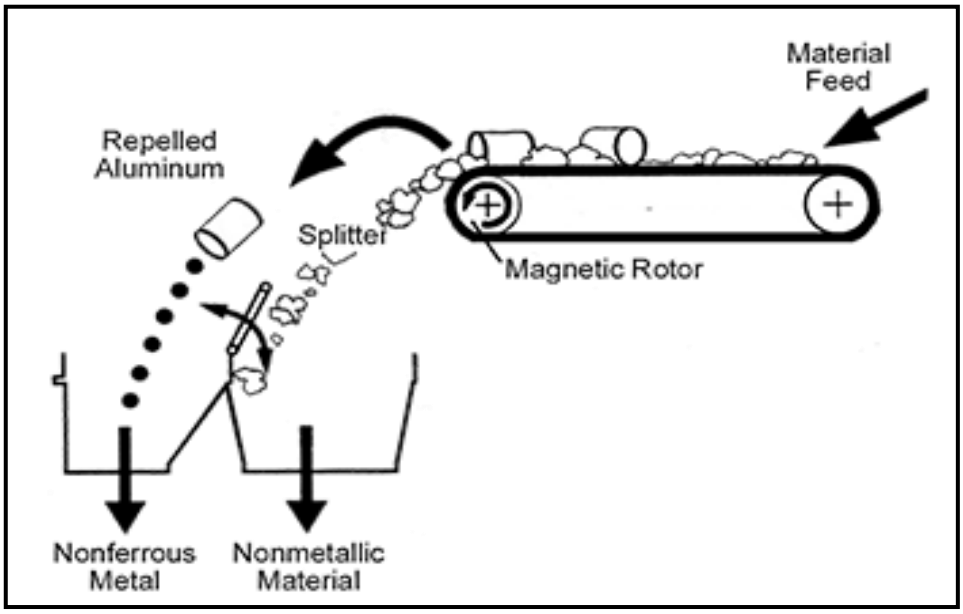
Figure 5.4: Schematic representation of a Trommel Screen



Eddy current Separators

The metallic – Non ferrous parts from the MSW are removed with Eddy Current Separator. It uses the principle of secondary current generation in the conducting materials. It consists of 2 drums at the driving end of the conveyors. The inside drum is an Electromagnet rotating at higher speeds than the outer drum. The inner drum generates eddy current in the metallic parts of the MSW as it passes on the belt. These secondary current induce magnetic properties in the conducting materials and thus repel away the metallic objects farther than the non-metalllic fraction. The metals and Non-Metals are collected separately in two different containers. The schematic representation of eddy current separator is shown in **Figure 5.5**.

Figure 5.5: Schematic representation of eddy current separator



Shredders

Shredding is necessary in order to increase the ratio of Surface area to volume of the MSW material. This will ensure more area is available for combustion air to fuel interaction leading to improved combustion characteristics. The metallic parts are removed before passing it to the Shredders in order improve the performance of the Shredder and prevent damage to its blades. There will be 2 Shredders (1W +1S) producing sizes in line with requirement of the boiler.

5.3.2 **Storage shed/ Drying area**

The Shredded MSW material will be stored in the storage shed near the boiler. This shed is bifunctional. It acts as a buffer storing for the fuel matching the MCR requirement of the boiler and also allowed for natural drying. The floor of the shed will be sloped to facilitate flow of water obtained from desorption of moisture from the MSW material. It flows into a drain and the further into water treatment unit.

5.3.3 **Feedstock Feeder System (FFS)**

The incineration system requires nonstop supply of feedstock of high Calorific value and low moisture content for which it is mandatory to have feedstock storage of 3 to 4 days operation with dedicated conveyors with one standby conveyor connected to the incineration system. The standby feedstock conveyor would be required during maintenance for diverting the fluff to the standby incineration and Boiler system. Such six to seven lines of 500TPD will be provided.

5.3.4 **Feedstock**

There are three possible options available when using refuse/ waste as a fuel for combustion:

a) Mass burning of “as-received” and heterogeneous

b) Burning of pretreated and homogenized waste

c) Refuse Derived Fuel (RDF)

5.3.4.1 **Mass burning of "as-received" and inhomogeneous**

Municipal waste consists largely of recyclable material viz. glass, metals, newspapers, plastic bottles and cans etc. and also a residue waste consisting of disposed food, scrap paper, polyethylene cover etc. Most of the waste is renewable biomass. Burning it in incineration plants, as an alternative to simple disposal, is becoming very common. Wastes include corrosive elements of similar and different kinds, which restrict high temperature operation in the boiler. The municipal waste contains some polyethylene, metals etc. that will produce chlorides, ammonia and trace metal fumes and salts. The wet compounds would affect combustion resulting in dioxin generation. So burning of wastes in "as-received" and inhomogeneous form will result in lower heating value, in turn lower efficiency of combustion and leading to high emissions.

5.3.4.2 **Burning of Pre-treated and homogenized waste**

Depending on the quality of the waste and the incineration system, pre-treating and homogenizing the waste before incineration may be necessary. This creates a more uniform mixture of the waste, which evens out the variation in calorific value of the feed to a high extent. This helps in achieving better incinerator efficiency and support reliable operation of the incinerator.

The details of the pre-processing options are already discussed in the above sections.

5.3.4.3 **Refuse Derived Fuel (RDF)**

Using raw unprocessed MSW as a fuel is problematic due to the heterogeneous nature of the material, which varies from suburb to suburb and season to season. It also has a low heat value and high ash and moisture content. This makes it difficult for plant designers and operators to always provide acceptable pollution free levels of combustion. Processing of the waste to RDF partially overcomes these problems and the fuel can then be used more successfully in either chain grate water-tube boilers or in circulating fluidised beds.

Refuse derived fuel (RDF) is defined as the product of a mixed waste processing system in which certain recyclable and non-combustible materials are removed with the remaining combustible material converted for use as a fuel to create energy. Typical RDF processing includes ferrous material removal, shredding, screening, crushing, and even eddy-current separation or air classification for aluminium recovery. Some plant follow further grinding/shredding, and mix material to generate a homogeneous fuel. It is also common for processors to press and extrude the material into pellets. The RDF Manufacturing Process Outline shown in **Figure 5.6**.

Figure 5.6: RDF Manufacturing Process Outline

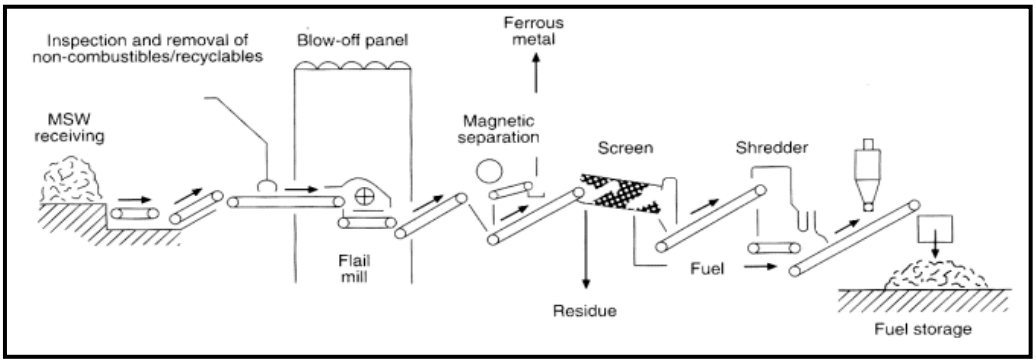


Figure 5.6 illustrates a typical line configuration for a RDF production train. Shredders typically use hammers running at high speeds to chop and shred the waste. Trommel screens are rotating, tubular vessels used for sorting the waste by size. Eddy current separators use induced magnetic fields to create repelling forces that eject non-ferrous metals into a bin separate from the remaining materials. The magnetic separator uses magnets to remove ferrous metals that can ultimately be recycled. Finally, mills using hammer type shred the material into fine particles. Additional stages can be included at various points in the system including hand sorting and air classification. Air classification, when used, can separate glass from metal free MSW. The process flow diagram shown in Figure yields a low-density product fuel known as fluff. Densifiers or pelletizers are commonly added at the end of a system to generate an easily stored and transported fuel. Several types of RDFs can be made, such as coarse, fluffy, powdered or densified, depending on the composition of the refuse, and the technology used.

These products have significantly smaller volume than the original waste and thus have a higher volumetric energy density (VED) making them a more compact source of energy. They are also easier to transport and store than other forms of waste derived energy. The briquettes and pellets can be used directly on a large scale as direct combustion feed. RDF pellets have a heat value of around 60% of coal.

The RDF technology helps in achieving higher calorific value waste. The calorific values of 2500- 3500kcal/kg are possible with this technology. This will lead to efficient combustion as well as less emissions and higher power output at lesser fuel firing rate. Apart from the increase in amount of pre-processing, the yield of RDF fuel from MSW decreases as we aim for higher calorific value. The residue after the processing of MSW then adds to the land filling cost.

5.3.5 **Advantage of Pre-processing**

The details given in above section indicate that pre-processing definitely has advantage in terms of higher reliability, emission control and redundancy of the WtE plant. This is more relevant in Indian scenario, where pre-stream management of waste is in primary stage like source segregation, separate transport and disposal of inert waste etc is not followed.

The pre-processing system would be mandatory for the proposed WtE plant in Mumbai, however, extent of pre-processing would be the discretion of contractor/ agency keeping the other conditions of emissions and reject management.

5.4 Incinerator/ Steam Generator for MSW

Incineration is a thermal waste treatment process where raw or unprocessed waste can be used as feedstock. The incineration process takes place in the presence of sufficient quantity of air to oxidize the feedstock (fuel). Waste is combusted in the temperature of 850ºC and in this stage waste converted to carbon dioxide, water and non-combustible materials with solid residue state called incinerator bottom ash (IBA) that always contains a small amount of residual carbon. Incineration is the most popular waste treatment method that transforms waste materials into useful energy. Incinerators reduce the solid mass of the original waste by 80–85% and the volume by 90-95%, depending on composition and degree of recovery of materials such as metals from the ash for recycling. This means that while incineration does not completely replace land filling, it significantly reduces the necessary volume for disposal.

The following are the types of MSW incinerators:

1) Moving Grate Incinerator
2) Fluidized Bed Incinerator
3) Rotary Kiln Incinerator

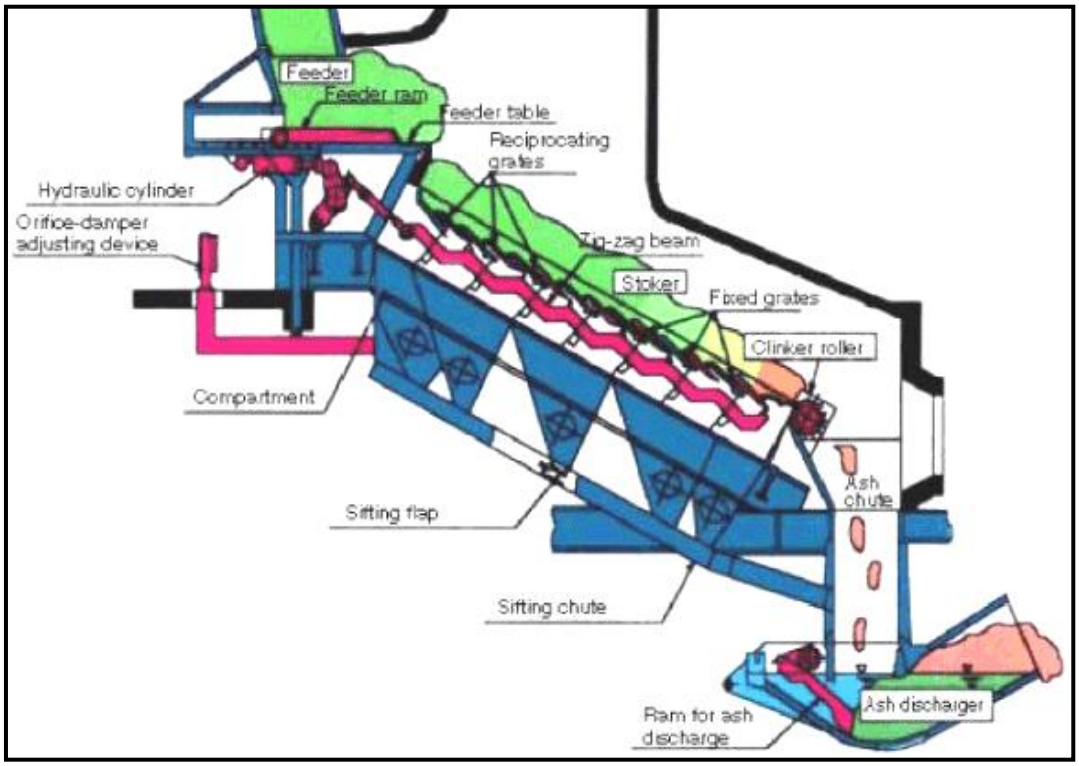
5.4.1 **Moving Grate Incinerator**

Moving-grate incineration requires that the grate be able to move the waste from the combustion chamber to allow for an effective and complete combustion. Incinerators can easily process large variations and quantities of MSW. Most of these incineration plants have hydraulic feeders to feed MSW to the combustion chamber (a moving grate that burns the material), a boiler to recover heat, an air pollution control system to clean toxins in the flue gas, and discharge units for the fly ash. The air or water-cooled moving grate is the central piece of the process and is made of special alloys that resist the high temperature and avoid erosion and corrosion. The Moving Grate MSW incineration system is shown in **Figure 5.7**.

The waste is first dried on the grate and then burnt at a high temperature (850 to 950°C) accompanied with a supply of air. With a crane, the waste itself is emptied into an opening in the grate. The waste then moves towards the ash pit and it is then treated with water, cleaning the ash out. Air then flows through the waste, cooling the grate. Sometimes grates can also be cooled with water instead. Air gets blown through the boiler once more (but faster this time) to complete the burning of the flue gases to improve the mixing and excess of oxygen.

The grates in the furnace are one of the most important parts of this type of incinerator. If refuse were merely dumped on a grate and burnt without turning or agitation, burning would take place only on the top. Hence the refuse not exposed to the flame would leave the furnace incompletely burnt.

Figure 5.7: Moving Grate MSW incineration system



The following are the types of moving grate combustion systems used for MSW:

- **Travelling Grate** – This provides movement of refuse through the furnace by means of a continuous, conveyor type movement. They are usually installed in line in numbers of two or more.
- **Reciprocating Grate** – This grate advances and agitates the refuse by means of alternate rows of grates sliding back and forth over a stationary row of grates.
- **The Roller Grate** – this consists of adjacent drum or rollers located in a stepped formation, with the drums rotating in the direction of the waste movement
- **The Stepped Inclined Grate** – this system uses bars, rockers or vibration to move the waste down each of the grates (typically three)
- **Inclined Counter-Rotating Grates** – grate bars rotate backwards to agitate the waste and prevent it tumbling down the forward inclined grate until burn out is complete.

For developing countries with overflowing landfills, the moving grate incinerator seems suitable and efficient. Moving grate incineration is presently the most efficient technology for a large-scale mixed MSW treatment because it is the only thermal technology that has been able to treat over 3,000 tons of mixed MSW per day.

Compared to other types of Waste-to-Energy technologies, this type of system also shows the highest ability to handle variation of MSW characteristics.

The main advantages of Moving Grate Incinerator are as follows:

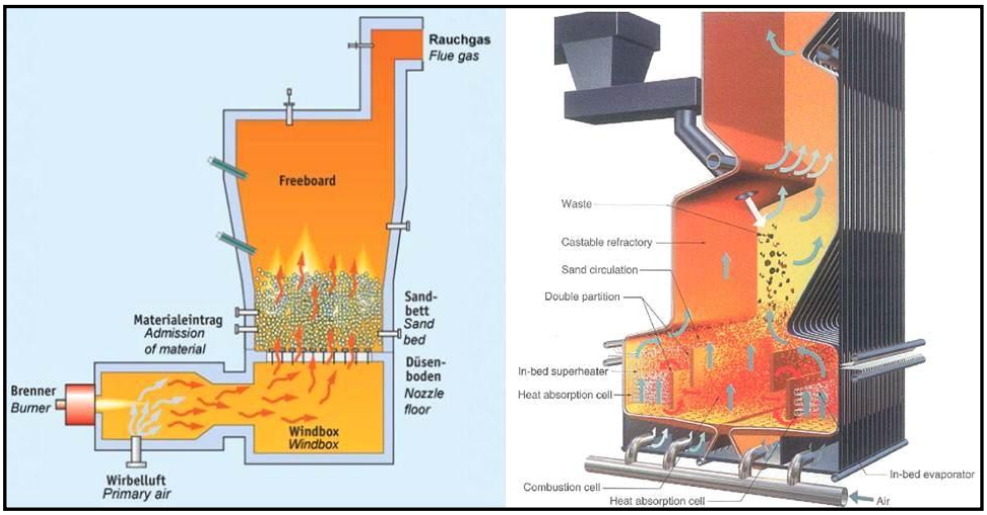
- The technology is widely used and thoroughly tested for waste incineration and meets the demands for technical performance
- It can accommodate large variations in waste composition and calorific value
- Allows for an overall thermal efficiency of up to 75~80%
- System is able to operate upto 8,000 hours per year with one scheduled stop for inspection and maintenance of a duration of roughly one month
- Proven to be capable of treating over 3,000 tpd of mixed MSW

5.4.2 **Fluidized Bed Incinerator**

The fluidized bed incinerator consists of a lined combustion chamber loaded with a large granular bed of inert material (coarse sand or silica) which acts to transfer heat to the waste uniformly. During operation, heated air is blown vertically through the bed at a high flow rate causing the bed of particles to bubble/ boil much as a liquid, allowing intimate contact between the waste and the fuel and facilitate drying and combustion. Fluidized bed combustion is conducted at relatively low temperature at 760°C to 870°C and the average gas residence time is high (over 5 seconds), resulting in effective combustion even with wet waste. Fluidized bed technology is widely applied to treating sewage sludge. A main disadvantage of the fluidized bed for waste incineration is the usually demanding process of pre-treating the waste before the fluidized bed so that it meets the rather stringent requirements for size, calorific value, ash content, and so forth. Because of the heterogeneous composition of MSW, it can be difficult to produce a fuel that meets the requirements at any given point. Main advantages for the fluidized bed are as follows:

- Allows an overall thermal efficiency of up to 80-90 percent.
- Suitable for a wide range of fuel and mixtures of fuel and can handle liquid or solid waste either in combination or separately.

Figure 5.8: CFB MSW incineration system



Disadvantages for the fluidized bed are as follows:

- At present, neither common nor thoroughly tested technology for MSW incineration.
- Relatively strict demands to size and composition of the waste, which usually requires thorough pre-treatment.

5.4.3 **Rotary Kiln Incinerator**

Types of waste treated in a rotary kiln incinerator

- Hazardous waste and PCB waste
- Medical, clinical or hospital waste like "Red bag waste", infectious waste, surgical waste, injection needles, rubber gloves and tubing, tissues and bandage, drop-bags, medical remains, scalpels, infectious and pathological waste, blood plasma remains, cloths, laboratory waste, medicine remains, glass pipette, plastic samples, steel tools, etc.
- Chemical waste and pesticides
- Sludge waste, cattle waste, industrial waste, petro-chemical waste, oil waste, etc.

The steps of drying, combusting and ash cooling are accomplished along the length of cylinder as the waste moves through it with a tumbling action, with ash discharged at the lower end. Application of rotary kiln incineration to treat mixed MSW is susceptible to numerous technical problems such as thermal shock, ash melting and deposition and corrosion which require intensive maintenance.

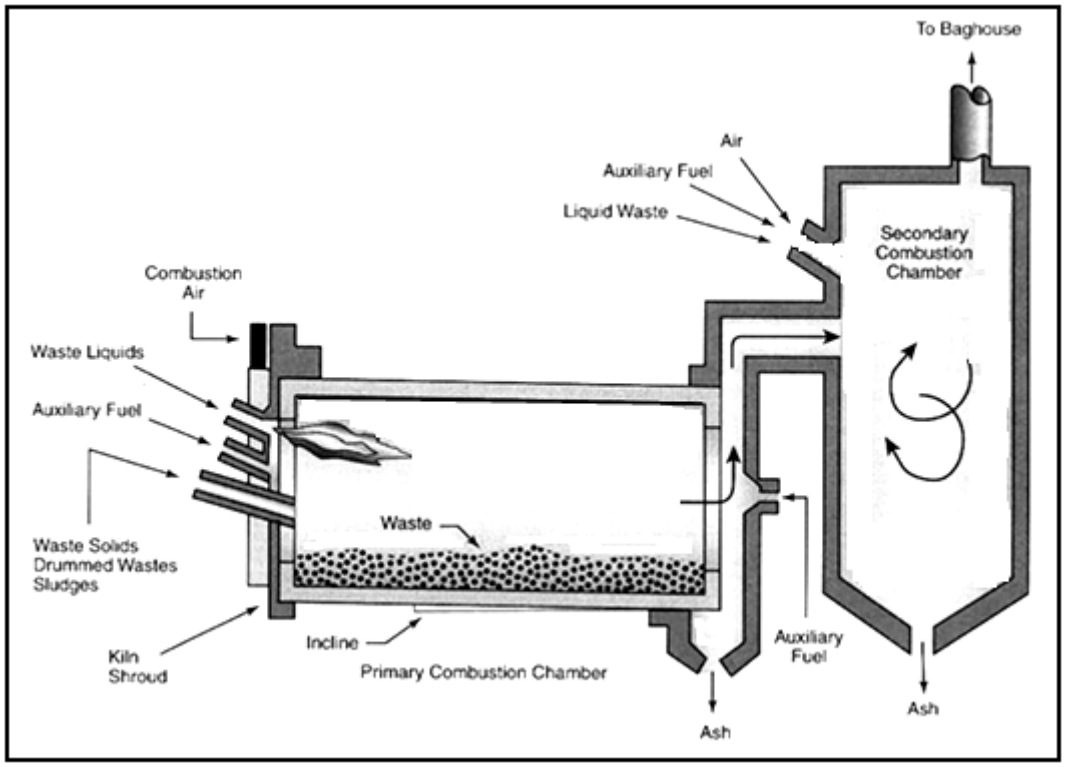
Incineration in a rotary kiln is normally a two stage process consisting of a kiln and a separate secondary combustion chamber as shown in **Figure 5.9**. Solid waste is introduced into the upper end of an inclined, slowly rotating refractory-lined steel cylinder (can also be equipped with water walls). The material is transported through the furnace by the rotations of the inclined cylinder.

The cylinder may be 1 to 5 meters in diameter and 8 to 20 meters long. The capacity may be as low as 2.4 tpd (0.1 tph) and up to approximately 480 tpd (20 tph). The excess air ratio is well above that of the moving grate incinerator and even the fluidized bed. Consequently, the energy efficiency is slightly lower and may be up to 80 percent. As the retention time of the flue gases is usually too short for complete reaction in the rotary kiln itself, the cylinder is followed by, and connected to, an after burning chamber which may be incorporated in the first part of the boiler. The rotary kiln may also be used in combination with a moveable grate - where the grate forms the ignition part and the kiln forms the burning-out section. This allows for a very low level of unburned material in the slag. The slag leaves the rotary kiln through the ash chute.

Main advantages for the rotary kiln are as follows:

- No need for prior sorting or shredding
- Allows an overall thermal efficiency of up to 80 percent
- Able to accommodate large variations in waste composition and calorific value

Figure 5.9: Rotary Kiln incineration system

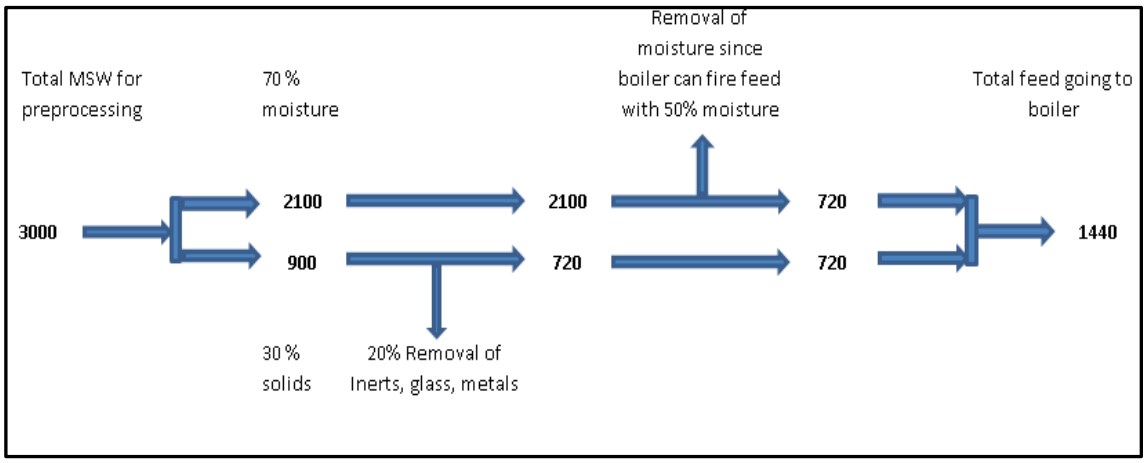


Disadvantages for the rotary kiln are as follows:

- A less common technology for waste incineration
- Capital cost and maintenance costs are relatively high
- The maximum capacity of each furnace is limited to approximately 480 tpd (20 tph)

For the proposed plant, 3 x 50% (2 working + 1 standby) capacity of single drum, natural circulation, balanced draft, water tube reciprocating grate incinerator is considered. The flow diagram for feed to incinerator is given in **Figure 5.10**.

Figure 5.10: MSW feed to the incinerator flow diagram



In order for the feed to self-sustain the incineration process, the minimum requirements that the MSW feed to the incinerator shall satisfy are that the Calorific value should me more than 1500 kCal/kg and the moisture content shall be no more than 50%. On average the MSW received shall have 70% moisture; hence the moisture content has to be brought down by 20%. The inert and recyclables contribute to 20% approximately, which has to be removed. This leaves with 720 tpd of solid MSW and with 50% moisture the total feed to the boiler is calculated to be 1440 tpd. The above figure shows the calculation of the feed value of 1440 tpd to the incinerator.

This is based on analysis, as described in Chapter 2, it is seen that for about 90% of the time, the tonnage of the waste to be processed is above 1400TPD. So the incinerators are sized accordingly to cater the demand of 1400TPD. Each incinerator is capable of handling 720TPD of MSW at 50% moisture level. In normal condition, two (2) incinerators would be operated and One (1) incinerator will be kept on stand-by. In case of maintenance or restriction in of any of the working incinerator, the stand-by incinerator would be brought into operation. This redundant incinerator design ensures that the wastes are continuously incinerated. Each incinerator/ boiler generates 70 tph of steam at 45 bar (g) pressure and 400°C temperature. The salient details of the boiler are given in **Table 5.5**.

Incineration plants are designed to ensure that the flue gases reach a temperature of at least 850°C inside the incinerator in order to ensure proper breakdown of toxic organic substances. In order to comply with this at all times, it is required to install backup auxiliary burners often fuelled by oil, which are fired into the boiler in case the heating value of the waste becomes too low to reach this temperature alone. This will take care of the situations where the feedstock has less calorific value or high moisture content.

Table 5.5: Specifications of the boiler

Steam flow at main steam stop valve outlet	tph	70
Steam pressure at Main Steam Stop Valve outlet	kg/cm^2 (g)	45
Superheated steam temperature at Main Steam Stop Valve outlet	°C	400 +/- 10
Superheated steam temperature Control Range	%MCR	80-100
Feed Water temperature at Economizer inlet	°C	130
Feed water temp. at deaerator outlet	°C	130
No. of Boilers	no.	3 x 50% (2W + 1S)

The flue gas transfer the heat to superheater leading to increase in steam temperature to a condition as required for admission into steam turbine.

5.4.4 **Steam Turbine Generator and Auxiliaries**

From the reliability analysis done for the total solids, moisture, and calorific value of the MSW is given in Chapter 2, the power that can be generated in different scenarios is calculated and its variation is shown in the table below:

Table 5.6: Reliability Analysis for Power generated – Seasonal Variation

Power Generated (MW)	Occurrence	% of Occurrence
Pre-Monsoon		
19	1	4.0%
21	6	24.0%
23	8	32.0%
25	7	28.0%
27	3	12.0%
Monsoon		
3	2	8.0%
5	0	0.0%
7	4	16.0%
9	1	4.00%
11	5	20.0%
13	6	24.0%
15	4	16.0%
17	3	12.0%
19	2	8.0%
Post-Monsoon		
11	3	12.0%
13	4	16.0%
15	5	20.0%
17	3	12.0%
19	3	12.0%
21	1	4.0%
23	4	16.0%
25	1	4.0%
27	0	0.0%
29	1	4.0%

The analysis shows that of all the seasons the maximum power that can be generated would be 25MW, and at few occasions, because of high calorific value and low moisture content in the feed, the power generation can vary between 25 - 27MW.

The proposed steam turbine would have a maximum continuous rating of 25MW with throttle steam conditions of 40 bar and 400°C, and with condenser cooling by water

cooled condenser. The steam turbine would be of single cylinder extraction cum condensing type. In the situations, where the calorific value of the feed is high or when additional feed has to be incinerated, the additional heat can be utilized to generate electricity in the turbine-generator. The turbine-generator shall be sized to cater such situations with overload capacity up to 10%. The turbine generator would be complete with all accessories such as protection system, lube and control oil systems, jacking oil system, seal steam system, turbine drain system, electro-hydraulic control system, and turbine supervisory instrumentation. Other accessories of the turbine generator would include an oil purification unit with transfer pumps, overhead lube oil tank for emergency oil supply, and clean and dirty oil storage tanks of adequate capacity. The steam parameters at different points in the cycle are shown in **Table 5.7.**

Table 5.7: Steam parameters at different points in the cycle

Type	Boiler outlet steam parameters	Turbine inlet	Condenser inlet	Turbine Extractions to deaerator	Feed water inlet
Without LP heater	42 bar 402.4°C	40 bar 400°C	0.1 bar 45.81°C	1.245 bar 114.1°C 9.024 tph	47.69 bar 105°C

- The boiler superheated steam outlet pressure and temperature selected is 42 bar & 402.4°C.
- The steam turbine inlet pressure and temperature is 40 bar and 400°C.
- The deaerator pressure corresponds to the saturation pressure for 105°C.
- The steam requirement for deaerator is met by extraction from the steam turbine.
- The condenser provided for in the steam cycle is water-cooled condenser, which operates at a vacuum of 0.1 bar and temperature of 45.81°C.
- The feed water enters the boiler at 105°C.

5.4.4.1 **Condenser**

The condensing plant would comprise divided flow, double-pass, horizontal, surface type construction. The condenser would have SS tubes. Air ejector would be provided to remove the non-condensable gases liberated during normal operation.

In case of a trip of ST, the steam could be bypassed to condenser after reducing the pressure and temperature of steam to an admissible limit of condenser. Additionally this condenser would be designed to take care of excess steam that is produced due to variance in calorific value of MSW, if received.

5.4.4.2 **Condensate Extraction Pumps**

2 x 100% (1 working + 1 standby) capacity condensate extraction pumps would be provided. The pumps would be vertical, canister type multistage centrifugal pumps.

5.4.4.3 **Boiler Feed Pumps**

Feed water would be pumped from deaerator to the boiler/ steam generator by means of 3 x 50% (2 working + 1 stand-by) capacity boiler feed pumps. Pumps would be horizontal, multistage, centrifugal ring type construction.

5.4.4.4 **Deaerator**

The deaerating feed water heater would be direct contact, variable pressure type heater with spray-tray or spray-type of deaeration arrangement. The feed water storage tank would have a storage capacity adequate to feed the steam generator for atleast 10 minutes when operating at MCR conditions.

5.4.4.5 **Fuel oil system**

Two (2) no. Light Distillate Oil (LDO) tanks of 65m^3 capacity is planned to support oil supply during start-up and flame stabilisation purpose.

The LDO would be brought to the plant by road tankers. The oil from the tanks will be supplied to the boiler using LDO pressurising pumps.

As the proposed plant site is in landfill area, the fuel oil storage facility shall be safely designed and protected from the liberating landfill gas and also secured to limit any movement of personnel in this fenced area.

5.4.5 **Water system**

The proposed scheme of water systems for development of waste to energy (WTE) project in Mumbai for (1 x 25 MW) Units. The water will be used for condenser cooling, cooling of SG and TG auxiliaries and various other requirements like SG makeup, service water, ash handling system and fire protection system etc. The water systems consist of various sub-systems listed below and discussed in the subsequent paragraphs of this chapter:

(a) Raw water system
(b) Condenser cooling water (CW) system
(c) Make up water system
(d) Auxiliary cooling water (ACW) system
(e) Water treatment (WT) system
(f) Service and potable water system
(g) Fire protection system
(h) Effluent disposal system

5.4.5.1 **Raw Water Supply System**

The raw water requirement for 1x25MW Units about 4534m^3/day (min) and 5326m^3/ day (max) considering process steam and make-up of the STG condenser cooling system, DM water for Steam Generator make-up, cooling of auxiliaries and Ash Handling system, Two (2) nos STP water transfer pumps (1 working + 1 stand by) each of capacity 350 m^3/ hr would meet the total plant raw water requirement.

5.4.5.2 **Raw Water Storage and Treatment**

Source of treated sewerage water will be from Ghatkopar treatment lagoon, which is at a distance of approx less than 3.5km from the plant site. The water will be drawn through the pipe line to a raw water reservoir/ storage tank located in the plant area. The reservoir/ tank will be sized to store about 16 hrs requirement of water with separate compartment for fire water system. The capacity of the raw water reservoir/tank will be about 3000 cum. The reservoir will have reserve storage for fire protection system, which are about 524 cum capacity.

STP water is mostly normal turbidity/ suspended solids through year and the quality of influent water required for the various systems in the plant is filter water (with turbidity and suspended solids less than 50 ppm), it is proposed to provide filtration plant (3 X 50%) for the total capacity of the water make-up DM This filter will take care of any suspended solid presence. The water quality for Lagoon is given at **Annexure 5.**

The filter water from the filtration plant will be stored in a filter water overhead storage tank of capacity 600 m^3 tank .DM water will be stored in a DM water storage tank with a capacity of 100 m^3.Feed water for DM plant shall be from filter water overhead tank.

To facilitate isolation, sluice gates would be provided between the suction sump and reservoir compartments. Level switches would be provided for annunciating low and high levels in the tank.

5.4.5.3 **Raw Water Pump House**

The following pumps will be located adjacent to the raw water storage tank under a top covered enclosure.

i). WTP supply pumps.
ii). Fire water pumps.
iii). Service water pumps
iv). Ash slurry disposal water transfer pump

WTP supply pumps, fire water pump, service water pumps and ash disposal water transfer pump will take suction from raw water storage tank/reservoir.

Chlorination will be done (continuous and shock dosing) as per requirements.

Plant Water Requirement

The total plant water requirement is summarized in **Table 5.8**.

Table 5.8: Plant Water Requirement

Sr. No	Item	Estimated Quantity		Quality
		m^3/hr	m^3/day	
1.	CW make up for condenser and other auxiliaries	115	2760	Filter water

Sr. No	Item	Estimated Quantity		Quality
		m^3/hr	m^3/day	
2.	Filter Backwash	-	70	Backwash water
3.	Service Water	-	1560	STP water
4.	Plant potable water	-	10	Filtered water (UF treated)
5.	DM water for SG makeup, ACW makeup and process steam make up	-	124	DM water
6.	UF-RO plant regeneration	-	10	DM water (Regenerated)
8.	Total raw water requirement per day (with recovery from ash pond)		**4534**	
9.	Water required for ash slurry disposal system		1200	
10.	Total raw water requirement per day (when no recovery from ash pond)		**5326**	

5.4.5.4 **Condenser cooling water (CW) system**

Recirculation type cooling system with cooling tower is proposed for CW system using Induced draught cooling tower (IDCT).

Cooling Water (CW) Pumps

It is proposed to provide two (2) Nos. 100% capacity horizontal type centrifugal pumps of self lubricated type pumps with cast iron casing, stainless steel (SS 410) shaft and stainless steel (SS 410)/ bronze impeller C.W. Pumps, each of 5650 m^3/hr flow and adequate head.

Cooling Towers

It is proposed to install One (1) no. Induced draft-cooling tower arranged back to back, and of capacity 5650 m^3/hr. The cooling water would be collected in a basin. The cooling tower would be designed for a cooling range of 10^0C and an approach of 5^0C.The designs hot and cold water temperatures of the cooling towers would be 43^0C and 33^0C respectively. Tower construction would be of RCC material with PVC film type fill.

RC Channels

It is proposed to provide a common channel at the Cooling Tower (CT) basin connecting all the CT cells. Cooled water is led to C.W. pumps through individual steel pipes from this channel. The C.W. pumps would be located outdoor with suitable weather proof protection.

CW Forebay and Pumphouse

CW flow for 1x25 MW Unit proposed to be discharged from the open channel to a common forebay and pump house. The forebay is designed to ensure equidistribution of flow to the CW pumps as well as to limit the entrance velocity at the CW pump house. The top level of the forebay walls is fixed on the basis of maximum upsurge expected in the forebay when all the CW pumps trip under normal water level condition. The sump level of the pump house is fixed so as to ensure adequate submergence to the CW pumps.

CW Inlet and Outlet Conduits

From the CW pump house, the CW discharge for 1x25 MW Unit proposed to be conveyed to the condensers located in the station building, through One (1) no. CW inlet conduit. This conduit is of mild steel with about 1000 mm internal diameter with RC encasement and buried throughout. RC encasement is provided as external protection against corrosion and to take care of the swelling property of the black cotton soil. The hot water from the condensers will be conveyed back to the cooling towers through One (1) no. of CW outlet conduits of mild steel with RC encasement having similar size as the inlet.

Valves and Specialties

Motor operated butterfly valves will be provided at the discharge of the CW pumps and the condenser inlet/ outlet piping to facilitate isolation and control. Expansion joints are proposed in the CW pump discharge lines and condenser inlet and outlet lines to take care of any misalignment, thermal expansion, etc., and to facilitate erection and maintenance. The CW pumps and their discharge valves would be suitably interlocked to result in a co-ordinated operation.

CW Blowdown and Make-Up Water Requirements

Make-up water requirement of CW system is obtained as the sum of drift and evaporation losses from the cooling tower and blow down from the CW system (by way of water drained from the hot water conduit of the CW system). In order to conserve water, the blow down would be utilised to meet the water requirement of the ash handling system and excess blow down will be led down to guard pond. Table 5.9 indicates the CW blow down/ make-up water requirements, for the cooling water system.

The analysis of raw water (make up water) is presented in **Annexure 5**. Based on this water analysis and ash handling requirement, a cycle of concentration (COC) of 4.0 has been adopted for CW system. The CW blow down will be done from the condenser outlet conduits. The blow down water from the condenser outlet will be utilised in the ash handling, and excess blow down water is led to guard pond. The water balance details are shown in **Annexure 6**.

To prevent scaling arising due to the operation of CW system with a higher COC, chemical dosing system with scale inhibitor/ dispersant is envisaged. In order to

prevent/ minimise growth of algae in the CW system, Chlorine dosing system is envisaged.

Table 5.9: CW System Make-Up Requirements

Sr. No.	Item	Quantity (m^3/day)
1.	Cooling Tower (Evaporation + Drift Losses)	86
2.*	Condenser CW System Blow down*	29
3.	CW Make-up requirement (item 1 + item 2)	115
4.	Concentration Ratio 'C' (item 3/ item 2)	4.0
***The CW system blow down amount of 33m^3/hr will be utilized for Ash handling system. The rest amount will be led to the guard pond.		

CW Make-Up System

Filtered water from the main filter water overhead storage tank will be led/conveyed by gravity flow to the CW channel near IDCT.

Raw Water System Chlorination

In order to prevent/ minimise the growth of algae in the raw water system, chlorine dosing is proposed. Provision will be made for shock dosing and continuous dosing. However, the continuous dosing rate would be adjusted during operation phase to meet the chlorine demand.

Auxiliary Cooling Water (ACW) System

The ACW system meets the cooling water requirements of all the auxiliary equipment of the TG and SG units such as turbine lube oil coolers, generator air cooler, exciter air coolers, sample coolers ID/ SA/ PA fan bearing oil coolers, BFP auxiliaries such as lube oil coolers, working oil coolers, drive motors, etc., condensate pump bearings, sample coolers and air compressors.

It is proposed to adopt a common circulating water system for the condenser and the auxiliaries. The estimated cooling water flow for Steam turbine condenser is 4750 m3/hr and that for auxiliaries is about 628 m^3/hr.

The total estimated cooling water requirement for the above auxiliaries is about 5378m^3/hr. A closed loop system using passivated DM water is proposed for the ACW system. The DM water is circulated through the auxiliary coolers by Two (2) 100% capacity (1 working + 1 standby) auxiliary cooling water (ACW) pumps, each of 690 m^3/hr capacity. The hot water from these auxiliaries is cooled in the plate type ACW heat exchangers.

5.4.6 **Water Treatment Plant**

The water treatment plant broadly consists of Filtration plant, UF-RO Plant. The filtration plant consists of Two (2) vertical pressure sand filters, each of the capacity 75 m^3/hr, to remove turbidity and suspended solid. The pressure sand filters will be of mild steel construction with five- (5) mil thick epoxy painted internally. Filter media will be graded sand supported on graded gravel. Two (2) nos., 100% capacity filter air blowers will be used for loosening filter airbed before filter back washing. Back washing of filters will be done by means of gravity flow from filtered water storage tank. Part of the filtered water will be stored in filtered water storage tank of capacity 600m^3 which will be located on the roof of water treatment plant building. This tank will supply water for CW make-up, UF-RO plant and potable water system. Water will be supplied to the filtration plant by means of Two (2) nos., (1 working + 1 standby) WTP supply pumps each of capacity 165 m^3/hr. The material of construction of these pumps will be in cast iron casing, bronze impeller and stainless steel (410) shaft. The WT plant supply pumps will take suction from the raw water storage tank and will be located in the raw water pump house.

5.4.6.1 **DM Plant/ UF-RO Plant**

The UF-RO (2x 100%) plant will meet the requirements of steam generator (SG) feed water make up, and system make-up and designed for a total output of 134 m^3/day of DM water based on SG feed water make up at 3% MCR for each unit. It is proposed to provide Two (2) streams UF-RO-MB plant, each stream designed for an output of the 10 m^3/hr with 16 hours productive run time. Each stream of the plant will consist of the following:

UF Unit

To remove colloidal silica and organic content in the water 2X100% Ultra filtration plant will be provided. From this plant water will be led to Micro cartridge filter (MCF) to ensure Silt density index less than 5 for RO plant. Water from MCF will be led to UF plant Chemical cleaning system and backwash system shall be provided for backwashing the UF modules.

RO Unit

RO is a membrane based water treatment process. The effluent after pre-treatment would be passed through the membranes to produce fresh water with TDS of 15 ppm (approx). Two (2) x 100% RO units will have a recovery about 85%. A portion of the product water from the RO unit would be stored in RO plant feed tank and utilized as feed to the unit requirement. RO reject would be led to neutralization pit.

Mixed Bed (MB) unit

The final polishing of DM water will be done in 2x100% MB unit. The MB unit will be designed to limit the silica less than 0.02 ppm, as SiO_2 and conductivity will be restricted to 0.1 micro mho/cm at 25°C.

DM water from the mixed bed units will be led to the One (1) no. DM water storage tank of capacity 100 m^3. The DM water from the DM plant storage tanks will be

pumped to condensate storage tank by Two (2) nos. (1 working +1 stand by) DM water transfer pumps each of capacity 7m^3/hr.

Regeneration System

33% hydrochloric and 48% sodium hydroxide will be used as regenerates for the purpose of regeneration. The equipment of regeneration system will comprise bulk acid and alkali storage tanks, acid/ alkali transfer pumps, acid/ alkali solution 33% hydrochloric and 48% sodium hydroxide will be used as regenerants for the purpose of regeneration. The equipment of regeneration system will comprise bulk acid and alkali storage tanks, acid/ alkali transfer pumps, acid/ alkali solution preparation and measuring tanks, ejectors and all associated piping/ valves, etc. one (1) no., each bulk acid and alkali storage tanks will be provided to meet the requirement of both streams. Each of the tanks will be sized to hold 15 tonnes of respective chemical.

Neutralising System

The acidic and alkaline effluents from UF-RO plant and the filter backwash will be led to the neutralising pit. The pit will be of a capacity of 27 cu.m. Acid or alkali will be added to the neutralising pit depending on nature of effluents from UF-RO plant. Two (2) nos., pumps, (1 working + 1 standby) each with capacity of 30m^3/hr to handle effluents with SS 316 material of construction are proposed to lead the neutralised effluents to the guard pond.

Mode of Operation of DM Plant/ Filtration Plant

The complete mode of operation of UD-RO plant and filtration plant will be semi-automatic for which a PLC based control system will be provided.

The piping upto the UF will be of cast iron, IS 1239, heavy class while the piping beyond the UF unit will be mild steel rubber lined.

5.4.7 Service and Potable Water System

Water required for plant HVAC, FGD, MSW pre-processing plant and cleaning/ washing will be provided from the service water overhead tank. 2x100% service water pump 60cu.m/ hr have been envisaged for service water system.

Requirements of plant potable water system would be met from drinking water supply of MCGM by Two (2) nos. (1 working + 1 standby) plant potable water pumps, of capacity 5m^3/hr which will pump potable water from supply terminal point of MCGM to the potable water over head tank of capacity 10m^3. Further distribution of potable water to various consumer points would be by gravity.

5.4.8 Fire Protection System

This system will consist of the following sub-systems:

a) Hydrant system covering all areas of the plant.

b) High velocity water spray (HVWS) system for the protection of generator transformers, turbine oil tanks, lube oil system equipment, unit auxiliary transformers

c) Automatic deluge (medium velocity water spray) system for the protection of cable galleries

The system would be designed to conform generally to the rules and regulations of the Tariff Advisory Committee (TAC).Two (2) no (one electric driven and one diesel driven). Fire water pumps of horizontal, centrifugal type, each with 171 m^3/hr capacities would be provided. The above pump would be located in the raw water pump house. The raw water storage tank would have a dead storage of 524m^3 of water for the fire protection system in line with the regulations of the TAC.

5.4.8.1 **Chemical Laboratory Equipment**

A separate chemical laboratory to enable testing of fuel, water, flue gas, etc. as required for normal operation of the power plant would be setup.

5.4.9 **Effluent Disposal System**

The oil sewer will collect water from the areas where there are possibilities of contamination by oil (fuel oil storage area) and the drains from such areas will be connected to an oil separator. From the oil separator the clear waste water will be led to Guard pond compartment-1, while the oily waste sludge will be collected separately and disposed.

Cooling tower blow down water will be utilised for ash handling system make-up and excess water is led to Guard pond compartment-1.

The backwash from the filtration plant will be lead to Guard pond compartment-1 through neutralization pit.

UF-RO plant neutralised effluents will be led to Guard pond compartment-1 through neutralization pit.

Boiler blow down will be led down partly to Guard pond compartment-1 and rest to Guard pond compartment-2.

Effluents collected in Guard pond compartment-2 will be utilised in gardening.

FGD waste will be led down to Guard pond compartment-1.

Effluent collected in guard pond compartment will be utilized suitably for ash water disposal system and for gardening and green belt.

Water requirement for ash slurry disposal system will be met by from guard pond without any treatment scheme and rest of the water requirement will be met from raw water tank by (3 x 50%) ash slurry disposal water transfer pumps capacity 18cu.m/hr. As recovery from ash pond will start the ash slurry disposal water pump operation will be adjusted accordingly (throttling/ recirculation/ start/ stop of pumps). When recovery of water from ash pond will start then water requirement for ash disposal will be done only from Guard pond.

5.4.10 **Electrical Systems for Power Plant**

5.4.10.1 **Electrical Generator Features**

The key one line diagram (Exhibit -06) describes the proposed plant electrical system (Annexure 7). One number of Steam Turbine Generator of rating 25MW with capacity 27.5MW under overload condition at ambient air temperature, 0.85 lag to 0.95 leading PF, 11kV, 3000 rpm, 50 Hz, is proposed. The generator winding would be star connected with the phase and neutral terminals brought out. The generators would deliver rated MVA output under ±5% variation in voltage and +3 to -5% variation in frequency. The generator winding (Stator & Rotor) would be provided with Class-F insulation or better. However, temperature rise would be limited to that of Class – B. The station point of the generator would be connected to earth through an earthing transformer, the secondary of which is connected to an earthing resistor.

The generators would be provided with either brushless or static excitation system. Suitable fast acting non-dead band type continuous acting digital type automatic voltage regulator (AVR) provided to maintain steady generator terminal voltage within ±0.5% of the pre-set value under different load conditions.

5.4.10.2 **Generator Transformer**

The GT's would be 3-phase, 2 winding, 11kV/33kV, *MVA rated with oil cooled & on load tap changer. The selected vector group of this GT is Delta/ Star (Ynd11).

5.4.11 **Auxiliary Power Supply System**

The proposed auxiliary power supply system is shown in enclosed key line diagram. Various auxiliaries would be supplied at the following nominal voltages depending upon their ratings and functions:

a) 11000V, 50 Hz, 3 phase, 3 wire, medium resistance grounded AC supply for motors rated above 200kW

b) 415V, 50 Hz ,3 phase, 3 wire, solidly grounded AC supply for motors rated 110 kW and below and other L.V. services

c) 240V, 1 phase AC supply for lighting, space heating of motors and panels, single phase motors, etc.

d) 110V, 1 phase, AC supply for AC control circuits

e) 220V, ungrounded DC supply for protection, control and indication

f) 110V, 1 phase AC uninterruptible power supply

5.4.11.1 **Auxiliary/ Service Transformers**

The required number of Service transformers shall be provided depending on service/ location/ segregation of the loads. Though the service transformers are indicated in the enclosed key one line diagram tentatively, these transformers will be rated at 1.25 to 2.5 MVA, 11kV/433V with a vector group of Dyn11 as per actual requirement. These transformers will be rated for 2 X 100% of associated loads. They will supply power to the 415 V auxiliaries associated with the steam turbine, cooling water system and station loads. The neutral of these transformers will be

solidly earthed. The transformers will be provided with + 5% off-circuit taps in steps of 2.5% on the HV side. The HV side will be provided with cable box suitable for XLPE cables. The LV side will be provided with cable box or provision for bus duct termination depending on final layout. The service transformers may be Oil filled or resin cast dry type and will be determined during detailed engineering. The details of the Service Transformers are given below

33kV Switchgear

The switchgear will comprise draw-out type Vacuum circuit breakers housed in indoor, metal-enclosed cubicles. The switchgear will be equipped with control, protection, interlock and metering features as required.

11kV Switchgear

The switchgear will comprise draw-out type Vacuum circuit breakers housed in indoor, metal-enclosed cubicles and will cater to 11 kV motors. The switchgear will be equipped with control, protection, interlock and metering features as required.

415V System

The 415V, 3 phase, 3 wire power for the 415V auxiliaries will be obtained from 11kV/433V transformers. The system will be a solidly earthed system. For maximum reliability, duplicate power supplies with auto changeover facility will be provided for the essential power and motor control centres. The 415V switchgear will be of metal enclosed design with a symmetrical short circuit rating of 50 kA for 1 sec.

All 415V switchgears would be provided with air circuit breakers (ACB) for all incomers/ bus coupler/ bus tie/ motor (90kW & above) feeders and moulded case circuit breakers (MCCB) for all other outgoing feeders.

DC SYSTEM

220V batteries would be provided for feeding the essential loads of STG, Emergency lighting system etc. For catering to steam turbine generator (STG) and station DC loads, 2 x 100% capacity, 220V battery bank with associated 2 x 100% capacity chargers with float cum boost units which will feed a DC switchboard. The ampere hour ratings of these batteries would be firmed-up during detail engineering stage.

5.4.11.2 **Emergency Power Supply**

Certain important plant auxiliaries require a reliable source of power supply to enable safe shut down of the unit in the event of failure of complete AC supply in the station. For this purpose, one no. of * kVA, 415V with Auto mains failure (AMF) Diesel Generator set considered. The exact rating of the DG set will be finalised during detail engineering.

5.4.11.3 **Un-Interruptible Power Supply System**

110V single phase A.C uninterruptible power supply will be provided for the Plant DCS/Instrumentation system derived from DC system.

5.4.11.4 **Control System**

All the 11kV and main 415V circuit breakers shall be controlled from DCS. The DCS will have control, protection, measurement, indication and annunciation functions of all these feeders.

5.4.11.5 **Cabling System**

The following types of cables are proposed:

For 11 kV system: 11kV unearthed grade, stranded aluminium conductor, cross linked polyethylene (XLPE) insulated, extruded black PVC inner sheathed, galvanized steel wire armoured for three core or aluminium wire armoured for single core and overall FRLS extruded black PVC sheathed cables conforming to IS : 7098.

For 415 system: Power cables of 1100V grade, stranded aluminium conductor, PVC insulated, Inner sheath of extruded black PVC, galvanised single steel wire armoured for three core or aluminium armoured wire for single core and overall FRLS extruded black PVC cables conforming IS: 1554.

For control applications: 1100V grade annealed high conductivity stranded copper conductor, PVC insulated, PVC inner sheath, galvanised single steel wire armoured and overall FRLS extruded black PVC outer sheathed cables conforming to IS: 1554.

For Instrumentation application: Stranded high conductivity annealed, tinned copper conductor, multi core, PVC insulated flexible twisted pair/triplets, individually shielded for low level analog signals and overall shielded for digital signals, PVC inner sheathed, steel wire armoured and overall FRLS PVC sheathed cable.

Cables would be laid in prefabricated steel ladder type or perforated type cable trays in the station and other auxiliary buildings. All the cabling will be done considering cable cellar and cable racks.

5.4.11.6 **Lighting System**

Suitable illumination necessary to facilitate normal operation and maintenance activities and to ensure safety of working personnel would be provided in the plant.

Pole mounted high pressure sodium vapour fixtures would be used for approach and work roads.

Generally, fluorescent fixtures would be used for indoor illumination. High pressure sodium vapour fixtures would be used for the turbine hall and steam generator platforms as required.

The illumination levels at different places would be maintained as per accepted codes. The lighting system design would be to ensure uniform illumination as far as feasible.

The supply to lighting panels would be through 415V, 3 phase, 4 wire system derived through 415/433 V lighting transformers. Suitable number of lighting panels would be located in each area.

About 80% of the total light fittings in turbine buildings, transformer yard and control room would be connected to the normal AC lighting supply and the balance 20% to the emergency DG set supply.

DC emergency lights are envisaged at strategic points in the power station viz., near entrance, staircase, control rooms, etc. These would be fed from the 220V DC system, which would be normally off when AC power is available. These would be automatically switched on when the normal AC supply fails.

5.4.11.7 **Safety Earthing and Lightning Protection**

A safety earthing system comprising buried mild steel conductor earthing grid would be provided for TG building, transformer yard and other areas.

Lightning protection system comprising roof conductors, vertical air termination and down comers would be provided for all structures with a calculated risk index requiring protection as per applicable Indian standards.

5.4.11.8 **Communication System**

For effective communication in the plant, public address system and electronic private automatic branch exchange system (EPABX) with the features described below are proposed:

Public Address System

This system would consist of paging and party channels comprising hand set stations with amplifiers, transmitters, receivers and loud speakers. This system facilitates paging communication and also private conversation as in conventional telephone.

EPABX System

This system has adequate number of dial type hand-set stations, central automatic telephone exchange, etc. The handsets in control room would be provided with priority service facility to enable them to have immediate access to any handset.

Fire Detection and Alarm System

Fire detection and alarm system would provide visual and audible fire detection at the incipient stage of fire in the power station. This system comprises automatic fire detectors such as ionisation type smoke detectors, optical type smoke detectors, rate of rise of temperature detectors with fixed temperature setting, linear heat detectors etc. which provide continuous surveillance in an area. Based on the type of fire expected in a particular area of application, these detectors would be chosen except for plant area and transformer yard where only manual call points would be provided. The detectors would be grouped zone wise and alarm signals would be transmitted to local and main control panels to indicate the location of fire. Fire detection and alarm system, on detection of fire by sensors, would initiate shutting off air conditioning and ventilation system and initiation of automatic fire protection system such as water spray system as required.

Fire Proof Sealing System

Fire proof sealing system would be provided for all cable penetrations through walls and floors to prevent spreading of fire from one area/floor to another.

5.4.11.9 **Elevators**

One freight-cum-passenger elevator of adequate capacity would be provided in the boiler area to serve major platforms of the steam generator/ boiler. A common passenger, elevator would be provided for the station / TG building. This elevator would have access to different floors of the TG building.

5.4.11.10 **Evacuation of Power**

The proposed scheme for power evacuation is shown in enclosed single line diagram (Annexure 8). The Generator 27.5MW connected to 33kV switchgear through Generator transformer 11/33 kV, 26MVA.

5.4.12 **Auxiliary Power Supply system**

5.4.12.1 **Proposed Power Distribution System:**

- Power requirement for pre-processing plant & its auxiliary buildings shall be distributed from the proposed 11kV MRS switchgear panel (Generator Bus) with 2 nos of 11kV feeders.
- For Proposed facility, 1 No. of 11 KV Main HT switchgear VCB panel with Two (2) incomers, Two (2) Outgoings & One (1) Bus PT shall be provided in the Electrical room near to Pre-processing plant.
- 1kV switchgear panel shall be metal enclosed, indoor type with VCB (Fully draw out type), CTs, PTs, meters, relays, bus bars etc. The fault withstand capacity shall be 40 kA for 1 sec.
- 2 Nos. of 11 KV, E grade HT cables running from the two feeders (of suitable rating) from MRS shall be connected to the Main HT switchgear incomer breakers.
- The breaker closing coils, tripping coils, indications, annunciator shall be rated for 30 V DC which is supplied from in-built 30V DC Power Pack.
- The spring charging motor shall be suitable for 230V AC. Space heater, power socket, panel illumination lamp shall be fed from 230V, 50 Hz, 1 phase raw power supply.
- The Transformer outgoing breaker shall be electrically interlocked with downstream LT breaker such that if HT breaker trips, LT breaker shall also trip, and LT breaker cannot be closed until HT breaker is closed.

5.4.12.2 **Metering & Protection**

Following Metering & Protections shall be considered for the Incomer & Outgoing breakers panel:

RELAYS	
Over-current & Earth Fault protection [IDMT & Instant.] (50/50N, 51/51N) relay	Siemens (7SJ Series)/ Schneider (Sepam Series)/ ABB (RE Series)
Master Trip/ Lock out Relay (86)	Alstom Make VAJHM23
Instantaneous Under Voltage Relay (27)	Alstom Make VAGM22
Stand by Earth Fault Relay (51NS)	Siemens (7SJ Series) – For Outgoing breaker feeders only.
Supervision of trip circuit (95)	Alstom Make VAX 31
Supervision of lock out relay	Alstom Make VAX 21
Contact multiplication relay	Alstom Make VAA
METERING	
Analogue Ammeter	Analogue Type, 144 mm x 144 mm (Taut band type with 240^0 Scale)
Analogue Voltmeter	Analogue Type, 144 mm x 144 mm (Taut band type with 240^0 Scale)
Multi Function Meter (MFM)	Digital Type, 96 mm x 96 mm

Along with the Numerical relay for protection above, auxiliary relays for multiplication of contacts for following oil type transformer protections shall be provided.

Sr. No.	Transformer Protection	Function
1.	Buchholz protection relay (63)	Alarm + Trip
2.	Oil temperature indicator (49 O)	Alarm + Trip
3.	Winding temperature indicator (49 W)	Alarm + Trip
4.	Magnetic oil level gauge (MOG)	Alarm
5.	Oil surge relay (OSR)	Alarm
6.	Pressure relief device (PRD)	Trip

Based on the preliminary load assumption (Refer Annexure 9) & calculation, it is proposed to consider 2 Nos. of two winding, three phases, 50Hz, 3.15MVA (2 x 100% capacity) with ONAN cooled, 11/ 0.433kV, percentage impedance of 9% (no negative tolerance) to limit the fault level to 50kA, Dyn11, Oil type transformers for proposed facility. Exact requirement of transformer qty & rating will be finalized during detailed engineering.

- An 11kV air insulated cable box with air insulated disconnecting chamber shall be provided on 11 kV side of transformer.
- LV Terminal box shall be suitable for connecting LV Air insulated type 5000A, AL conductor bus duct.
- The transformer will be provided with OLTC on HV side having +5% to –15% taps in steps of 1.25%.

- 5000A, 415V Air insulated type aluminium conductor bus duct shall be proposed between 3.15 MVA transformer secondary terminal and 415V Main PCC incomer respectively.
- The 415V PCCs/Main PDBs/ MCC/ Main Lighting Distribution Board/ ACDBs will be 3-phase, 4 wire, free standing/floor mounted, modular, single front access, metal enclosed design and shall have compartmentalised construction with AL busbar.
- No parallel operation is envisaged between transformers. Suitable interlocks shall be provided between Transformer incomers & Bus coupler in the Main PCCs to avoid their parallel operation.
- For all utility panels supplied by utility vendor (like ventilation/ AC, fire hydrant system, ETP/ STP plant etc.), only single point supply will be given up to main control panel of that particular utility system & further distribution will be done by respective utility system Vendor.
- Upto and including 630A, Fixed type TPN/FP MCCB with microprocessor based trip unit shall be considered, while from 800A onwards TPN/FP ACB (EDO/MDO Type) with microprocessor based trip unit shall be considered.
- All ACBs shall be with Ics=Icu=Icw=100% & MCCB with Icu=Ics=100%.
- Main bus bar for all the panels shall be of electrolytic grade Aluminium conductor. Current density for the same shall be considered to limit the temperature rise as per IS 8623-1993. Phase & neutral bus bar shall have similar cross-section.

It is envisaged to improve the power factor to meet minimum statutory requirement of 0.95. To meet this 1000kVAr APFC panel is considered & same shall be connected to main PCC Bus. However, actual capacitor sizing will be done based on load p.f. during detailed engineering.

The proposed auxiliary power supply system is shown in enclosed key single line diagram (TCE.10176A-733-SK-2001).

5.4.12.3 **Emergency Power Supply**

Certain important plant auxiliaries require a reliable source of power supply in the event of failure of complete AC supply in the station. For this purpose, one no. Normal/ Emergency (N/E) panel is considered. Suitable rating emergency power supply feeder for this panel shall be considered from Main power plant DG switchgear Panel.

5.4.12.4 **Un-Interruptible Power Supply System**

20kVA, 415V, 3Phase, 4 wire UPS with SMF/VRLA battery of 30 min power back up has been considered for critical lighting & plant critical controls. The exact rating of the UPS will be finalised during detail engineering.

5.4.12.5 **Control System**

All numerical relays will be PC compatible & will be having RS-485 port with mod-bus communication protocol for SCADA/EMS system. Digital type Multi function meter

shall be communicable type with RS 485 port. All the SCADA compatible equipment mounted in an individual switchgear panel shall be looped & provision shall be made at one point to connect up to SCADA.

5.4.12.6 **Cabling System**

The following types of cables are proposed

For 11 kV system: 11kV earthed grade, stranded aluminium conductor, cross linked polyethylene (XLPE) insulated, extruded black PVC inner sheathed, galvanized flat strip armoured for three core, extruded black PVC outer sheathed cables conforming to IS : 7098.

For low voltage system : Power cables of 1100V grade, stranded aluminium/ copper conductor, XLPE insulated, Inner sheath of extruded black PVC, armoured and overall FRLS extruded black PVC outer sheathed cables conforming to IS: 1554.

Inside the substation area, cables will be laid in cable trays mounted on structures supported on substation wall/ ceiling. Whereas for Plant area, cable would be primarily laid in the overhead cable tray system along the side supports/ rafter/ beam/ Column support up to MCC panel. From the MCC panel up to individual machine location/ panels, the cable will be laid through cable trays/runners/trenches as per the requirements.

Separate cable trays will be used for control, signalling, FDAS and supervisory cables. In case separate cable tray provision is not possible, then separation distance of minimum 300mm shall be maintained between 11 kV/0.415/0.230 kV power/control & signal cables.

For underground cables, cable route marker shall project 150mm above ground and shall be spaced at an interval of 15 metres, and at every change in direction. They will be located on both sides of road and drain crossings. Top of cable marker/ joint marker shall be sloped, to avoid accumulation of water/ dust on marker.

Point Wiring

(a) Point wiring is envisaged for the offices/ Canteen/ utility/ Lab areas i.e. mainly for the enclosed areas other than Plant areas.

(b) Point wiring shall be inclusive of wires, 25/32 mm MS Black enamelled conduit, switch board, switches, sockets, box, blank plates, and accessories.

Lighting System

The illumination levels for various indoor/ outdoor areas would be maintained as per accepted IS codes.

LED light fittings are proposed for Pre-processing plant area & street lighting. Fluorescent fixtures are proposed for other auxiliary buildings.

Normal Lighting

Normal lighting in all indoor and outdoor areas will be operated on 230V, 1 Phase, 50 Hz, AC, supplied from NLP (Normal Lighting Panel). NLPs shall be supplied from

Main Lighting Distribution Board (MLDB) located in substation/ Utility room. Main Lighting distribution board shall be fed from Main PCC.

Emergency Lighting

Emergency lighting shall be supplied through DG power. Emergency lighting shall be considered for 10% of total plant lighting & 100% outdoor lighting.

Critical/ Escape Lighting

Critical Lighting shall be supplied through UPS power supply, which will be backed again by DG power. Critical Lighting shall be designed such that at all junctions, exit passages, Lux level shall be maintained at average 10 Lux. Critical lighting/ Escape lighting fixtures will be directly controlled from lighting panel without any switchboard in between.

Safety Earthing and Lightning Protection System

Presently the fault currents considered are as tabulated below-

Sr. No.	System	Fault Level & duration
1.	11 kV	40 kA for 0.16 Sec for outgoings 40 kA for 0.4 sec for incoming
2.	415 V	50 kA for 1 Sec

With reference to IS 3043:2006, overall earthing resistance shall be designed to achieve less than 1 Ohm. All individual earth grids of buildings shall be interconnected with each other & shall be connected to main power plant earth grid at minimum two locations.

The following conductor materials are proposed for the earthing system:

Requirement	Specification
Main Earth grid material below ground level	(65 mm x 10 mm) GI flat for Substation (50 mm x 10 mm) GI flat for Plant (50 mm x 8 mm) GI flat for other auxiliary buildings
Conductor above ground level, cable trenches and along cable trays	GI flat to withstand fault level for 1sec.
Lightning protection air terminations and down conductors for buildings	GI flat (25 mm x 6 mm)
Distribution Transformer body Earthing	(65 mm x 10 mm) GI flat
Distribution Transformer Neutral Earthing	(65 mm x 10 mm) GI flat
Receptacles Earthing	8 SWG GI wire
Light Fittings Earthing	10 SWG GI wire

Type of earth pits considered for different areas/ applications are decided as follows-

a) CI Pipe Earthing – For Plant, Substation, Auxiliary Buildings Earthing pits e.g. Transformer/ DG body, lightning protection etc.
b) Cu Plate Earthing – For dedicated earth pits e.g. IT/ UPS panel equipment. & For Transformer/ DG neutral

For all Mechanical Utility System like HVAC, fire hydrant system, water system, ETP & STP etc., 2 Nos earthing strip shall be provided up to incoming of utility control panels & further distribution will be done by utility Vendor.

Lightning Protection

a) The lightning protection system need will be established by calculating the risk factor value of each building, structure etc. as per procedure given in IS/IEC 62305, Part-2 – 2010. Since, early streamer type lightning protection is not applicable as per IEC 62305. Same shall not be considered.
b) For all structures, Air termination system comprising of horizontal roof conductors will be provided. Spacing between the roof conductors will be as recommended by IEC 62305 – 2010.
c) The down conductors from the PEB/ RCC roof will be fixed and run along the outer surface of the building and connected to the earth electrodes inside the ground provided along the building.

5.4.13 **Control & Instrumentation (C&I) System**

The proposed control and instrumentation (C&I) system will integrate the functions of monitoring, control and protection to facilitate the safe, reliable and efficient operation of Power plant equipment.

5.4.13.1 **Control Philosophy**

Boiler, BOP systems, Plant electrical systems will be controlled by Plant Distributed Control system (DCS). Steam Turbine Generator will be controlled by dedicated control system. Utility Packages will be controlled by Programmable Logic Controller (PLC) based control systems. Operation of Boiler, Steam Turbine Generator (STG), Balance of plant (BOP) systems (steam-water cycle, HP/LP bypass, Auxiliary PRDS, Condenser, Closed cooling water system, DM water system etc.), and plant electrical systems is envisaged from the operator work stations located at central control room (CCR).

The following operator stations (OS) with 22” LED screens would be considered at CCR:

- 1 no. Operator station, 1 no. Operator cum engineering station for operation and monitoring of STG and for performing required engineering functions
- 3 nos. Operator station for operation and monitoring of Boiler, BOP and plant electrical systems.

One no. Large Video Screen (LVS) of size 67” would be located at CCR for monitoring of Power plant equipment and important Parameters. It would be

connected to all three operator stations, and screens from any one of the operator station would be projected to LVS.

One no. engineering station located at CCR is envisaged for performing required engineering functions for Boiler, BOP and Plant electrical systems. One no. A3 colour laser printer, and 2 nos. A4 laser printers located at CCR is envisaged.

One no. Redundant Historian server located at CCR is envisaged for logging important plant parameters and alarms/ events.

Electronic cubicles related to STG control system, Plant DCS will be located at Central control Room.

Utility Packages like Water Treatment plant, Effluent treatment Plant, Flue gas cleaning system (as applicable), Fuel handling system, Ash handling system and other utility packages will be controlled by dedicated PLC based control systems with Operator cum Engineering stations located at respective local control rooms. These independent PLC systems will have bi-directional communication interface (Modbus TCP/IP) with DCS for monitoring from the CCR. Compressors will be controlled by Manufacturer proprietary Control system (MPCS) with panel mounted HMI and will have communication interface (Modbus) with DCS for monitoring. Alternatively all controls of Utility packages can be included in DCS system by providing remote I/O systems at respective local control rooms. This will facilitate the operator to operate all systems from CCR.

Emergency push buttons (shrouded and two in tandem) for Boiler and STG trip will be provided on the unit control desk. Emergency local stop push button operation will be provided for all drives except for motorised valves and solenoid valves. For motorised valves open/ close functions will be available in the integral starter of the actuators.

5.4.13.2 **Control System Requirement**

A dedicated control system would perform the normal start-up/ shutdown and emergency operations of the STG and its auxiliaries. It would be designed to perform turbine governing, speed, temperature, load and frequency regulation, automatic start-up/ shutdown, protection interlocks, turbine supervisory functions including Vibration measurement, monitoring and annunciation of malfunctions. STG control system will be with dual redundant controllers, redundant Power supply and Communication hardware.

The Plant DCS will implement control requirements of Boiler (Drum level control, Fuel control, Furnace air control, Flame detection, Flue gas pressure control, Steam temperature control, Deaerator level control etc.) Balance of plant (BOP) systems (steam-water cycle, HP/LP bypass, Auxiliary PRDS, Condenser, Closed cooling water system, DM water, etc.), and plant electrical systems. In addition, control system for utility packages like Water treatment plant, Effluent treatment plant, Flue gas cleaning system, Fuel handling system, Ash handling system etc. will be interfaced to plant DCS through bi-directional communication interface (Modbus over

TCP/IP).Functionally distributed and geographically centralised DCS is envisaged with Human machine interface (HMI) located in the CCR.

Control system configuration is detailed in attached Exhibit “Control system configuration diagram”.

Grouping of systems/ equipment in the controllers of the DCS will be based on criticality and availability requirements to be decided during detail engineering phase. DCS will implement the basic requirements of plant performance monitoring (Plant heat rate, Auxiliary power consumption, etc.) of the plant as per relevant ASME standard.

In the DCS systems, Measurement system (MS), Closed loop control system (CLCS) and Open loop control system (OLCS) are envisaged as part of Multi function controllers with redundancy at processor modules, communication modules, data bus and power supply modules. Redundant sensors are provided for all control applications. For all important and critical controls triple redundant sensors are provided. Critical CLCS and OLCS will be configured with redundant I/O channels for each sensor/ signals. Where redundant sensors are provided redundant I/O channels will be provided for each sensors/ signals. Redundant channels will be in different modules. Signals from single sensors/ initiating devices/ final control elements (eg. Position transmitter, MCC feedback, etc.) that are used in critical OLCS/ CLCS will also be provided with redundant I/O channels. Burner Management System/ Boiler protection system would be provided as per NFPA guidelines and original equipment manufacturer’s recommendations.

The interconnecting cables between any two cabinets and between cabinets and panels would be of prefabricated type. The communication bus of the DCS would be coaxial/ twisted pair cable as per DCS vendor’s standard. Fiberoptic cables are envisaged for communication between Local control rooms and central control room as well as for interfacing remote I/O and independent PLC systems to DCS.

5.4.13.3 **Features of the C & I System**

Sequence of Events Recording System

Sequence of events (SOE) recording is envisaged to be integral to DCS. In case the control systems for the steam turbine is different from the plant DCS, SOE events related to the steam turbine will be logged in the STG control system with resolution of 1ms time stamp. These events will be transferred to the station DCS using OPC communication and a consolidated SOE report will be made available in the DCS.

Annunciation system

Annunciation system will be integral to the DCS and STG control systems as available as inbuilt system feature. Window based annunciators are not envisaged.

Analytical Instruments

Steam and Water Analysis System (SWAS)

On-line, continuous, steam and water quality analysis system is envisaged. Various steam and water samples would be routed to a centralised place and cooled to the

required temperature before analysis. The complete hardware associated with this sampling system and sample cells will be mounted in a sampling rack with facility for grab sample. The analysers will be located in a separate panel near the sampling rack in an air-conditioned environment. Both the sample rack and analysers will be located in a container with the analyser panel section partitioned for air-conditioning. Adequate number of analytical instruments would be provided for continuous monitoring of de-mineralized water, feed water and steam. The analytical instruments proposed are typically for specific conductivity, cationic conductivity, pH, dissolved oxygen and silica measurements.

Continuous Emission Monitoring System

Continuous Emission Monitoring system (CEMS) will be provided to monitor the stack emissions. From the data acquisition system, the hardwired signals will be transferred to the DCS. CEMS will have bi-directional communication interface (Modbus TCP/IP) with DCS for monitoring of CEMS parameters, alarm status from the CCR.

Ambient Air Quality Monitoring System

Ambient Air Quality Monitoring systems are envisaged for the monitoring of SOx, NOx, CO, PM_{10}, & $PM_{2.5}$ and any additional measurements as required by local pollution control board.

Vibration Monitoring System

A vibration monitoring system complete with transducers and remote monitor is envisaged for monitoring vibrations of STG as a part of Turbine Supervisory system. Signals from Turbine Supervisory system will be wired to STG control system to facilitate monitoring, alarm and trip based on the vibrations observed. Vibration analysis system for analysis of Turbine vibration and related parameters is envisaged. For other HT drives such as boiler feed pumps, vibration sensors and transmitters will be provided. The signals from the Vibration transmitter will be wired to the DCS to facilitate monitoring, alarm and trip based on the vibrations observed. The vibrations would be measured and monitored in both X and Y directions for each measurement.

Master clock system

A master clock system with time synchronisation equipment is envisaged, complete with all hardware and software to receive the synchronizing signals from remote satellite and provide outputs to synchronize plant wide control systems like Plant DCS system, STG control system, SCADA, all utility package PLCs, and any other control systems to ensure a common time reference. The system will be based on Global positioning system reference and will include GPS antenna, GPS receiver, signal processing unit etc. Time accuracy will be 1 PPM. The master clock will be configured as real time clock with display of time in 24 hours format and date and will drive slave clocks located in different plant control buildings.

Final Control Element Actuators

All final control elements of regulating type (control valves) will have actuators of pneumatic type. Control Valves: Valves will be designed to have suitable capacity (in terms of CV) and rangeability for the flow conditions indicated. The design/ selection will ensure accuracy of control for small control signal changes and high rangeability to take care of differential pressure across the control valve during start-up, shutdown and low load process conditions. Actuators will meet the specified shut-off differential pressures. Materials for body, trim, packing box and other parts of the valve will be compatible for the fluid and its multiple operating conditions specified.

Local Instruments

The proposed local instruments are as follows:

- Adequate number of local indicating instruments would be provided to enable local operators to supervise and monitor equipment/process.
- Indicating type smart transmitters are envisaged for better accuracy and response. Also, smart transmitter maintenance facility will be provided.
- All temperature sensors will be duplex type and the signal transmission of thermocouple would be through compensating cables.

Air supply for pneumatic equipment

Air supply for pneumatic equipment: oil free, dry instrument air from instrument air compressor system at a pressure of 6 - 8 bar (g) would be drawn for various pneumatic instruments like control valve positioners, control damper positioners, I/P converters, etc. Each of this pneumatic equipment which requires air supply at different levels would be provided with an air-filter regulator.

Power Supply

A parallel redundant uninterrupted power supply (UPS) system with static bypass would be provided to cater to power supply requirements of instrumentation and control systems such as HMI equipment, analysers, receiver instruments, DCS etc. 24VDC required by C&I loads will be derived from the UPS. Conversion for UPS power to any other voltages required including control system supply would be derived from the UPS.

Testing and Calibration of Instrument

Necessary testing and calibration instruments required for the complete C&I system would be provided.

Earthing

Dedicated electronic earthing system, in addition to electrical safety earthing would be provided to take care of requirement of various control systems.

5.4.14 **Fire Fighting**

5.4.14.1 **Input Data**

The basis on which the concept report is prepared is given below:

1) Tariff Advisory Committee (TAC) guidelines
2) National Building Code (Part 4) – Fire and Life Safety

3) National Fire Protection Association (NFPA),

4) Following IS standards:

Sr. No.	IS Code		Detail
i	IS 1239 Part-I: 2004	:	Steel Tubes, Tubulars & other Wrought Steel Fittings
ii	IS 3589 : 2001	:	Steel Pipes for Water & Sewage (168.3 to 2540 mm Outside diameter)-Specification
iii	IS 5290 : 1993	:	Landing Valves Specification
iv	IS 15683 : 2006	:	Portable Fire Extinguisher, Performance & Construction
v	IS 903 : 1993	:	Fire hose delivery coupling, branch pipe, nozzle and nozzle spanner – Specifications
vi	IS 636 : 1988	:	Specifications for Non percolating flexible fire fighting delivery hose
vii	IS 13039: 1991		External Hydrant Systems--Provision and Maintenance

1) Drawings received from Architects, Plot plan and all floor drawings

List of Architecture drawings:

Sr. No.	Drawing No	REV	Drawing Title
1.	TCE.10176A-2024-GA-6001	P0	Plant Layout
2.	TCE.10176A-2024-GA-6002	P0	Available Land Parcel
3.	TCE.10176A-2024-GA-6003	P0	Interim Plan

5.4.14.2 **Design Criteria**

Fire fighting measures that can be applied for waste-to-energy (WTE) project comprise;

a) Portable extinguishers, to fight fire in incipient stage.
b) Sprinkler system for detection of fires and automatic actuation of fire fighting operation in the region of fire, thus preventing spread in administration building.
c) HVWS system shall be provided for transformers, waste carrying conveyor, boilers and feed stock storage.
d) MVWS system shall be provided cable galleries.
e) Hydrant system for fighting fires of higher intensity and as back-up to fire fighting operations with portable extinguishers and sprinkler system.

Fire fighting systems, in India, are planned as per guidelines of local municipal rules, which are statutory, and/or Tariff Advisory Committee (TAC) guidelines. Most of the municipalities adopt the National Building Code of India guidelines in framing their requirements. The TAC was an advisory body to the nationalised insurance companies in India for setting insurance premium rates and discounts for safety norms adhered. However are still being referred as the TAC guidelines are more

elaborate, on fire fighting measures to be adopted, than the local statutes. The TAC classifies a WASTE-TO-ENERGY (WTE) PROJECT under Light Hazard category. The TAC guidelines recommend following fire fighting measures:

a) Portable extinguishers within the building.
b) Hydrant system outside and within the building.
c) Sprinkler system within the building
d) HVWS/ MVWS system.

Municipal statutes are essential for compliance for any construction within a city. Also, interaction with municipal officials is required for ensuring compliance of proposed fire fighting scheme to the municipal statutes. The proposed fire fighting scheme will be required to be submitted to the insurance companies for approval and availing discount in insurance premium. The proposed fire fighting measures for the Waste-to-Energy (WTE) project would comprise of portable extinguishers, hydrant system, HVWS System, MVWS System and sprinkler system. The fire fighting system is designed as per the local municipal rules, National Building Code of India recommendations and TAC guidelines. Reference is made to National Fire Protection Association (NFPA), USA, recommendations where necessary.

5.4.14.3 **Discussion**

Portable Extinguishers

For occupancy, the class of fires (as defined by the TAC) anticipated are as under:

a) Class A fire: fires in ordinary combustibles (like wood, paper, plastics, rubber and the like).
b) Class B fire: fires in flammable liquids (like oil, paints, grease, solvents and the like).
c) Class C fires: fires in gaseous substances under pressure including liquefied gasses.
d) Class D Fires: Fires in reactive chemical, active metals and the like.
e) Fires in energised electrical equipment.

Portable extinguishers of following types are recommended for the different class of fires:

(a) Water gas pressure type in 9 lts cap for Class A fires.
(b) Portable extinguishers of carbon dioxide type in 2kg and 4.5kg for Class B fires.
(c) Portable extinguishers of carbon dioxide type in 2kg and 4.5kg for Class C fires.
(d) Portable extinguishers of carbon dioxide type in 2kg and 4.5kg for fires in energised electrical equipment.

Portable extinguishers of dry chemical powder (DCP) can also be used on Class B, C, D and energised electrical equipment. However, DCP type extinguishers leave messy residue after operation. Hence carbon dioxide extinguishers are

recommended. The portable extinguishers would be so distributed that a person would not have to travel more than 15m to fetch an extinguisher. Also, every room/ enclosure would be provided with minimum of one extinguisher.

Hydrant System

The hydrant system shall comprise of:

(a) External and internal hydrant valves with hoses in hose boxes

(b) Hose reels at internal hydrant locations

(c) Underground and above ground fire water piping with necessary valves.

(d) Hydrant system pumps comprising - one motor driven hydrant system pump, one standby diesel engine driven hydrant system pump and a line pressurisation jockey pump.

(e) Panel, cables and instrumentation

The external hydrants are planned at the distance of 45m apart and within 2m -15m from the building. The hydrant system outdoor piping shall be buried. External hydrants shall be used for fighting fire outside building and at ground floor within the building, provided no point at the ground floor is more than 45m from an external hydrant. For each external hydrant, a hose box with two nos. hoses, each of 15m length, will be provided.

Internal hydrants shall be provided for fighting fire within the buildings. The internal hydrants shall be provided in sufficient quantities such that no portion of the floor is more than 30m from an internal hydrant. For each internal hydrant a hose box with two nos. hoses, each of 15m length, and a hose reel of 30m length will be provided. The hose reel enables fighting low intensity fire at lesser water discharge. All the internal hydrants are placed on wet risers which is connected to main hydrant line with isolation valve

The system shall be designed to operate automatically on operation of any of the hydrant valve(s). The system shall be always pressurised and will operate by a set of pumps and related instrumentation and controls. The operation of pumps shall be sequential. The jockey pump shall start and stop to maintain header pressure. In case of operation of hydrant(s), the jockey pump would be unable to maintain the pressure and the pressure drops further. At a lower predetermined pressure the motor driven hydrant system pump starts. In case motor driven pump fails to start, the pressure continues falling. At a further lower predetermined pressure, the diesel engine driven standby hydrant system pump shall operate. Stopping of hydrant system pumps shall be manual.

HVWS/ MVWS System

HVWS system shall be provided for transformers, Boilers, Waste Storage area and conveyor. The HVWS system around each transformer shall be complete with piping, supports, bulb detectors, spray nozzles, deluge valve with accessories/instruments, isolation valve downstream of deluge valve isolation valve, strainer upstream of each deluge valve and barrier wall around deluge valve.

The system shall be hydraulically so designed that minimum 3.5kg/ sq.cm pressure is obtained at hydraulically remote nozzle. The pressure at any nozzle shall not exceed 5kg/sq.cm.

MVWS system shall be provided for cable galleries. The system shall be hydraulically so designed that minimum 1.4kg/ sq.cm pressure is obtained at hydraulically remote nozzle. The pressure at any nozzle shall not exceed 3.5kg/sq.cm.

Fire Water Pump House and Underground Fire Water Tank

A fire water tank adjacent to fire water pump house is proposed to facilitate positive suction. The fire water pump house shall house four pumpsets (each for hydrant and sprinkler system), pump delivery and suction piping, instruments, diesel engine control panels and motor control centre-cum-instrument control panel. The fire water tank and pump house shall be below ground.

Clear water is suggested for fire fighting purpose. To avoid water stagnancy, it is proposed to construct the service/ potable water tank adjacent to fire water tank so that the water from the fire water tank overflows into the service/potable water tank. The fire water tank shall have two compartments. Fire water tank shall have baffle walls to avoid water stagnation.

As per the TAC guidelines, the fire water storage required is as under:

a) Two hour pumping capacity for hydrant system and sprinkler system, i.e. 171 X 2 = 342 cub. m
b) Assumed 182 cub. m. storage HVWS/MVWS system.

The total fire water storage capacity hence works out to 524 cub. m. Other fire safety measures recommended for implementation are:

a) Installation of fire detection and alarm system
b) Providing a compartmentalised approach in design of the building and its services with the aim of restricting the fire spread.
c) Provision of fire door at staircase landing for access to floor.
d) Provision of fire doors and fire rated walls for typical hazardous areas in the complex like the LPG cylinder storage room; diesel generator set room, boiler room etc.
e) Provision of fire rated stairwell enclosure walls.
f) Provision of fire rated walls in emergency escape paths.
g) Provision of fire rated sealing in slots provided in partition walls for routing cables/ other items.
h) Provision of fire lifts.
i) Provision of fire dampers in the ventilation system, pressurisation of stairwells and lobbies and smoke evacuation system.
j) Use of fire retardant materials like FRLS cable, non-combustible furnishings etc.

Fire Station

Fire station building with one number of fires tender near fire pump house of 12K capacity is planned within the premises of proposed waste to energy plant. The Exhibit Control System Configuration Diagram is shown in Annexure 10.

Electrical Requirement

Electrical load list for water pumps are as below:

Sr. No.	Description of Equipment	Qty (Nos.)	Approximate Power Input (in KW)
1.	Electric Motor driven Pump, 273 m^3/hr @ 70 MWC for deluge system	1W	110
2.	Electric Motor driven Pump, 171 m^3/hr @ 70 MWC for sprinkler and hydrant system	1W	75
3.	Electric Motor driven Pump, 12 m^3/hr @ 70 MWC	2W	15

Fire fighting system comprising following is proposed,

(a) Portable extinguishers within the building.

(b) Hydrant system outside and within the building.

(c) Sprinkler system within the building.

A fire water tank of 524 cub. m capacity adjacent to fire water pump house is proposed. The fire water pump house shall house four sets of pump sets (each for hydrant, sprinkler system and Deluge system), pump delivery and suction piping, instruments, diesel engine control panels and motor control centre-cum-instrument control panel.

Other fire safety measures such as those listed in chapter 4, above are proposed.

The fire fighting system and fire safety measures shall comply with local statutory norms. Other useful fire safety features would be adopted from national codes/ standards/ guidelines (such as National Building Code, TAC) and international codes such as the NFPA as necessary.

5.4.15 **Emission Control System (ECS)**

The emissions due to firing of MSW need to be controlled, monitored and controlled effectively to avoid environmental damage. The emission standards for incineration are specified in the Solid Waste Manual (SWM) 2016. Following are the different types of pollutants and their level of concentration permitted as per SWM 2016. The values given in the **Table 5.10** are corrected for 11% O_2 on dry basis.

Table 5.10: Particulate and Emission standard

Parameter		Emission Standard
Particulates	50 mg/Nm^3	Standard refers to half hourly average value
HCl	50 mg/Nm^3	Standard refers to half hourly average value

Parameter		Emission Standard
SO_2	200 mg/Nm^3	Standard refers to half hourly average value
CO	100 mg/Nm^3 50 mg/Nm^3	Standard refers to half hourly average value Standard refers to daily average value
Total Organic Carbon	20 mg/Nm^3	Standard refers to half hourly average value
HF	4 mg/Nm^3	Standard refers to half hourly average value
NOx (NO and NO_2 expressed as NO_2)	400 mg/Nm^3	Standard refers to half hourly average value
Total Dioxins and Furans	0.1ng TEQ/Nm^3	Standard refers to 6-8 hours sampling.
Cd + Th + their compounds	0.05 mg/Nm^3	Standard refers to sampling time anywhere between 30 minutes and 8 hours
Hg and its compounds	0.05 mg/Nm^3	Standard refers to sampling time anywhere between 30 minutes and 8 hours
Sb + As + Pb + Cr + Co + Cu + Mn + Ni + V + their compounds	0.5 mg/Nm^3	Standard refers to sampling time anywhere between 30 minutes and 8 hours.

5.4.15.1 **Removal of SO_2**

The plant uses municipal waste for firing in the boiler and the maximum sulphur content in the fuel is about 1.4% corresponding to which the maximum estimated emission concentration level is 5845 mg/Nm^3 pegged at 11% O_2, Dry basis. The emission level of SO_2 would vary depending on the nature, composition and moisture content in waste products being fired. Since, the estimated emission level of SO_2 exceeds the applicable standard of 200 mg/Nm^3 at 11% O_2, Dry basis, as stated in the Solid Waste Management Rules, 2015 issued by MOEF&CC; hence the abatement of SO_2 is required to meet the new regulation.

Lime stone based wet FGD is proposed for SO_2 abatement. The proposed FGD unit Scheme is indicated in Annexure 11.The outlet ducts of the ID fans 1 and 2, each carrying 50% of the total flue gas flow are connected to a common header for WFGD system. The header serves as the inlet of the WFGD system which aids the total flue gas (100%) through Gas Heater (GGH) and Absorber of the FGD system, as depicted in the flow diagram of Annexure 11. The clean flue gas coming out of the absorber and Gas to Gas heater is then exhausted through the chimney with the SO_2 emissions being controlled to the allowable limits.

GGH is a heat exchanger where the entering flue gas exchanges the heat carried to the conditioned flue gas at the outlet of the absorber.

Flue gas enters the absorber near the bottom of the spray-tower and flows upward to react with a descending spray of finely divided droplets of recycle slurry counter-currently. The slurry contains the alkali which react with SO_2 in incoming flue gas.

Intimate contact of the flue gas with the alkaline limestone slurry is achieved in successive spray zones. Each spray bank/header is provided with a series of spray nozzles designed to achieve proper atomization of slurry. Absorber recirculation pumps are provided for recirculation of reagent.

The scrubber recirculation liquid is maintained at 5.5 to 6.2 pH for optimum performance. The acidic pH level helps in avoiding scale formation in the scrubber.

Each recirculation pump is dedicated to a single spray bank. The absorber reaction tank is designed with sufficient retention time for reaction of acids in flue gas. Side entry agitators are installed to ensure optimum utilization of limestone mixing and crystallization as well as precipitation of gypsum.

The lower portion of the absorber tower is sump to collect the scrubbing liquid. Atmospheric air is pumped through air spargers/ air lances in the sump to convert the calcium sulphite into calcium sulphate. The oxidation air is supplied through air blowers which generate the discharge air at higher temperature. The discharge air from the oxidation air blower is quenched with fresh water to avoid hot spots, to prevent build up in the spargers/ lances and also enhance oxidation process. The side entry agitators in this section keep the solids from settling while the material is crystallizing. The conditions are maintained to permit the crystals to grow in a manner that they can be filtered easily into a manageable and useful gypsum material. The solution/slurry in the sump is the main working fluid of the absorber.

The conditioned flue gas at a lower temperature, gains heat at the GGH from the incoming hot flue gas and is exhausted to the atmosphere through the stack. Gypsum solids are removed from the system by the bleed system. The bleed is based on density control of the recirculation liquid.

Engineering Issues/ Impact on Plant

a) **Flue gas temperature and impact on stack:** The flue gas temperature at stack inlet would be reduced to about 85 °C and hence corrosion resistant lining is required for the stack.

b) **Additional pressure drop in FGD:** The ID fans capacity would be increased to compensate the additional pressure drop in duct work, header along with pressure losses in absorber and gas to gas heat exchanger.

c) **Waste Water Treatment :** The FGD system will produce about 6 tph of waste water as which contains high chloride content of about 20,000 ppm and suspended solids of about 3%, and needs further treatment

Table 5.11: Wet FGD System (Estimated Values)

Sr. No.	PARAMETERS	UNITS	VALUES
1.	Moisture in waste products/fuel	*%*	50
2.	Calorific Value of Fuel	*Kcal/kg*	1800
3.	Fuel Firing Rate	*tph*	69.74
4.	Sulphur Content in Fuel	*%*	1.4
5.	Excess Air fired	*%*	70

Sr. No.	PARAMETERS	UNITS	VALUES
6.	Total Flue Gas Flow (Wet)	*Nm^3/hr*	297308
7.	SO_2 Emission Level before FGD	*mg/ Nm^3 at 11% O_2*	4395
8.	Total Flue Gas Flow (Dry)	*Nm^3/hr*	245042
9.	SO_2 Emission Level Before FGD for Dry Gas	*mg/ Nm^3 at 11% O_2, dry basis*	5845
10.	SO_2 Emission Level Post FGD Treatment	*mg/ Nm^3 at 11% O_2*	132
11.	SO_2 Emission Level post FGD Treatment for Dry Gas	*mg/ Nm^3 at 11% O_2, dry basis*	175
12.	Estimated Limestone Consumption for FGD	*tph*	4
13.	Estimated Raw Make-up Water Consumption for FGD	*tph*	40
14.	Estimated Effluent Waste-Water collected as blow-down	*tph*	6
15.	Estimated Chloride Content of Effluent Waste Water	*ppm*	20000
16.	Cooling Water requirements for pumps, blowers, etc	*tph*	20
17.	Estimated Suspended Solids Concentration of Effluent Waste Water	*%*	3
18.	Estimated Gypsum Formation for FGD	*tph*	8
19.	Estimated Auxiliary Power Consumption	*Kw*	900
20.	Intermediate Auxiliary Steam Requirement for GGH/Absorber	*tph at 300 °C, 16 ata*	3
21.	SO_2 Removal Efficiency of the FGD System	*%*	97

5.4.15.2 **Particulate Matter**

Dry Electrostatic Precipitators (DESP) is suggested for removal of particulate matter from the flue gas. In case the level of emission standard is not achieved bag/filter in conjunction with DESP can be adopted. The DESP will be installed in each flue can upstream of FGD unit.

Dry Electrostatic precipitators (DESP)

DESP are used to capture the particulate matter (dust and fly ash) entrained in the flue gas stream. Typical operational temperatures for operation of DESP are 160°C - 260°C. The temperatures of the flue gases exiting from the incinerator will be ensured to be in the same temperature range. The efficiency of dust removal of electrostatic precipitators is mostly influenced by the electrical resistivity of the dust. If

the dust layer resistivity rises to values above approx. 1011 to 1012Ω cm removal efficiencies are reduced. The dust layer resistivity is reduced by dust composition. Sulphur in the waste (and water content at operational temperatures below 200°C) often reduces the dust layer resistivity. Operation at higher temperatures (e.g. above 250°C) is avoided which increases the risk of formation of PCDD/F formation. The DESP in such a scenario may have to be sized for a higher resistivity, depending on the feasibility of design and operation.

Wet Electrostatic Precipitators (WESP)

WESP use the same principle of DESP. However the precipitated dust on the collector plates is washed off using water. However this technique is applicable when moist and cooler flue-gas enters the ESP.

Bag/ Fabric filter

In case of high resistivity the option of Bag/fabric filter can also be explored. These filters have very high filtration efficiencies across a wide range of particle sizes. Hence low dust emissions can be achieved. These can also be used in conjunction with DESP installed downstream of DESP. The compatibility of the filter medium with the characteristics of the flue-gas and the dust and the process temperature of the filter are important for effective. The sensitivity of bag/ fabric filter to fluctuations in the temperature needs to be mitigated. Moreover, in continuous operation there is gradual loss of pressure across the filtering media due to the deposit of particles. Periodic replacement is required when the residual lifetime is achieved or in the case of irreversible damage. Irreversible deposit of fine dust in the filter material leads to an increased loss of pressure. Often if high flue gas temperatures of 300°C to 600°C are encountered the dust becomes sticky at these temperatures. Such scenarios warrant the usage of unconventional cleaning methods such as ultrasound vibration.

5.4.16 **Ash Collection and Management System**

5.4.16.1 **Assessment of Quantity of Ash Generation**

The maximum percentage of ash generated will be during the monsoon season and is about 23.41% as per NEERI report. The quantity of fly ash would be about 4% and Bottom ash would be about 20% of the total input feed to the boiler. This works out to about 300 tpd of bottom ash and 60 tpd of fly ash. The details of collection and handling of bottom ash and fly ash are furnished below:

5.4.16.2 **Bottom Ash Handling System**

Bottom ash generated will be quenched and evacuated through submerged scraper chain conveyor (SCC). The bottom ash falls into a water filled trough where the scraper chain will be provided for evacuating this bottom ash. The SCC will be provided on rails for easy maintenance of the equipment.

The overflow water from the seal trough and SCC trough shall be collected in the overflow drain sump. Overflow drain sump will be provided with two nos (1W + 1S) BA overflow drain sump pumps, to pump the water from the sump to the settling tank. The clear water from the settling tank will be collected in the Surge tank. The sludge

from the Settling tank will be pumped in to the scraper chain conveyor trough by Sludge pumps (1W + 1S). Recirculation surge water return pumps (1W + 1S) will re-circulate the water to the SCC trough through heat exchangers (1W + 1S) provided for cooling. Cooling water to the heat exchangers will be provided from Closed Cooling water system.

The bottom ash will be further conveyed to a Bottom Ash Silo and will be disposed through trucks for utilisation or land filling. The capacity of the BA silo will be about 133 TPD.

5.4.16.3 **Fly Ash Handling System**

The fly ash will be collected from the Bag filter hopper, Economiser Hopper and Air preheater hopper. This ash will be evacuated from these hoppers and will be conveyed to the FA storage silo using pneumatic system. The FA generated will be disposed of through trucks for utilization. The capacity of silo will be 200 Ton.

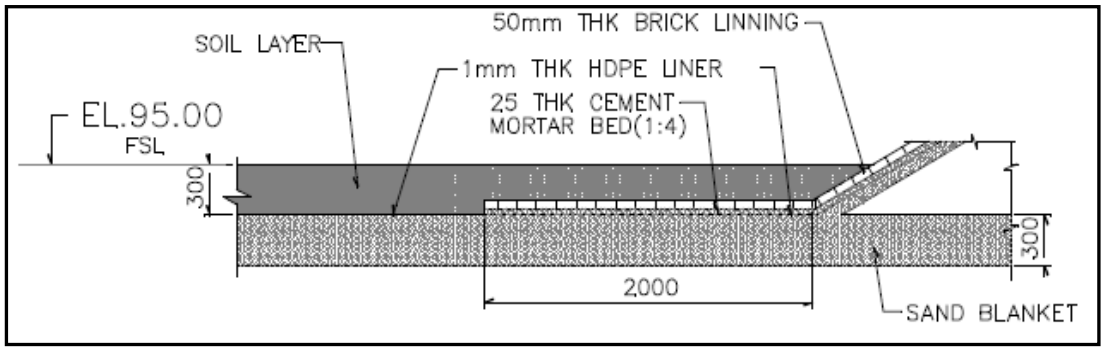
5.4.16.4 **Emergency Ash disposal system**

It is proposed to dispose both bottom ash and fly ash to ash disposal area during emergency through high concentrate slurry system. The ash disposal area would be about 1.6 hectares which is considering a mound height of 8m. Ash disposal area will be provided with necessary lining to avoid contamination of ground water. A retaining wall/ bund of about 2.5m height would be provided all round the ash disposal area to contain rain water flowing down the ash mound and is allowed to evaporate naturally as the same would be contaminated with ash.

5.4.16.5 **Ash Disposal Area**

The bottom and Fly ash generated at site will be used for making bricks, tiles etc. In case of emergency, it will be stored in Ash pond planned in an area of 1.66 Ha, located in the north of the project plot. The ash pond will have bottom liner system as presented in **Figure 5.11.**

Figure 5.11: Details of Ash Pond



Design details of the Ash pond (Interim period) are presented below.

Table 5.12: Ash Pond Capacity (Interim period)

Particulars	Quantity	Unit
Plot Area	16674	Sqm.
Plot Area	1.67	Ha
Plot Area	4.12	Acre
Height/ Deep	7	m
Side Slope V:H	1:3.5	
Volumetric Capacity	77249	Cum
Density	1.20	Ton/ Cum
Tonnage Capacity	92698	Ton
Daily Intake	159	TPD
Storage Period	583.01	Days
Storage Period	1.60	Years

Two options for Ash disposal studied are presented in the **Table 5.13.**

Table 5.13: Ash Disposal Option-1

Ash Disposal as Pre-cast/ Road Raw Material (Option-1)		
	Qty.	**Unit**
Bottom Ash	133	TPD
Fly Ash	27	TPD
Total	159	TPD
Total	**1,162,627**	Qty. (Ton) for 20 year

Table 5.14: Ash Disposal Option-2

Particulars	Quantity	Unit
Required Plot Size		
Length	300	m
Width	300	m
Plot Area	90000	Sqm.
Plot Area	9	Ha
Plot Area	22.24	Acre
Landfill Height	23.5	m
Landfill Side Slope V:H	1:4	
Volumetric Capacity	968036	Cum
Density	1.20	Ton/Cum
Tonnage Capacity	1161644	Ton
SLF Life Span	**19.98**	Years

As per option-2, SLF land requirement for 20 years of Ash disposal is 9.0 Ha, and land parcel of such size is not available in the proposed WtE plot. Therefore, as per Option-1, it is recommended that Operator will arrange use ash for manufacturing tiles, bricks etc, or to sell it to buyers for cement industries or other uses on regular

basis. Land area of 2 Ha is available for reject management facility. The area requirement for ash disposal is also discussed in Section 5.2.3.2.

5.4.16.6 **Inert Management**

It is evident from the literature reviewed that 16% inert, accordingly 480 TPD inert will be generated from the pre-processing facility, for its disposal two options have been studied and presented below.

Table 5.15: Inert Disposal Option-1

Inert Disposal as Soil Cover (Option-1)		
	Qty.	**Unit**
Inert	**480**	TPD
Surface Area	78	Ha.
Surface Area	780000	Sqm.
Depth of Soil Cover	1.00	m
Vol. of Soil cover	780000	Cum
Period Soil cover	4.5	years

Based on the contour map from MCGM and site reconnaissance, it is evident that waste is spread in the dumpsite for which Soil cover required in order to avoid fire hazard as well as bird menace. Accordingly, if the 480TPD pre-processing inert is used as 1m thick soil cover, disposal period of 4.5 years is possible.

Table 5.16: Inert Disposal Option-2

Particulars	**Quantity**	**Unit**
Required Plot Size		
Length	380	m
Width	380	m
Plot Area	144400	Sqm.
Plot Area	14.44	Ha
Plot Area	35.68	Acre
Landfill Height	30.5	m
Landfill Side Slope V:H	1:4	
Volumetric Capacity	1991691	Cum
Density	1.80	Ton/Cum
Tonage Capacity	3585044	Ton
SLF Life Span	**20.46**	Years

As per option-2, SLF land requirement for 20 years of inert disposal is 14.5 Ha. Such land parcel is not available in the proposed WtE plot. Therefore, as per Option-1, it is recommended that MCGM will accept the inert for soil cover material for the existing dump. For remaining 15.5 years, MCGM to plan for development of SLF at Deonar site as separate project. The inert can also be disposed of with C&D waste facility.

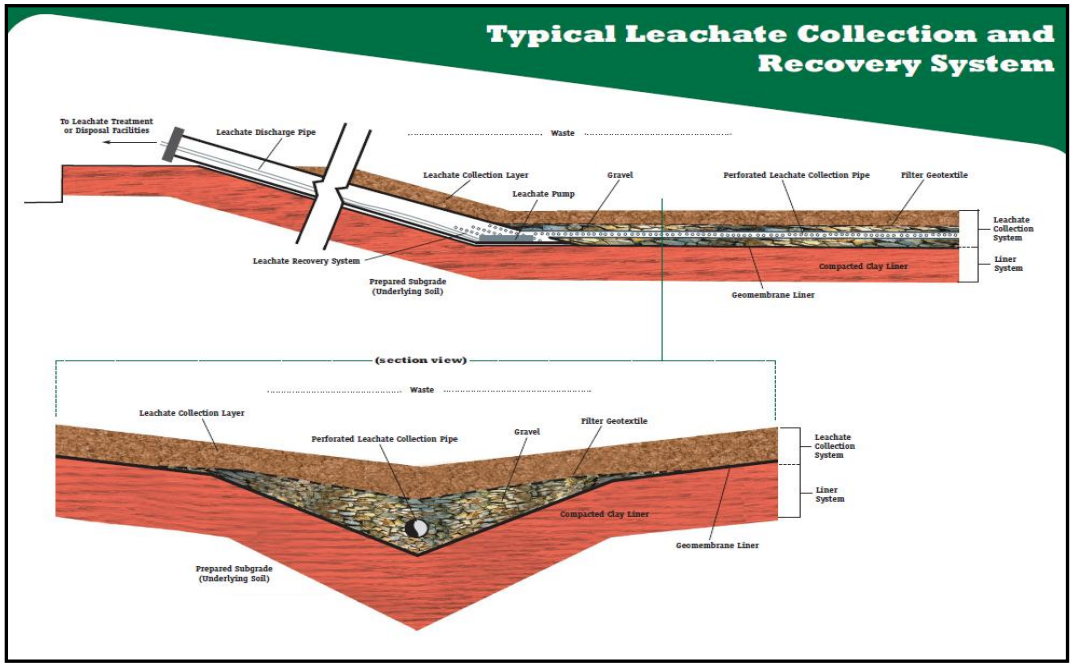
Land availability is one of the major constraint in overall waste management practices for Mumbai. Additional land needs to be identified for disposal of inert and rejects from waste processing in the window period of 4.5 years. Land from existing dump can also be freed by processing the waste. However, these activities should be independent of WtE project. The land area requirement for reject disposal is also discussed under Section 5.2.3.2.

5.4.17 **Leachate Collection and Management System**

As per Draft MSW Manual 2014, the principal source of Leachate applicable to the proposed plant is from moisture content of waste entering the pre-processing facility.

- It is proposed to have a closed pre-processing facility with shed in order to avoid direct precipitation on the incoming MSW waste. Hence, Moisture content remains the only source of Leachate. As per the reports received from the client and referred SWM manual, expected moisture content in the incoming waste is very high. Considering two shifts operation of pre-processing area, the retention time of incoming Waste in receiving area would not be more than 8 Hours. It is expected that 10% of incoming MSW waste i.e. 300 cum/day (300KLD) could be the total Leachate generation for which Leachate Treatment Facility is proposed.
- Leachate collected from the Waste receiving and pre-processing area would be channelized to the leachate collection sumps, it will be equipped with non-clog submersible pump to transfer the leachate to Leachate Treatment Plant (LTP) for treatment.
- The material of construction will be suitable to handle Leachate. Two (1W+1S) non clog submersible pump of 25 m^3/hr capacity at a head of 10m will be provided in the sump. 100 mm HDPE pipe will be provided to transfer the leachate from sump to LTP.
- As there is limitation of land availability, land disposal of the treated leachte is ruled out. There are no water body nearby to the apart from stream leading to creek. Leachate disposal in creek water with marine ecology is not considered viable solution; hence it is proposed to dispose the treated Leachate in to the Public Sewer near to the Ghatkopar-Mankhurd road as per norm specified in SWM Rules 2016.
- The leachate collection system should be routinely monitored, inspected and flushed as may be necessary, employing proven methods. Monitoring of the system can be accomplished by measuring and logging the volume of leachate extracted as a function of time.

Figure 5.12: Typical leachate collection and recovery system

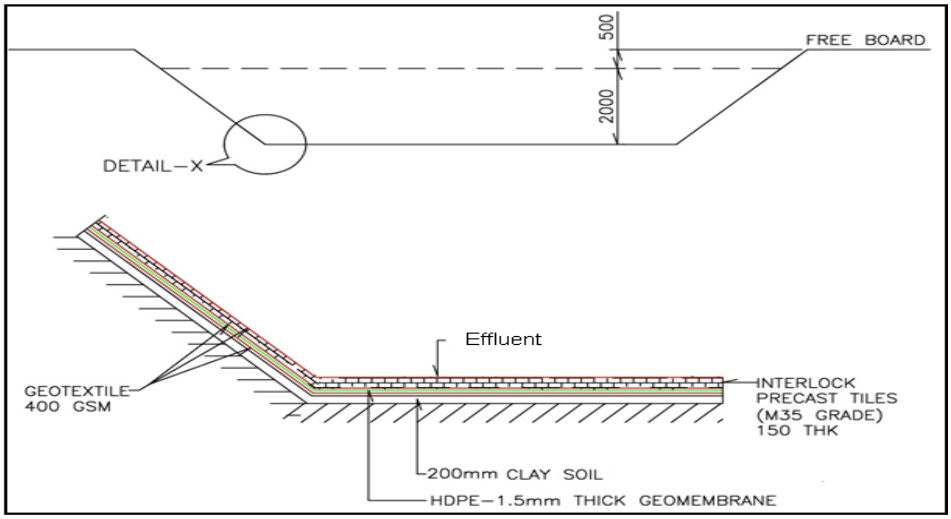


- A reduction in the flow rate during the operational life of the landfill is typically an indication that the system is under the influence of clogging mechanisms. To prevent the movement of leachate beyond the landfill site, an effective impermeable liner collection system becomes critical. The typical leachate collection and recovery system is shown in **Figure 5.12**.

5.4.18 **Treatment of Effluent from Ash Pond**

Effluent generated from Ash pond will be first collected in the Effluent Pond, further it will be sent to ETP for treatment. The effluent pond is shown in **Figure 5.13.**

Figure 5.13: Lining arrangement for Effluent Pond



Based on quantities from WtE plant and Ash pond design, the effluent generation calculation is presented in the table below. Accordingly ETP of 600 KLD is proposed.

Table 5.17: Effluent Pond

Design Capacity of Effluent Pond		
		KLD
1	Ash Pond	440.69
2	20% extra	88
3	Total	528.69
4	Design Capacity	600.00
Effluent Qty. from Ash Pond		
Rainfall	26.43	mm/day
Area	1.67	Ha.
Qty.	440.69	Cum/day
Qty.	440.69	KLD
Qty.	440.69	KLD

5.4.19 **Effluent Treatment Plant**

An ETP of 600 KLD is proposed for treatment of Effluent Ash Pond and other utilities.

5.4.20 **Sewage Treatment plant**

The total manpower envisaged at the plant is 200, based on that; it is proposed to have package type Sewage treatment plant of 10 KLD Capacity.

5.4.21 **Process Water Conveyance Pipeline**

Water required for the MSW Processing Plant, fire fighting and other utilities services will be catered through the waste water of lagoon in Ghatkopar. The water gets the primary treatment in the lagoon. A sump is proposed to be constructed near the 4th lagoon of Ghatkopar.

The sump 3m x 4m with a depth of 4m is proposed near the existing pump house at fourth lagoon. An isolation valve will be provided on the pipe connecting the sump and the lagoon. The valve on the pipe will facilitate in taking outage for cleaning and maintenance of the sump. 300 mm DI pipe will be provided to connect the lagoon and the sump. The pump house will be built over the sump.

Two (1W+1S) non clog submersible pump of 160 m^3/hr capacity at a head of 20m will be provided in the sump. The pumps will be connected to the delivery pipe through duck foot bend. The pumps will be provided with guide rail and lifting chain to facilitate operation and maintenance. The pump house will be equipped with hook and chain pulley to pullout the pump from the sump during maintenance.

Delivery valves will provide on the delivery pipe outside the pump house. The distance between the pump house to the ETP is around 3.5 km. DI pipe of 300 mm diameter will be used to convey the water to ETP. The air valves will be provided at every summit/ peak of the pipeline and at maximum intervals of 300m for ascending or descending climb of the pipelines and 1000 m for the straight pipeline in level ground.

5.4.22 **Storm Water Drainage System**

It is important to collect rain water separately to minimize volume of leachate and also to prevent flooding of the Site during heavy rains. Adequately sized storm water drainage network in RCC has been designed to evacuate run-off water. Rainfall intensity of 100 mm/hr. has been considered while calculating the total discharge.

Rational Method:

The Rational Method is widely used to estimate the peak surface runoff rate for design of a variety of drainage structures, such as a length of storm sewer, a storm water inlet, or a storm water detention pond. The Rational Method is most suitable for small urban watersheds that don't have storage such as ponds or swamps. It is best for areas less than 100 acres, but is sometimes used for up to 2 sq. mile Areas. In this method,

a) The intensity of the rainfall is constant and is applied to the entire watershed
b) The runoff coefficient remains constant throughout the storm event
c) The frequency of the peak flow is equal to the frequency of the rainfall intensity

Rational Formula:

Q = 10 C.i.A

Q - peak runoff, m^3/hr

C - runoff coefficient

i - rainfall intensity, mm/hr

A - Tributary area, hectares.

The runoff coefficient, C, is a function of the ground cover and a host of other hydrologic abstractions. It relates the estimated peak discharge to a theoretical maximum of 100 percent runoff. The assumed runoff coefficient is 0.75 which is for small industrial area[25]. The rainfall intensities for Mumbai region are:

Return period	Colaba	Santacruz
(years)	(mm/hr)	(mm/hr)
2	53.1	55.2
3	60.8	64.5
5	69.4	74.9
10	80.1	87.9
20	90.5	100
50	104	117
100	114	129
200	124	141

[25] M. Zafar et al Landfill Surface Runoff and Its Effect on Water Quality on River Yamuna, Journal of Environmental science and health Part A—Toxic/Hazardous Substances & Environmental Engineering Vol. A39, No. 2, pp. 375–384, 2004

Rainfall intensity of 100 mm/ hr having 20 years return period may be adopted for the specific areas where tidal effects are observed. Since Deonar site is closer to Santacruz, rainfall intensities of Santacruz are considered[26].

Hence, the rainfall intensity adopted is 100 mm/hr.

The area for catchment is 12.19 Ha (for contagious land parcel).

The total area is divided in two catchments. One is Parcel A with area 1.39 Ha and other is combination of parcel B and C with area 10.8 Ha.

Both the catchments are further divided in half considering half of the storm water drains in left side drain and other half in right side drain.

Therefore from Rational formula, the runoff is calculated to be 9142.5m^3/hr.

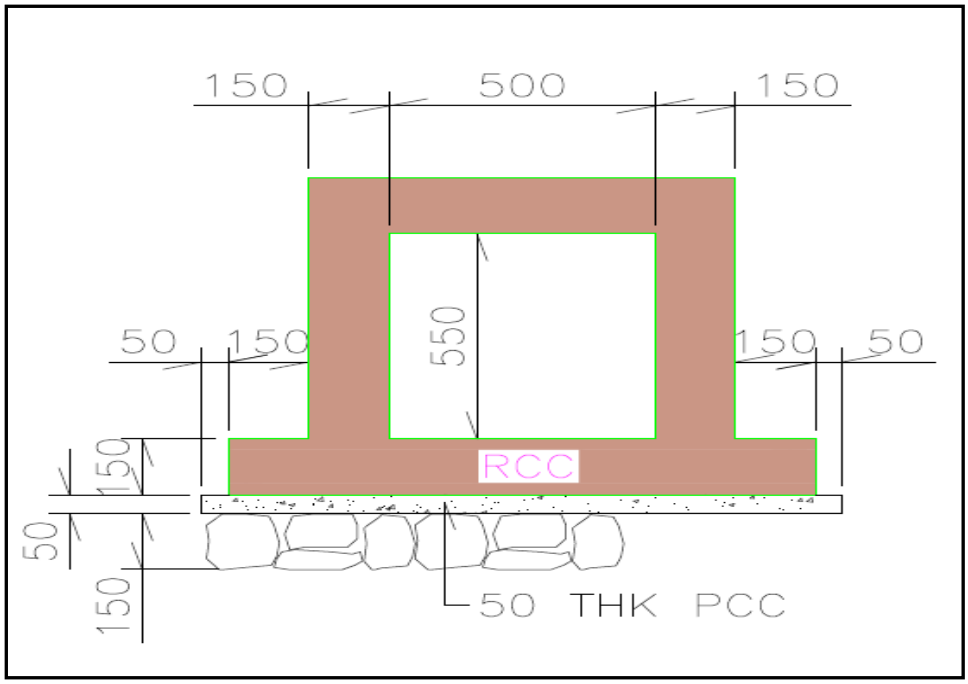
As per the CPHEEO manual on sewerage, the design practice is to use Mannings formula for open channel flow.

Manning's Formula: V=1/n x R2/3 x S1/2
V= Velocity in m/s
n= Manning's roughness coefficient
R=Hydraulic radius in m
S=Slope of hydraulic gradient
For catchment 1, the assumptions are as follows,
n = 0.015
Width = 0.5 m
Depth = half of width (for economical design)
Free board = 0.3 m
For catchment 2, the assumptions are as follows,
n = 0.015
Width = 1.2 m
Depth = half of width (for economical design)
Free board = 0.3 m
The velocity is calculated for both the catchments are 1.16 m/s and 1.76 m/s respectively, which is acceptable as per CPHEEO manual.
Grade of Concrete – M20

Grade of Steel – Fe 500

[26] Zope P. E et.al Study of spatio - temporal variations of rainfall pattern in Mumbai city, India Journal of Environmental Research And Development, Vol. 6 No. 3, Jan-March 2012

Figure 5.14: Cross section for storm water drain for area parcel A



5.4.23 **Internal/ Service Road Network**

The road is designed as a flexible pavement referring to IRC 37:2012. As per master plan, total road length is 2300m. Out of this, 1600m is the outer road with width of 12m and the remaining 700m is the 6 m wide road. It is designed as a single lane road considering 6% CBR and also that the subgrade will be stabilized and compacted to a minimum of 97% of laboratory dry density. It is also assumed that 250 vehicles will move on the pavement per day. The vehicle distribution factor of 3.5 is assumed considering plain terrain. Before any construction activity, it is recommended to undergo the CBR testing.

Figure 5.15: Cross section for storm water drain for area parcel B&C

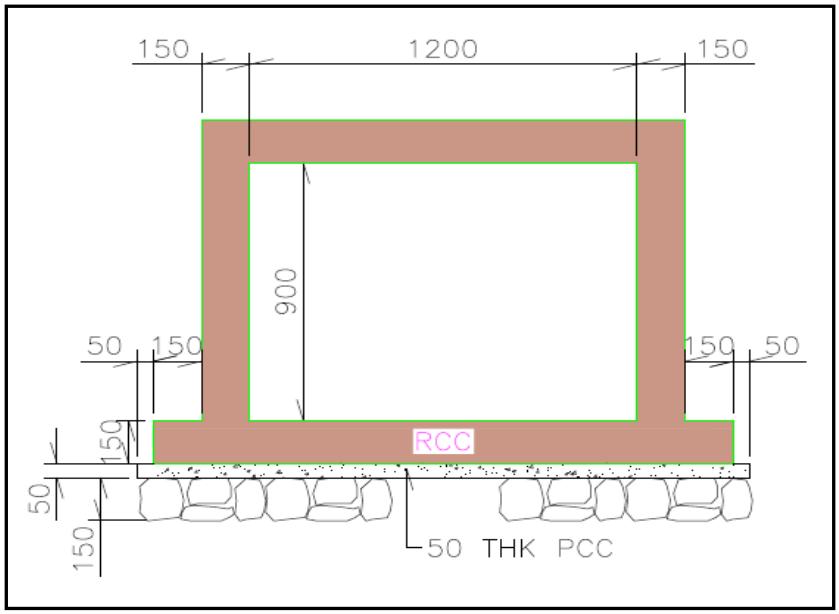
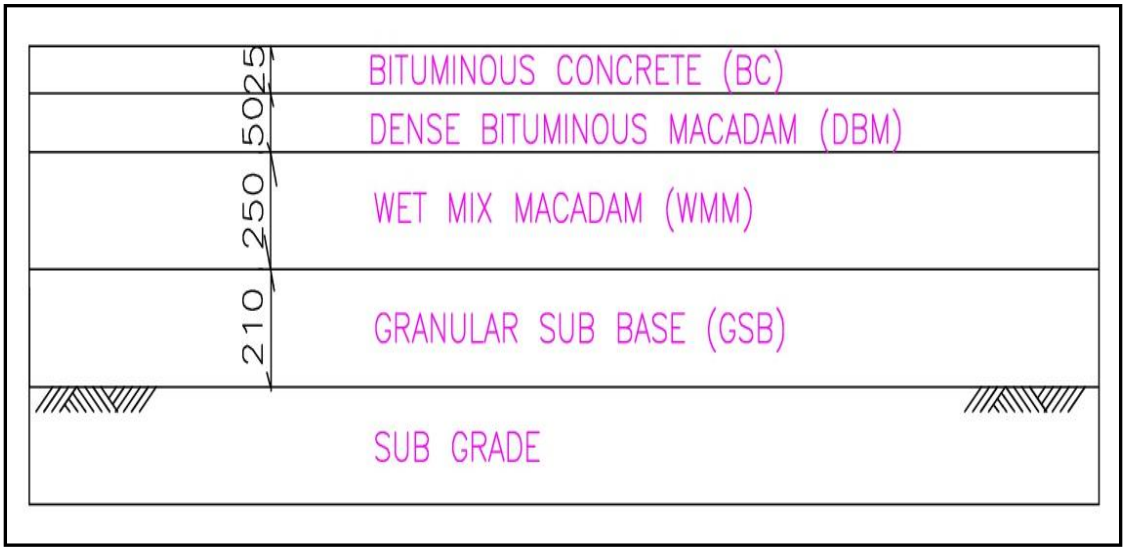


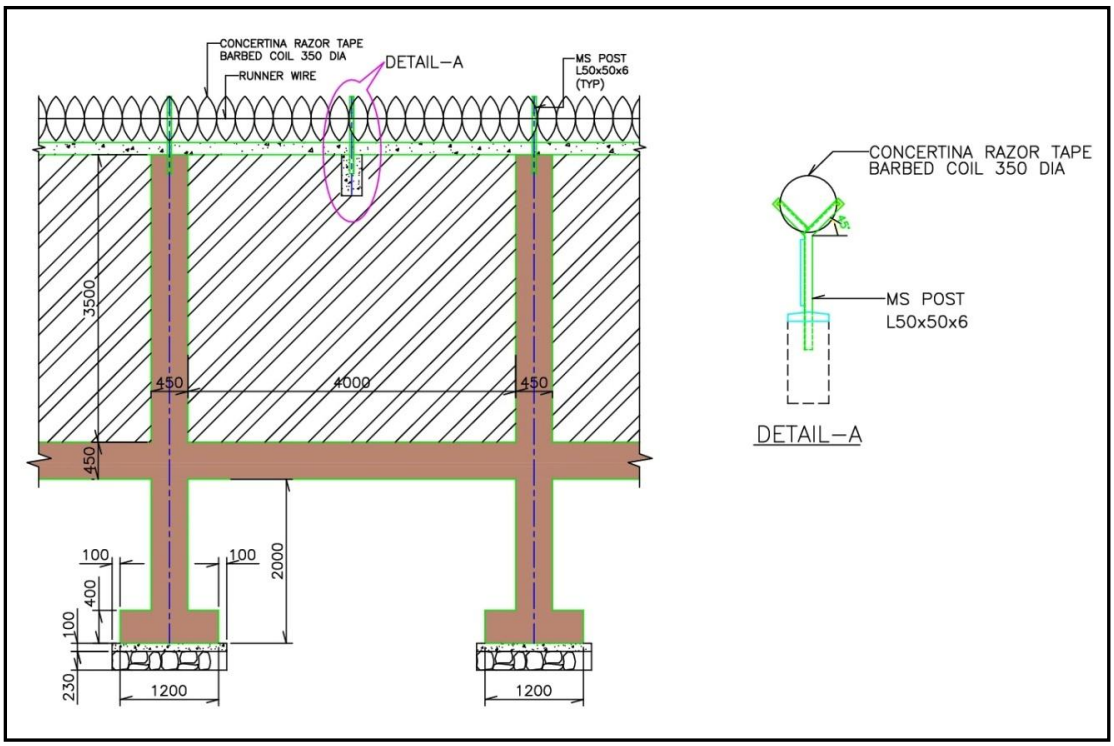
Figure 5.16: Section of Internal Road



5.4.24 **Boundary Wall**

Compound wall constructed with RCC column/ beam/ brick masonry and concertina coil fence on top has been proposed all along the boundary of the Site to restrict unauthorized entry of people into the site. MS gate with cattle trap has been proposed for entry/exit to the Site, flaring station and the water/ leachate treatment units.

Figure 5.17: Typical view of Boundary Wall



The boundary wall spans for a length of 2250m approximately. Boundary wall is required to protect the facility from the stray animals, rag pickers and trespassers.

The columns are built at every 4m. The brick wall is 230mm thick. Capping is also provided at top to keep away rain water from face of the wall. Height of the wall is taken 3.5m above average GL considering rag picker issue. The grade of concrete and steel used are M25 and Fe 500, respectively.

5.4.25 **Administration office**

The building would be of RCC frame with hollow concrete block/ brick wall cladding, inter/ external plaster, painting, distempering, electrification, water and sanitation provision as per IS specification and MCGM SoR and norms. The building area is 250 sq.m. It is planned for the staff of around 50 people. It comprises of working space for 50 people, conference rooms, small pantry area, washrooms and a reception.

5.4.26 **Worker's Area**

The building area is 150 sq.m. It is planned for the staff of around 150 people. It comprises of cabinets for workers to keep their belongings and washroom. The building would be of RCC frame with hollow concrete block/ brick wall cladding, inter/ external plaster, painting, distempering, electrification, water and sanitation provision as per IS specification and MCGM SoR and norms.

5.4.27 **Security Cabin**

A security cabin is proposed at every gate. The building would be of RCC frame with hollow concrete block/ brick wall cladding, inter/ external plaster, painting, distempering, electrification, water and sanitation provision as per IS specification and MCGM SoR and norms. The cabin has an area of 39.69 sq.m. Security cabin, each at the entrance gates of the site.

5.4.28 **Various Plant Buildings/ Structures**

Steam Turbine Generator Building & Deaerator Building

STG building framing shall be of structural steel with moment connection framing in the transverse direction and bracing in the longitudinal direction. EOT crane is envisaged in STG area for proposed power plant facility. Cladding shall be a combination of brick wall/ concrete block/ aerated concrete blocks supported on concrete encased steel wall beams and permanent colour coated sandwiched insulated metal cladding system. Roof of station building would be made of sandwich metal panels provided with roof skylight for natural light. De-aerator building shall be outdoor open type steel structure with structural steel framing suitably braced along the length.

Steam Generator Area

The steam generator structure would be of structural steel-framed construction. Concrete paving would be provided in the steam-generator area with necessary drains and trenches. Pipes and cables in this area, in general, would be routed on overhead pipe/ cable racks.

Chimney/ Stack

A Steel Stack is proposed for the power generation plant. The total height of stack would be around 50m above mean sea level. This would meet the requirement of Indian emission regulations. Aviation warning lamps would be provided for the stack as per regulatory requirements.

The color coded zoning map for Mumbai and Navi Airports are given at **Figure 4.3**. The stack location is also given in this map. Clearance from Civil Aviation Authority would be required for the WtE Plant Stack.

CW and ACW System

The plant would be provided with a circulating cooling water system and auxiliary cooling water system with cross flow type induced draft cooling tower (IDCT).

CW Pump house:

CW pipeline from pump house to condenser, condenser to IDCT.

Cooling water for ACW system draws water from CW pump discharge header and circulate water to plate type heat exchangers.

The CW conduits would be buried MS pipes with cement mortar lining and concrete encasement. CW headers shall be underground from CW Pump house to condenser and the same shall be above ground near the condenser & Plate heat exchanger.

Ancillary Building and Structures

These buildings would be of RCC frame with hollow concrete block/ brick wall cladding. Pipe & Cable rack shall be of Structural steel.

The area is going to experience settlement due to presence of organic material. The settlement extent cannot be predicted as it is landfill site having majority of fill as loose fill. Hence flexible structures directly resting on fill area like –grade slab, roads etc would be preferable. Flexible structures will help in avoiding or minimize development of cracks due settlement.

5.4.29 **Ground Improvement Measures**

The following ground improvement measures are suggested with the available data, the same may be deemed ‘preliminary’. Detailed ground improvement measures need to be explored by experts (who have adequate experience in the field) after detailed study with detailed soil investigation data in the area.

a) Dynamic compaction: The Dynamic compaction is the process of densifying ground material to relatively great depths by applying energy at the existing ground surface. Densification results from systematically lifting and dropping a heavy steel weight from a crawler crane in pre-determined height on-centre grids. Following impact, deep craters will be created and later backfilled utilizing fill material. The hammer weight, spacing, number of times of dropping of weight in one place need to be established by the expert and confirmed by performance in trial area. If performed properly, dynamic compaction allows for construction of

conventional spread footings and for supporting utilities like roads, drains, trenches, etc.

b) R.C.C bridge/ ramp supported on piles: In this method, R.C.C piles to be installed in the ground which supports the RCC bridge/ ramps. Driven piles shall be installed upto the hard weathered rock strata covering the area (requiring ground improvement). The piles would be considered partial free standing and partial embedment in dump and sub soil. RCC raft / bridge shall be constructed above the piles at pile cap level. This arrangement could be considered to support utilities like roads, drains, trenches, etc.

c) Vibro Concrete Columns: Vibro Concrete Columns are an innovative piling technique developed to provide enhanced load bearing capacity at shallow depths. They are often used where weak organic soils overlie granular deposits could be considered to be installed. The technique uses custom-built Vibro Replacement machines where no water jetting is required. Concrete can be fed using a skip to the top of vibrator and transferred through a special delivery tube attached to the vibrator directly into the ground. This method uses a pure displacement process where no soil or garbage will be removed. After reaching the desired depth, the vibrator was pulled up slightly and the concrete will be discharged to fill the cavity. During re-penetration the concrete will be compacted.

d) Complete removal of legacy waste from the land area of proposed WtE project: In addition to the above mentioned ground improvement techniques, complete removal of legacy waste from the land area of proposed WtE project is also an available alternative method of ground/ site development. Complete removal of legacy waste from the land area of proposed WtE project is envisaged in order to ensure following requirements

    1. To avoid/ minimise methane and other landfill gases which are corrosive in nature may harm the instruments and equipments of the WtE plant.
    2. To avoid chances of spreading fire from the existing dump
    3. To avoid the differential settlement to the building, plants and plant infrastructure due to the decomposition of the organic content in the legacy waste lying in the plot
    4. To avoid the contaminations due to legacy waste.

Based on the detailed geotechnical study, topographical survey and as per the requirement of site grading, the methodology of site development shall be prepared. It shall include the depth of excavation, calculations and quantum of excavation, philosophy of segregation (for Soil, C&D, RDF etc.), stacking & storing of the segregated RDF material as feedstock for the WtE Plant. Reuse of good quality segregated material such as Soil, C&D and inert materials to be considered for backfilling in order to reduce the disposal quantity of excavated legacy waste.

The detail of using good quality legacy waste for re-filling and land development as per NHAI guidelines is given in Section 5.2.3.4.

5.4.30 **Field Testing**

Detailed geotechnical investigation shall be carried out in the area. Reputed experts who have adequate experience in the field shall be involved to arrive at the ground improvement measures considering detailed sub soil data in the area.

Trial area shall be created in the near vicinity and the adequacy of improvement methods shall be checked before implementing the same at field.

Proto type foundations, Plate load tests and other relevant field tests etc. shall be considered to be carried out in the trial area to check the load settlement behaviour thereby quantifying the ground improvement achieved at site.

5.4.31 **Further Scope**

CONTRCATOR shall carry out detailed geotechnical investigations at site by deploying competitive geotechnical agency. Specialized experts who have adequate knowledge and expertise in landfills shall be engaged for exploring ground improvement options for foundations on landfills.

Suitable care and precautions shall be exercised in course of construction on landfills. Ground improvement methods shall be checked for its adequacy by testing on trial area before implementing at site.

5.4.32 **Foundations**

Building Foundations

It is observed from the sub soil profile that the depth of encountering of weathered rock/ hard stratum is varying. Hence foundation recommendations are to be made specific to the areas depending upon the depth of existence of weathered rock/ hard stratum. In view of the above, Rock socketed piles are recommended depending on the proximity of hard stratum.

Pile foundations can be recommended as piles socketed in medium weathered basaltic rock. The actual type of foundation would be finalised as per the detailed geotechnical investigation during engineering stage.

Machine Foundations

Foundations of major equipment such as turbo generator, PA fans, SA fans and ID fans would be supported on conventional frame/ block foundation designed as per relevant BIS codes. Machine foundation would be isolated from main building with a clear gap of 50 mm to prevent transmission of vibration.

For Industrial floor area

If only floor is expected with no equipments resting on the same, then Top 1m of soil replacement by good soil (Clayey sand) by layer wise compaction at min. 95% proctor density is adequate.

Base for Road, Storm Water Drain, etc.

Top 2 m of soil shall be replaced by good soil (Clayey sand) by layer wise compaction at min. 95% proctor density, alternatively, Top 2 m of soil shall be excavated. Geocell shall be placed and 1m of good soil shall be placed (Clayey sand) by layer wise. Compaction at min. 95% proctor density. The area for replacement by compaction shall be considered around 1m offset from the edge of Roads/ Roads + shoulder + storm water drains. Slope of 1:2 shall be provided at edge and covered with pitching.

5.4.33 **Specification of Materials**

1. 1.5 mm HDPE Geo-membrane (GRI Specification-**Annexure- 12)**
2. Geotextile 400 GSM (GRI Specification-**Annexure- 13**)
3. Geoclay Liner (GRI Specification-**Annexure- 14**)
4. **Cement**

   Cement shall be Ordinary Portland Cement /Portland Pozolona Cement/ Portland Slag Cement (Should be considering extreme environmental condition)
5. **Steel**

   Tor steel reinforcement of Grade Fe500 TMT as per IS 1786
6. **Concrete grade should be as follows but not limited to**

   M 35 for Foundation
   M 30 for Superstructure
   M 20 for PCC

5.4.34 **Design Codes and Standards**

All the design and construction procedures to be followed as per below codes and standards,

Table 5.18: Electrical Design Codes

DESIGN CODES FOR ELECTRICAL WORKS	
WORKS	**CODES**
CENTRAL ELECTRICITY AUTHORITY 2010 (CEA) REGULATIONS.	
NATIONAL LIGHTING CODE	
NATIONAL BUILDING CODE OF INDIA	
CODE OF PRACTICE FOR SAFETY EARTHING	IS 3043
CODE OF PRACTICE FOR THE PROTECTION OF BUILDINGS AND ALLIED STRUCTURES AGAINST LIGHTNING.	IS 2309
A.C. METAL ENCLOSED SWITCHGEAR AND CONTROL GEAR FOR RATED VOLTAGES ABOVE 1KV AND UPTO AND INCLUDING 52KV	IS 3427 / IEC 62271-200

DESIGN CODES FOR ELECTRICAL WORKS	
HIGH VOLTAGE SWITCHGEAR AND CONTROLGEAR – GENERAL SPECIFICATIONS	IEC 62271-1
CURRENT TRANSFORMER	IS 2705 / IEC 60044-1
INDICATING ANALOGUE ELECTRICAL MEASURING INSTRUMENTS	IS 1248 / IEC 60051
DEGREE OF PROTECTION	IEC 60529
CODE OF PRACTICE FOR PHOSPHATING IRON AND STEEL	IS 6005 / BS 3189
THREE PHASE INDUCTION MOTORS - SPECIFICATION	IS 325 / IEC 60034
DISTRIBUTION TRANSFORMER	IS 1180 & IS 2026
LV SWITCHGEAR GENERAL REQUIREMENTS	IS:13947/BS:5486/IEC: 60947
FACTORY BUILT ASSEMBLIES OF SWGR AND CONTROLGEAR FOR VOLTAGES UPTO AND INCLUDING 1000V AC & 1200V DC	IS:8623/ BS:5486/IEC:61439
SPECIFICATION FOR LOW-VOLTAGE SWITCHGEAR & CONTROLGEAR ASSEMBLIES: PART 2 (PARTICULARS REQUIREMENT FOR BUSBAR TRUNKING SYSTEMS)	IS 8623 PART II
SPECIFICATION FOR DISTRIBUTION PILLARS FOR VOLTAGES NOT EXCEEDING 1000V AC & 1200V DC.	IS:5039
MOULDED CASE CIRCUIT BREAKER	IS 2516/ IEC 60947-2/ BS EN 60947-2
MINIATURE CIRCUIT BREAKERS	IS:8828/BSEN:60898
LOW VOLTAGE FUSES	IS:13703/BS:1362/IEC: 60269-1
CONTACTORS	IS:13947/BS EN60947-4 /IEC:60947-1
STARTERS	IS:13947/BS EN60947-4/ IEC:60292-1TO 4
CONTROL SWITCHES / PUSH BUTTONS	IS:6875/ BSEN 60947
VOLTAGE TRANSFORMERS	IS:3156/BS:7625/IEC:60044, 60186
A.C. ELECTRICITY METERS	IS:722, 8530/BS:5685/ IEC 60145,60 211
SELECTION INSTALLATION AND MAINTENANCE OF SWITCHGEAR AND CONTROLGEAR	IS:10118
SPECIFICATION FOR COPPER RODS AND BARS FOR ELECTRICAL PURPOSES	IS:613
CONTROL TRANSFORMERS FOR SWITCHGEAR AND CONTROLGEAR VOLTAGE NOT EXCEEDING 1000V AC	IS:12021

DESIGN CODES FOR ELECTRICAL WORKS	
SHUNT CAPACITORS FOR POWER SYSTEMS	IS : 13340
INTERNAL FUSES AND INTERNAL OVERPRESSURE DISCONNECTORS FOR SHUNT CAPACITORS	IS : 12672
SHUNT CAPACITOR FOR NON-SELF HEALING TYPE FOR AC POWER SYSTEMS HAVING A RATED VOLTAGE UPTO & INCLUDING 650V	IS 13585
SPECIFICATION FOR XLPE INSULATED PVC SHEATHED CABLE (FOR WORKING VOLTAGE UP TO 3.3 KV)	IS: 7098, PART I
SPECIFICATION FOR XLPE INSULATED PVC SHEATHED CABLE (FOR WORKING VOLTAGE FROM 3.3 KV TO 33 KV)	IS: 7098, PART II
SPECIFICATION FOR PVC INSULATED CABLE (FOR WORKING VOLTAGE UPTO 1.1 KV)	IS: 694
SPECIFICATION FOR PVC INSULATED HEAVY DUTY CABLE (FOR WORKING VOLTAGE UPTO 1.1 KV)	IS: 1554, PART I
SPECIFICATION FOR PVC INSULATION & SHEATH OF ELECTRIC CABLE	IS: 5831
LOW CARBON GALVANIZED STEEL WIRES, FORMED WIRES & TAPES FOR ARMOURING OF CABLES	IS: 3975
SPECIFICATION FOR CONDUCTORS FOR INSULATED ELECTRIC CABLES & FLEXIBLE CORDS	IS 8130
METHODS OF TEST FOR CABLES	IS 10810
SPECIFICATION FOR DRUMS OF ELECTRIC CABLES	IS:10418
CODE & PRACTICE FOR INSTALLATION & MAINTENANCE OF POWER CABLES UP TO & INCLUDING 33 KV RATING	IS:1255
STEEL FOR GENERAL STRUCTURAL PURPOSES	IS: 2062
DIMENSIONS FOR HOT ROLLED STEEL BEAM COLUMN CHANNEL AND ANGLE SECTIONS	IS:808
CODE OF PRACTICE FOR USE OF METAL ARC WELDING FOR GENERAL CONSTRUCTION IN MILD STEEL	IS: 816
HOT DEEP GALVANISING OF IRON & STEEL	IS: 2629
METHODS OF TESTING UNIFORMITY OF COATING OF ZINC COATED ARTICLES	IS: 2633
HOT DIP ZINC COATINGS ON STRUCTURAL STEEL AND OTHER ALLIED PRODUCTS	IS: 4759
ELECTRICAL LIGHTING FITTINGS GENERAL AND SAFETY REQUIREMENTS	IS:1913/ BS: 4533
CALCULATION OF CO-EFFICIENT OF UTILISATION	IS: 3646 (PART - III)
DECORATIVE LIGHTING OUTFITS	IS: 5077
LUMINARIES FOR STREET LIGHTING	IS: 10322 PART 5

DESIGN CODES FOR ELECTRICAL WORKS	
BI-PIN LAMP HOLDERS FOR TUBULAR FLUORESCENT LAMPS	IS:3323
STARTERS FOR FLUORESCENT LAMP	IS: 2215/BSEN 60155
HOLDERS FOR STARTERS FOR TUBULAR FLUORESCENT LAMPS	IS: 3324/ BSEN 60400
BALLAST FOR USE IN FLUORESCENT LIGHTING FITTINGS	IS: 1534 (PAT I)
CAPACITORS FOR USE IN FLUORESCENT	IS:1569
TUBULAR FLUORESCENT LAMP	IS:2418 (PART –1)
EMERGENCY LIGHTING UNITS	IS:9583
LUMINAIRES	IS:10322 (PART I TO V)
SWITCHES FOR DOMESTIC AND SIMILAR PURPOSES	IS:3854
THREE PIN PLUGS AND SOCKET OUTLETS	IS:1293
BOXES FOR ENCLOSURE OF ELECTRICAL ACCESSORIES	IS:5133(1)
FLEXIBLE STEEL CONDUITS FOR ELECTRICAL WIRING	IS:3480
RIGID NON-METALLIC CONDUITS FOR ELECTRICAL INSTALLATIONS	IS:3419
FITTINGS FOR RIGID NON-METALLIC CONDUITS	IS:3419

Table 5.19: Civil Design Codes

DESIGN CODES FOR CIVIL WORKS	
WORKS	**CODES**
DESIGN OF LIQUID RETAINING STRUCTURES	IS 3370 PART I TO IV
PLAIN & REINFORCED CEMENT CONCRETE	IS 456-2000
CRITERIA FOR LOADING OF STRUCTURES	IS 875
DESIGN AIDS FOR REINFORCED CONCRETE TO IS 456-1978	SP 16
HANDBOOK OF CONCRETE & REINFORCEMENT DETAILING	SP 34
CRITERIA FOR EARTHQUAKE RESISTANT DESIGN OF STRUCTURES	IS 1893-2002
MOMENTS & REACTIONS FOR RECTANGULAR PLATES OF U.S.B.R PUBLICATIONS BY MOODY	
HANDBOOK OF CEMENT & CONCRETE ASSOCIATION OF INDIA FOR DESIGN OF WATER RETAINING STRUCTURES	
GEO-SYNTHETICS - GEO-TEXTILES USED AS PROTECTION (OR CUSHIONING) MATERIALS – SPECIFICATION	IS 16090:2013

5.4.35 Information Communication Technology (ICT)

ICTs are usually defined as technologies that facilitate communication and the processing and transmission of information by electronic means. Following components are envisaged for the proposed WtE project.

- Vehicle RFID System
- IP Based Video Camera
- Database Servers & other IT Infrastructure
- Biometric Attendance System
- Real-time Process Data Collection

5.5 Reject Management

The typical waste generate during pre-processing are as follows;

5.5.1 Inert waste: C&D

During the managing & processing of waste, inert waste needs to be sorted. Mainly Construction & Demolition (C&D) waste and the inert waste after the processing qualify under this type of waste. The C&D waste can be effectively used in several ways as inert fill material for low-lying areas, landscaping, and soil cover. Processed C&D waste can be used for road and embankment construction. Only the inert material or waste from treatment plants should end up in the landfills.

5.5.2 Recyclable Waste

The European Environment Agency (EEA) states “Increased recovery of waste and diverting waste away from landfill play a key role in tackling the environmental impacts of increasing waste volumes. As recycling and incineration with energy recovery are increasingly used, net greenhouse gas emissions from municipal waste management are expected to drop considerably by 2020.” Recycling and waste-to-energy go together perfectly. When materials recycling are no longer possible due to environmental, technological, economic or other reasons waste-to-energy is a good alternative. On the one hand by generating energy (heat and electricity) and on the other by recycling ferrous and non-ferrous metals, granulates and/or sand.

After thermal processing, approximately 20% (by weight) of the waste remains as bottom ash. They are recycled for the most part. Approximately 10% of the bottom ash is ferrous and non-ferrous metals, which are recycled in the scrap industry. Granulates can be used as foundation material in road construction or in construction or stability works in landfills.

5.5.3 Leachate

Decomposition of solid waste produces leachate containing concentrated organic loadings and heavy metals; gaseous emissions in the form of methane; and carbon dioxide and other landfill gases are also released in the process. Leachate has the potential to percolate and contaminate groundwater. Sanitary landfills must be designed to eliminate the problems of ground and surface water pollution and

emission of landfill gases. When water percolates through solid waste, both biological and chemical materials are leached into the effluent. If leachate is not managed properly, it can also result in odours, unsightly conditions, attract insects, and cause distress in vegetation. There are many factors that can influence leachate generation. These include precipitation volumes, landfill cover, type of waste deposited, vegetation, climate, and landfill design. The two main treatment technologies for leachate are biological and physical/chemical. The alternatives to be considered for leachate management are:

a) Discharge to Lined Drains: This option is usually not feasible. It can only be adopted if the leachate quality is shown to satisfy all waste water discharge standards for lined drains, consistently for a period of several years.

b) Evaporation of Leachate: One of the techniques used to manage leachate is to spray it in lined leachate ponds and allow the leachate to evaporate. Such ponds have to be covered with geo-membranes during the high rainfall periods. The leachate is exposed during the summer months to allow evaporation. Odour control has to be exercised at such ponds.

Treatment of Leachate: The type of treatment facilities to be used depends upon the leachate characteristics. Typically, treatment may be required to reduce the concentration of the following prior to discharge. Degradable and non-degradable organic materials, specific hazardous constituents, ammonia and nitrate ions, sulphides, odorous compounds, and suspended solids are the general composition of leachate from MSW facility. Treatment processes may be physical processes (such as air stripping, activated adsorption, ultra filtration etc.), biological processes (such as activated sludge, aeration, nitrification (dentrification), and chemical processes (such as oxidation, neutralisation). The treated leachate may be discharged to surface water bodies.

5.5.4 **Sludge**

The sludge from the Leachate treatment plant (LTP) and Effluent Treatment Plant (ETP) are the sources which are the primary source of sludge generation. It is characterized as highly concentrate dewatered part of Sludge. Application of the sludge varies with the characteristics of it like nutrients, heavy metals and organic micro pollutants. The sludge can be used in the following areas after certain quality and quantity examination[27]:

a) Agriculture use:

i. Dry Matter: Dry matter plays a role in the transport, application and spreading operations. Methods and systems of application to land also depend to a great extent on rheological properties.

ii. Volatile Solids (Organic Matter): The reduction of volatile solids through stabilisation is very important, mainly to avoid odour problems. Organic matter

[27] Sludge Treatment and Disposal: Management approaches and experience, issue series7, by ISWA's Working group on Sewage and Water works sludge

also exerts beneficial effects on land, but changes in the content of organic matter do not significantly modify sludge applicability.

iii. Nutrients, Heavy Metals, Organic Micro pollutants, Pathogens, pH: Application rates are affected by the content of nutrients, heavy metals and organic micro pollutants in sludge and soil, while hygienic risks are associated with the pathogens presence. All of the above factors are influenced by pH.

b) Composting:

i. Temperature, Dry Matter, Volatile Solids: The process performance strictly depends on temperature, dry matter and volatile solids in terms of both biological evolution and hygienization (pathogens reduction). In particular, a concentration of solids of 40-60% and a temperature around 60°C are generally required.

ii. Nutrients: The C/N ratio is very important to ensure a proper process evolution and a good end product. Values of 25-30 should be maintained.

iii. Heavy Metals, Organic Micro pollutants: Heavy metals and organic micro pollutants can either prove to be toxic to the process or reduce application rates of compost.

c) Incineration:

i. Temperature, Dry Matter, Volatile Solids, Calorific Value: The economics of incineration depend to a great extent on auxiliary fuel requirements and, therefore, the above parameters are all important to ensure an autogeneous combustion.

ii. Rheological Properties: Rheological properties are important as far as the feeding system is concerned.

iii. Heavy Metals, Organic Micro pollutants: The toxicity of emissions (gaseous, liquid, and solid) depends on the presence of heavy metals and organic micro pollutants at origin and/or when improper operating conditions occur.

d) Land filling:

i. Dry Matter: It is important to know whether the sludge is consistent enough to be land filled. Additionally, rheological properties are essential in relation to the sludge bearing capacity.

ii. Volatile Solids: The amount of volatile solids has an impact on the development of malodours and process evolution, including biogas production.

iii. Heavy Metals: Heavy metals can negatively affect the evolution of the biological process and the quality of the leachate.

From the above it follows that dry matter and volatile solids are the most important parameters in sludge characterization involved in all the application/disposal methods. They can be modified through stabilisation and solid-liquid separation

processes, which are operations almost always present in a waste water treatment system.

Apart from the conventional rejects and waste generation discussed in the above section, Fly Ash and Bottom Ash will be generated due to the incineration process. The typical waste generate during processing are as follows;

5.5.5 **Fly ash**

It is the fine particulate matter still in the flue gases downstream of the heat recovery units and is removed before any further treatment of the gaseous effluents. The chemical composition shows that the major elements are Si, Al, Fe, Mg, Ca, K, Na and Cl. Chloride content and heavy meals is higher in the fly ash. CaO is the most abundant compound that exists in MSWI fly ash.

The fly ash shall be collected in silos and most of it shall be utilized/ marketed in dry form. The fly ash which cannot be utilised / marketed shall be disposed to the ash dump area.

The fly ash generated in thermal power stations has commercial value because of its usage in cement and construction industries. Fly ash generated from the plant shall be commercially utilised in one or more of the following industries to the extent possible:

(a) Cement industry
(b) Brick industry
(c) Concrete making/ Building industry
(d) Fly ash aggregate making industry
(e) Road making/ paving

(a) Cement Industry

Fly ash is used in the production of Pozzolona cement by intergrading Portland cement clinkers and fly ash or by blending Portland cement and flyash intimately and uniformly. Indian Standard specifications limit the Pozzolona (fly ash or similar material) component up to 30% by weight whereas in other countries it varies from 15 to 50%.

The advantages of fly ash in the manufacture of Portland Pozzolona Cement (PPC) as compared to other Pozzolonic materials are two-fold.

a) Better hydraulic properties of fly ash.

b) Cement retains its natural and accepted grey colour instead of becoming mud-red, which is the case if bricks/ tiles are used as Pozzolonic materials.

(b) Brick Industry

Fly ash produced in modern thermal power stations can be used in making bricks. The Cement Association of India has conducted research and experiments for making hollow bricks using fly ash. The Central Building Research Institute (CBRI), Roorkee has also conducted experiments in making bricks by using fly ash as an

admixture with black cotton soil. In this project, bricks of minimum 105 kg/sq.cm strength were produced by CBRI.

(c) Concrete/ Building Industry

Fly ash is used in the building industry largely as a concrete additive. Fly ash can also be sintered into pellets for use as light weight aggregate.

Laboratory and pilot plant trials carried out at CBRI, Roorkee have established that sintered light weight aggregate can be successfully produced from Indian fly ash and used for producing plain concrete as well as reinforced concrete beams and slabs.

Laboratory investigations and factory trials have shown the technical feasibility of manufacture of cellular concrete from lime and fly ash. It is more economical to produce this cellular concrete than the cement-sand cellular concrete, which is being produced in the country at present.

Fly ash can also be used as masonry mortar. The work done at CBRI suggests that mixtures shall be thicker than 1:6 (by volume) to enable them to be used as mortar. As a masonry mortar, fly ash is used in place of Surkhi and prepared in a way similar to Lime-Surkhi mortar. Lime fly ash mortars are cheaper and better in performance and strength than Lime-Sand mortars.

Fly ash has also been used as raw materials for the production of glasses, glass-ceramics and ceramics under high temperature (>1,000 °C). Thermal immobilisation techniques, such as sintering/melting or vitrification have been proposed for the conversion of MSWI fly ash into ceramic type materials, although these processes are very expensive and problems may arise due to the presence of alkali chlorides and sulphates in raw fly ash[28].

(d) Fly Ash Aggregate making industry

The fly ash can be converted to light weight aggregate which can substitute the presently used conventional aggregate, in concrete blocks, flooring and non-load bearing structures such as compound walls, canals, pavements, etc. The main components of the process are fly ash, calcium oxide, fresh water quenched bottom ash (optional), sand, water and chemically bonding additives. The calcium from lime reacts with silica and alumina in fly ash to produce calcium/ aluminium materials in a reaction similar to that of Portland cement. These minerals bond the fly ash particles tightly so that hard, strong and practically unleachable pellets are formed. These pellets are heated at low temperature to cure them.

It may be noted that proportions of different ingredients to make bricks / cellular concrete/ briquettes with fly ash chiefly depends on the constituents of the particular fly ash. Therefore, the particular type of fly ash is to be analysed for the properties of its constituents and checked for suitability or otherwise and suitable proportions of ingredients are to be determined by laboratory tests/ pilot plant tests.

[28] Chang N. B., Wang H. P., Huang W. L., Lin K. S. (1999) The assessment of reuse potential for municipal solid waste and refuse-derived fuel incineration ashes. Resources, Conservation and Recycling. 25, 255–270.

(e) Roads making/ Paving

It has been reported from the laboratory tests conducted by the Cement Association of India that fly ash with other ingredients can be used for paving roads and airport runways. Fly ash mixed with sand and hydrated lime is used as a base course of asphalt pavement. The breaking strength of such a pavement is calculated to be as high as 68 kg/sq.cm (1000 psi). As a result of a series of experiments, the mixtures of ingredients added in the following recommended proportions gave a good paving material with adequate strength and reasonable setting time.

Ingredients	Composition by Weight (%)
Fly ash	12 – 14
Lime	2.8 – 3.6
Portland Cement	0.7 – 0.9
Sand	80 – 84.5

The above mixture developed strength from 54 to 95 kg/sq.cm (800-1400 psi) in about 90 days at a temperature of 18 °C to 21 °C. Further, the experiments have shown that by using 30% of crushed stones instead of sand established strength of 102 – 136 kg/sq.cm (1500-2000 psi). The total cost of manufacturing the paving mixture comes to about one and half that of ordinary road stone and to less than one third the cost of lime concrete. Road Stone has comparatively less strength where as lime concrete is proven to have good strength. Even with the extra strength obtained by using 30% crushed stones as a substitute for sand, the cost is not expected to exceed that of conventional materials

5.5.6 **Bottom ash**

It is composed of post-combustion solid waste including the ash, non-combustible residuals (such as metal, rock, concrete, some types of glass) and potentially residuals of incomplete combustion (carbon). Bottom ash from typical bass-burn facilities combusting MSW is typically classified as a nonhazardous waste[29]. SiO_2 is the most abundant compound that exists in MSWI bottom ash

- A possible way to reuse the bottom ash is to replace the materials in the base course and sub-base. The use of bottom ash in road pavement provides a simple and direct method for reuse of the incineration ash.
- As bottom ash contains acceptable amounts of phosphorous and potassium, it can be used as a partial replacement of commercial fertilizers. Also, the lime in fly ash can reduce the soil acidity, thus it can be used as a liming agent. However, there are many restrictions for these applications. MSWI fly ash has been examined for possible use as a landfill interim cover.
- The co-digestion of MSW with the proper amount of MSWI fly ash could facilitate bacterial activity, digestion efficiency as well as methane gas production rate. It

[29] A Technical Review of Municipal Solid Waste Thermal Treatment Practices

is found that the toxic heavy metals and released ions such as chloride do not have significant impact on anaerobic digestion.

- Bottom ash from MSWI has been employed for removing dye and heavy metals from wastewater.
- As MSWI bottom ash contains high content of SiO_2, Al_2O_3 and CaO, it is possible to use it to replace part of the clay for the production of ceramics without pre-treatment.
- Bottom Ash is non hazardous and consists of slag, glasses and partially unburned organic matter and chunks of metal and minerals. MSWI bottom ash is a light weight material from the specific gravity compared to natural sand and gravel. This is an advantage in the construction of fills on grounds with low bearing capacity.

5.5.7 **Flue-gas desulfurization (FGD)**

Most FGD systems employ two stages: one for fly ash removal and the other for SO_2 removal. Attempts have been made to remove both the fly ash and SO_2 in one scrubbing vessel. However, these systems experienced high maintenance problems and low removal efficiency. In wet scrubbing systems, the flue gas normally passes first through a fly ash removal device, either an electrostatic precipitator or a wet scrubber, and then into the SO_2 absorber. However, in dry injection or spray drying operations, the SO_2 is first reacted with the sorbent, and then the flue gas passes through a particulate control device.

5.6 Continuous Emission Monitoring Systems (CEMS)

It is a tool to monitor flue gases to provide information for combustion control in industrial settings. They are currently used as a means to comply with air emission standards as per Pollution Control Board. Facilities employ the use of CEMS to continuously report the required emissions data. The standard CEM system consists of a sample probe, filter, sample line (umbilical), gas conditioning system, calibration gas system, and a series of gas analyzers which reflect the parameters being monitored. Typical monitored emissions include: sulfur dioxide, nitrogen oxides, carbon monoxide, carbon dioxide, hydrogen chloride, airborne particulate matter, mercury, volatile organic compounds, and oxygen. CEM systems can also measure air flow, flue gas opacity and moisture.

The proposed WtE plant will be generating emission during the incineration process which will further pass through the pollution control equipments such as FGD and ESP. Considering the type of emissions from MSW based WtE plant, the composition of flue gas will be majorly consisting of Sulphur dioxide, Nitrogen oxides, Hydrogen Chloride, Carbon Monoxide, Particulate matter and VOC. Also considering the criticality of project, it is vital to monitor and control the emissions. Thus two CEMS are proposed i.e.

- Online Stack Monitoring

- Ambient Air Monitoring

The following items have been included in CEMS for Online Stack Monitoring

1. Design, engineering, & supply of gas analyzer system and other accessories as per the Bill of Material enclosed.
    - Supervision of installation & Commissioning of gas analyzer system

a) Cabling:

I. Analog 4-20 mA output signal cables from analyzer to other equipment's like DCS, PLC, recorders etc.

- RS-232 signals between Analyser and other equipment's like DCS, PLC, etc.
- Glanding, cabling and termination of all field cables.

II. Cable trays:

- Cable trays for power/ signal cables.

III. Site work:

- Laying of cables and cable trays.
- Shifting of the gas analyzer system from store to mounting location.
- Civil work like welding, hole drilling onto the stack/ duct.

5.6.1 **Utilities Requirements**

I. Instrument air for Blowback at 7 kg/cm^2 at dewpoint of +3 °C near Primary SHS & Analyser panel.

II. UPS and NON UPS Power supply 220VAC/110VAC near to the analyzer cabinet, sample Probe.

III. UPS and NON UPS Power supply 220VAC/110VAC near to the Dust Monitor Display box.

5.6.2 **Measuring Principle of SO_2, NOx, CO Analyzer Module – Non dispersive Infrared Sensor (NDIR)**

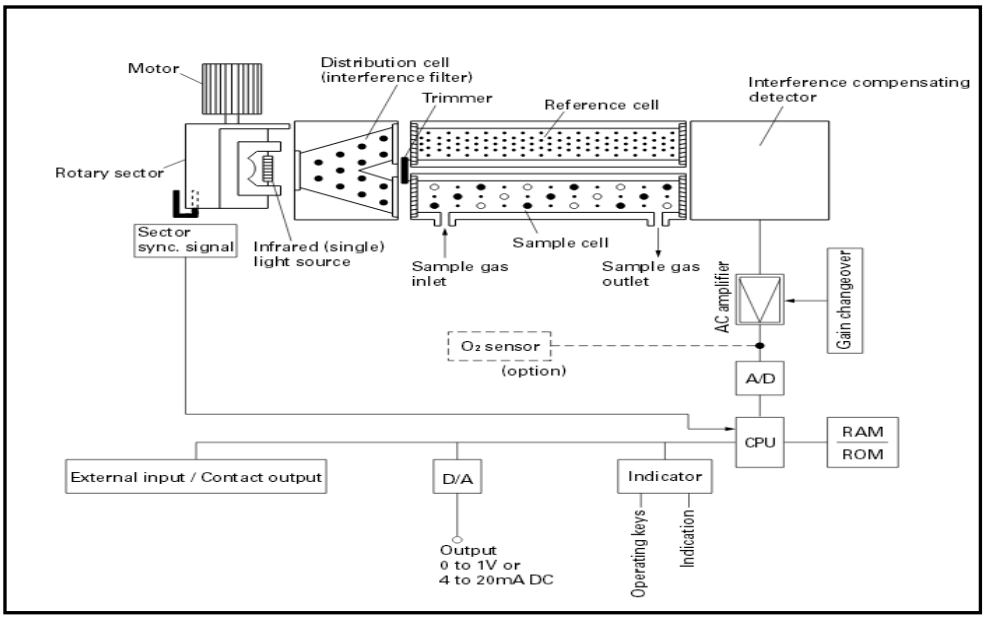
The NDIR analyzer is Single Source, Dual-beam and improved Luft-type detector. The detector is filled with the component to be analyzed and operate in the positive filtering mode. IR radiation from a single source is chopped and passed in- phase through the sample and reference cells to the detector. The NDIR analyzer shown in **Figure 5.18**.

Absorption of IR radiation by sample molecules results in a detector imbalance, which is sensed as a change in capacitance and amplified to provide an output corresponding to component concentration in the sample.

Filter cells are added, filled with interfering sample components, which remove undesirable wavelengths from both sample and reference beams.

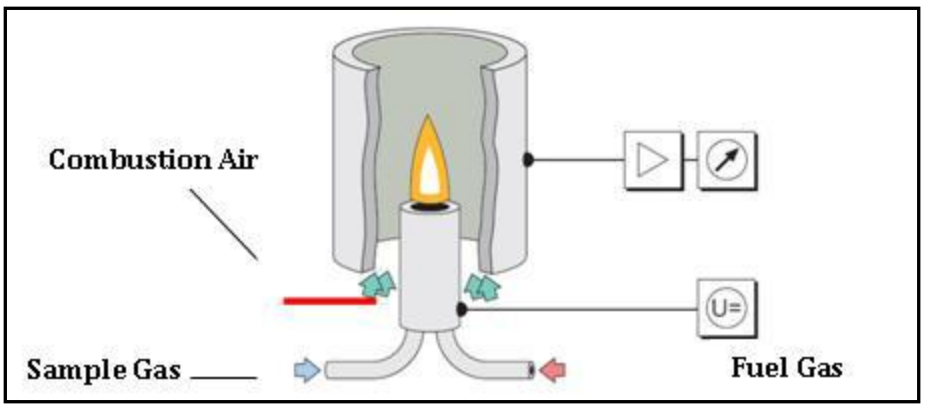
Molecules absorb energy at wavelengths determined by their molecular structure. The amount of energy absorbed is proportional to concentration. Optical Filter transmits a narrow wavelength of energy received at component of interest wavelength.

Figure 5.18: NDIR analyzer



5.6.3 **Measuring of Principle of VOC Analyzer Module**

The FIDOR uses a flame ionization detector (FID) for measuring the hydrocarbons. A hydrogen flame supplied by the fuel gas and combustion are air burns in the FID. The sample gas is routed into this flame. The hydrocarbons contained in the sample gas are split; the produced hydrocarbon fragments are ionized. A stream of ions forms in the electric field and this electrical stream are measured.



The measuring signal is proportional to the number of the listed, non-oxidized hydrocarbon atoms. Hydrocarbon atoms which are already oxidized are only partially detected.

The quantitative correlation between the measurement signal and the hydrocarbon concentration in the sample gas is determined by performing reference measurements with test gases which do not contain any hydrocarbons (zero gas) or of which the hydrocarbon concentration is known exactly (reference gas – e.g. 80ppm propane in air).

Only a small portion of the sample gas is burnt for analysis, the major portion is diluted with instrument air and combustion air and routed outside via the exhaust gas line.

5.6.4 **Bill of Material**

Table 5.20: Item description with quantity

Sr. No.	Item Description	Quantity
1.0	**S710 modular gas analyzer for SO_2, NO, CO, VOC** Make: M/s. SICK, Germany Model: S710 **Measuring Component 1: Sulphur-di-oxide (SO_2)** **Measuring Range: 0 to 2000 ppm** Min Range : 0 to 85 ppm **Measuring Component 2: Oxides of Nitrogen (NO)** **Measuring Range: 0 to 2000 ppm** Min Range : 0 to 75 ppm **Measuring Component 3: Carbon – mono – Oxide (CO)** **Measuring Range: 0 to 999 ppm** Min Range : 0 to 160 ppm Model: FIDOR **Measuring Component 4: VOC** **Measuring Range: 0 to 20%** Min Range : 0 to 100 ppm **H_2 gas for Combustion to be arranged by Customer**	1 nos.
1.1	**Probe at Tapping point on stack consists of:**	
	a. Probe with Electrically Heated external filter	1 nos.
	b. Prefabricated Electrically Heat traced sample line from Probe on Main Stack to Analyzer panel.	100 m
1.2	**Analyzer Panel at ground consists of:**	
	a. Air Accumulator with Pressure Gauge	1 nos.
	b. Air Filter Regulator	1 nos.
	c. 3 Way Air Operated Valve for Sample line Isolation	1 nos.
	d. 2 Way Solenoid Valves for Blowback from panel	2 nos.
	e. Filter	1 nos.
	f. Refrigerated dual stage sample cooler	1 nos.
	g. Peristaltic pump	1 nos.

Sr. No.	Item Description		Quantity
	h.	Auto drain Valve	1 nos.
	i.	Sample Diaphragm pump	1 nos.
	j.	NO_2 to NO Convertor	1 nos.
	k.	Condensate monitor	1 nos.
	l.	Bypass flow meters	1 nos.
	m.	2 way Solenoid Valve for Auto Calibration	6 nos.
	n.	Coarse filter	1 nos.
	o.	Sample rotameter	1 nos.
	p.	PLC	1 nos.
	q.	Analyzer Cabinet	1 nos.
1.3	**Calibration Setup**		1 nos.
	a.	Zero gas: 100% N_2 in 10 litres WC CS Cylinder	1 nos.
	b.	Span gas: 80% SO_2, NO mix gas and Balance N_2 in 10 litres WC cylinder	1 nos.
	c.	Span gas: 80% CO and balance N_2 in 10 ltrs. WC Cylinder.	1 nos.
	d.	Span gas: 80% HC and balance N_2 in 10 ltrs. WC Cylinder	1 nos.
	Computer for Evaluation		1 nos.
2.0	a.	Desk Top PC with Software for data logging	1 nos.

5.7 Landscape strategy:

As per the master-plan of the facility, zoning of buildings allows formation of open pockets giving opportunity to fit landscaped areas. Also tree buffer is planned along the boundary for odour and emission management.

5.7.1 Tree Buffer/ Green Belt Development:

- The idea behind planting the trees along boundary is to create a natural, vegetative filter that could trap many of the emissions. Planting trees around the plot boundary will help significantly cut emissions and odours before they reach residential areas nearby.
- Three rows of trees are enough to reduce emissions of dust and ammonia by 56% and 53%, respectively; they also help to kill 18% of the odour.

As per the objectives and guidelines as given by Ministry of Environment, Forest and Climate Change, the same will be applicable for the proposed WtE project site.

Objective of the Green Belt[30]:

- To improve the micro environment at site

[30] Guidelines provided by MoEF & CC

- To utilize the treated effluents and biodegradable solid waste generated at site
- To filter the pollutant gases and soli particulates from the air

Planting guidelines for Green Belt:

- Suitable trees shall be chosen as per the type of pollutants at site which will require minimum investment and care
- Choice of trees species should be such that, it should not be of any edible variety to avoid human interference from neighbouring land
- Staggered planting of trees should be done to avoid the formation of hollow pockets between two tress canopies and to maximize the volume of air filter.
- Shrubs with evergreen foliage should be planted at bottom of trees to filter air flowing along the ground level.

5.7.2 **Landscape pockets**

- Various open pockets along the buildings are created that have to be treated with landscape.
- Use of shrubs and groundcovers with colourful foliage will add interest as well as improve the micro-environment around the building complex.
- Ground modulation and mounds of varying heights, to create green pockets as well as allows visual connectivity.
- Use of trees with evergreen foliage will help to keep the pedestrian areas shaded.
- Proposed tree list is as below:

Sr. No.	Botanical name	Physical		Tree Description Deciduas/Evergreen	Flowering Season	Location on Proposed landscape plan
		Ht (m)	Dia (m)			
1	**Alstonia scholaris** 	up to 10m	8m-10m	Evergreen 	September to November	- Avenue of Approach area, - South and South-West side of tree buffer.
2	**Albizzia lebbeck** 	18m-30 m	8m-12m	Deciduas 	April to May	- West, South and South-West side of tree buffer.

Sr. No.	Botanical name	Physical		Tree Description Deciduas/Evergreen	Flowering Season	Location on Proposed landscape plan
		Ht (m)	Dia (m)			
3	**Azadirachta indica** 	20m-35m	More than 12m	Evergreen 	March to July	- All parts of tree buffer. - Avenue of Approach area,
4	**Cassia fistula** 	10m-12m	6m-8m	Deciduous 	April to May	- All parts of plot.
5	**Plumeria alba** 	Up to 10m		Evergreen 	April to mid May, June to July	- As a focal point tree at mounds of Approach area,
6	**Tabebuia auria** 	15m-20m		Deciduous 	January to March	- Avenue of Approach area,
7	**Delonix regia** 	15m-20m	Up to 12m	Deciduous 	April to June	- West, South and South-West side of plot.

Sr. No.	Botanical name	Physical Ht (m)	Physical Dia (m)	Tree Description Deciduas/Evergreen	Flowering Season	Location on Proposed landscape plan
8	**Bauhinia varigeta** 	Up to 10m	Up to 6m	Deciduous 	January to March	- Avenue of Approach area,
9	**Lagerstromea speciosa** 	Up to 10m	Up to 8m	Deciduous 	April to June	- Avenue of Approach area,
10	**Peltoforum pterocarpum** 	Up to 15m	8m-10m	Deciduous 	May to June and September to October	- South west side of plot.

The proposed layout for the green belt and landscape development is given at **Annexure 15**.

5.7.3 Landscape Costing

The costing for the landscape is given in Table 5.21

Table Landscape Cost Summary

Table 5.21 Landscape Cost Summary

No	Expense Heads	Unit	Rate (in Rs)	Quantity	Amount
1	**Softscape**				
1.1	Lawn 25%	SqM	195	1833	3,57,435
1.2	Trees 5%	No.	365	480	1,75,200
1.3	Shrubs 35%	SqM	285	2566	7,31,367
1.4	Groundcovers & Shrubbery 25%	SqM	315	1833	5,77,395
	Total Softscape (A)				**18,41,397**

2.0	Hardscape				
2.1	Pavers	SqM	2700	850	22,95,000
2.2	Kerbing	RMT	390	1350	5,26,500
	Total Hardscape (B)				**28,21,500**
5	Civil Works				
	Underground tank	CuM	5000	40	2,00,000
	Total Civil (C)				**2,00,000**
6	Electrical Work				20,00,000
7	Water Supply	Lump Sum			3,25,000
	Total MEP (D)				**23,25,000**
	Total A+B+C+D				**71,87,897**
	TOTAL COST FOR LANDSCAPE WORKS				**71,87,897**

5.8 Power Evacuation

The power generation from WtE is about 25 – 30MW. This power needs to be evacuated to the grid from nearest substation.

5.8.1 **Connectivity**

The power generated by the project will be generated 24x7, 365 days (except for maintenance outages). The power utilization shall be for internal usage by MCGM or can be injected in the grid.

In both the above cases, the plant needs to be connected to the nearest grid substation.

Grid substations of the both Tata Power (TPC) and Reliance Energy (the licensees) are available in the vicinity of Deonar project site. The nearest sub-station of Tata Power is shown in **Figure 5.19**.

5.8.2 **Regulatory Process for Connectivity**

In line with Electricity Act 2003, the licensees need to make available the network for evacuation of power.

Maharashtra Energy Development Agency (MEDA) has specific guidelines for connectivity of Industrial waste based project. However, similar guidelines from MEDA are not available for Waste to Energy based projects. Connectivity application for all the captive plants shall be in line with STU guidelines and obtained from STU.

The Flow chart for procedure for grant of Grid connectivity is given at **Annexure 16** and Application format is provided at **Annexure 17**.

5.8.3 **Evacuation Infrastructure**

The evacuation infrastructure is planned in line with the proposed connectivity at the voltage level of 33kV.

- Generation voltage proposed is 11kV. The generation voltage will be stepped up to 33kV. Two nos. redundant transformers are planned.
- 33kV Indoor GIS is planned for interconnection of transformers and the outgoing feeder. GIS switchgear is compact and with reduced maintenance. It will be located indoors.
- 33kV outgoing cables are planned for connection to the nearest utility substation. 33kV cables will be XLPE and will be directly buried. Approximate length of 3 kms is considered for connection.
- Two (2) Nos. 1Cx 630sq. mm cables are planned for each circuit. Both the feeders shall be capable to feeding the 100% generation in case of line outage.
- Evacuation infrastructure i.e. Switchgear at the utility premises shall also be considered in the present scope.
- In case there is change in evacuation voltage due to change in point of connection/ substation, EHV switchgear shall be provided by the Contractor. The same shall be connected to the grid substation by EHV cables. EHV switchgear shall be GIS indoor type only.

5.8.4 **Tariff**

Central Electricity Regulatory Commission (CERC) Terms and Conditions for Tariff determination from Renewable Energy Sources (4th Amendment) Regulation 2015. (Norms for determination of generic tariff for MSW/WtE projects and indicative tariff for 2015- 2016), indicates a table for the tariff guidelines to be adopted for the above Municipal solid waste projects based on the proposed fuel.

MERC is recommending tariff on case to case basis for MSW based waste to energy projects. Petition for the tariff finalization shall be filed with MERC with all the relevant details of the project at appropriate stage. The location of Tata Power substation is shown in **Figure 5.19.**

Figure 5.19: Location of Tata Power Substation

CHAPTER 6: ENVIRONMENTAL & SOCIAL ANALYSIS

The main constraint for the effective implementation of SWM Rules & setting up of waste processing facility for local bodies is non-availability of suitable land. Ideally dumping sites should be located at where there is, usually, no human population or at a safe distance from all human settlement. But the increase in the population of the city has forced people to settle near the dumping grounds. This leads to problems like people living in unhealthy conditions and protesting for the closure of the dumping grounds, as dumping causes health hazards for the people in the vicinity. Increasing population generates large amount of waste, which need the large patch of land for its proper disposal. But with increasing urbanization, land available for dumping and creation of landfill sites for disposal of waste is becoming difficult especially for metro cities.

Therefore, WtE is a waste processing site designed with minimum land requirements and also considered protective measures against pollution of ground water, surface water and air fugitive dust, wind-blown litter, bad odour, fire hazard, bird menace, pests or rodents, greenhouse gas (Methane) emissions and erosion. Waste Processing Projects with Energy Recovery has also benefits like power generation, employment opportunity, etc.

6.1 Environmental Analysis

The WtE is a technology to reduce the volume and destroy harmful substances in order to prevent threats to human health. The advantage of WtE technology over landfills is that it reduces the environmental burden of disposing solid wastes and also recovers the energy contained in MSW.

6.1.1 **Land area requirement**

The Land area requirement for the project and land availability is discussed in detail in Chapter 5.

6.1.2 **Adverse Impact due to Industries**

The proposed WtE site is surrounded mainly by slums like Kamala Nagar, Shivaji Nagar, Zhakir Hussain Nagar, etc. which support a large number of the population involved in unorganized and informal sectors such as waste segregation and sale, small traders, recyclers, repair of light and heavy vehicles, loading and unloading of goods, petty businessman, private transport, domestic work, wage labor, etc. Deonar abattoir is the largest in Asia and located within approximate aerial distance of 2 km from project site. Deonar also has several slum resettlement and rehabilitation projects from slums across Mumbai[31].

A number of chemical factories and refineries such as Rashtriya Chemical Fertilizers (RCF), Bharat Petroleum Corporation Ltd. (BPCL) and Hindustan Petroleum Corporation ltd. (HPCL) are located in surrounding areas like Chembur, Sion, etc. of project site. There are also a number of cottage and small scale industries along with

[31] India: 1000 TPD Waste to Energy Project at Deonar, Mumbai, IEE Report Deonar

pharmaceutical companies such as Hindustan Biologicals, Manish Pharmaceuticals, etc. The Tata Power Limited (TPS) is located at about 7km from the project site. As per Central Ground Water Board Report 2009, various industrial effluents from refineries, fertilizers, pharmaceutical plants at Chembur have polluted the surface and ground water. The surrounding of project site (5km) radius is shown in **Figure 6.1**.

Chembur found to have the pollution levels much higher and even exceeding National ambient Air Quality Levels as well as WHO guidelines, because it is housing major fertilizer industries, petro chemical industries, petroleum refineries and a thermal plant by which it is reading maximum levels of sulphur dioxide[32].

6.1.2.1 **Air Pollution**

Frequent fire at dumping sites tends to raise public health concerns for the following reasons:

- pollutants are typically released at ground-level which hinders dispersion;
- fires tend to be episodic in nature and localised with increasing pollutant exposure;
- non-point pollutant sources are not amenable to common abatement techniques;
- it is difficult to enforce restrictions on open burning;
- when fired with heterogeneous fuels, it can be difficult to attribute emissions to a single component.

Open burning, with its less than ideal combustion conditions, tends to produce soot and particulate matter that materialize as a visible plume. Such visible emissions and their impact on local air quality can be expected to prompt local residents to report the emission to the regulator[33].

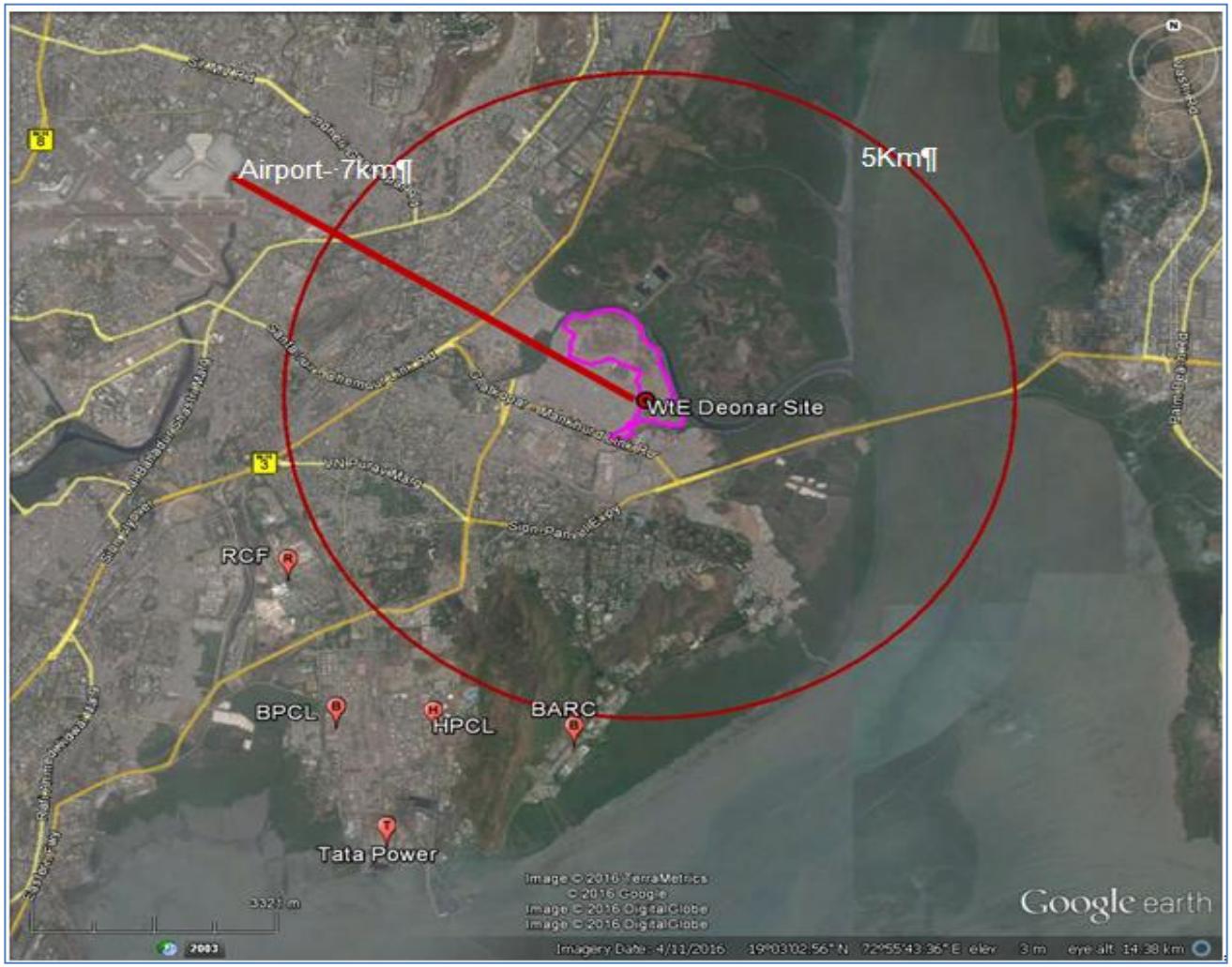
Although, combustion systems from the waste-to-energy facilities are the main source of chemicals emission to the atmosphere such as dioxins, mercury, particulate matter and hydrochloric acid etc. However, these emissions are enormously reduced to minimum level through reduction of toxic containing substance, improvement in combustion facilities and use of gaseous control systems etc.

6.1.2.2 **Water pollution**

The data of Maharashtra Pollution Control Board (MPCB) indicate high concentration of heavy metals from creek water. The studies in Chembur area reveals presence of Cu^{2+}, Cr^{3+}, Ca^{2+}, As^{3+}, Hg^{2+} ions in ground water[34]. In WtE plant, reject is generated in the form of ash which will be inert in nature and can be utilized for various purposes such as landfill, brick making etc. Instead of freshwater the Sewage Treatment Plant processed water will be used at the WtE site.

[32] Shankar et al. 2002
[33] Lemieux et al., 2004
[34] India: 1000 TPD Waste to Energy Project at Deonar, Mumbai, IEE Report Deonar

Figure 6.1: The surrounding of project site



6.1.2.3 **Odor**

Waste-to-energy facilities are designed to stabilize the waste. During the combustion process, source of odor emitting materials are completely destroyed and converted into slag and ash. The odor is mostly emitted during waste sorting and handling process. The odor emitted into the environment during unloading activities and from storage pits can be reduced by enclosed feeding hoppers of the combustion system and draft (i.e. negative air pressure) condition of unloading area.

6.1.2.4 **Noise**

Noise could be a source of pollution when waste transporting vehicles enters and comes out of the of the waste-to-energy facility. The noise pollution produced from waste transporting vehicles could be reduced by regular maintenance and responsible use of these vehicles. Certain hours of the day and specific routes for waste transportation are also other factors to reduce garneted noise from trucks. Disallow worker exposure to high noise areas, specially without hearing protection. The use of hearing protection shall be enforced actively. The closed system in WtE site will be meeting the CPCB norms.

6.1.2.5 **Adverse Impact on Ecology**

The project area has been used as dumping site since 1927. The surrounding areas are predominantly occupied by slums. On north, east and south side of the project area, creek is observed.

Flora: Some mangrove plantation is observed along these creeks. Apart from this there are few local plant species in area.

Fauna: The fauna comprises animals, mainly pigs and dogs, plus other species able to live close to man (urban birds, rodents and some insects). Some buffalos were also observed which belonged to local from nearby areas. No classified, endangered or extinct species were observed in nearby areas of project site. Animals were not noted in the landfill site. Sanjay Gandhi National Park is located at approximate aerial distance of 9 km from project area[35].

By WtE project green belt will be developed which will improved aesthetic condition and air quality. It will also reduce the bird and animal menace at the site.

Once the WtE plant is established, the leachate generation and waste flowing to the creek will also reduce significantly. This will lead to positive impact on the mangroves.

6.1.3 **Greenhouse Gases and Clean Energy Production**

Waste-to-energy facilities contribute in the production of renewable energy from solid waste stream and make less dependent on non-renewable energy resources. So the material left over after the segregation of recyclables and organics for composting came from renewable sources, this derived component of waste stream could be used as clean, sustainable and renewable fuel for heat and electricity production. It

[35] India: 1000 TPD Waste to Energy Project at Deonar, Mumbai, IEE Report Deonar

has been made confirmed by many independent studies that waste-to-energy facilities have capacity to generate electricity and avoid the greenhouse gases emissions and are more effective than landfills.

6.1.4 **Screening of no significant effect by WtE project**

There are several aspects of the environment which are not expected to be affected by the construction process;

Table 6.1 No Significant Impacts Due to Construction

Field	Rationale
Topography, Drainage, and Natural Hazards	Activities are not large enough to affect these features.
Geology, Geomorphology, Mineral Resources, and Soils	Activities are not large enough to affect these features. No mineral resources in the project sites.
Climate	Activities are not large enough to affect these features.
Air Quality	Short-term production of dust is the only effect on atmosphere
Geohydrology and Groundwater	Activities will not be large enough to affect these features
Protected Areas	No protected areas nearby the project
Flora and Fauna	No rare or endangered species
Land Use	No change in land use.
Health and education facilities	Activities are not large enough to affect this feature.
Historical, Archaeological, Paleontological, or Architectural sites	No scheduled or unscheduled historical, archaeological, paleontological, or architectural sites

6.2 Social Structure

The consumption rates are on the rise all over the world due to rapid urbanization process. The impact of inadequate SWM practices on natural and human environments is now being acknowledged. At dump sites, transfer stations, and street refuse bins, waste picking or scavenging activities are common scenes in developing countries. The existence of waste pickers/ scavengers creates often an obstacle to the operation of solid waste collection and disposal services. However, if organized properly, their activities can be effectively incorporated into a waste recycling system. Such an opportunistic approach is required for sustainable development of solid waste management programmes in developing countries.

6.2.1 **Demography**

The entire area including the Deonar Dumpsite and adjoining slums including Kamala, Nagar, Shivaji Nagar, Rafiq Nagar, Shanti Nagar, etc. are located in the M East Ward of Mumbai. As per the Census 2011, the population of the ward is

6,74,850 of which the slum population is 523,324 (77.5% of the total population of the ward). The slum sex ratio is 785 and the non slum sex ratio is 859. Ward has undergone unplanned development with most social development indicators much below the average for Mumbai. Infant mortality rate for the ward is 66.47 compared to 34.75 per 1000 live births for Mumbai, average age of death is 39.30 years as compared to 52.16 years for Mumbai.

A large number of slum people are migrants; most of them belong to the lower socio economic group and come from different parts of the country. Most of slums are unhygienic. In rainy season the people are more vulnerable to the diseases because most of the slums are in the low lying areas and nallas emerging in the creek tend to get flooded and or overflow. These slums are not only congested places, but also have open sewerage and lack private toilets. Wherever community toilets are available they are not properly maintained and as a result people resort to open defecation.

6.2.2 **Health and Educational Facilities**

M East ward has 1 Municipal Hospital, 2 Municipal Maternity Homes, 4 Municipal dispensaries and 9 Municipal Health Posts. There are two private hospitals and 34 private nursing homes. Some dispensaries and health services are also provided by NGOs in the various slums. There are 3 cemeteries in the Ward. Ward has 70 government primary schools and three secondary schools. Private and aided schools are also located in the ward.

Almost 46% of the workforce in the ward is employed as casual labour, 33% are self-employed, and 20% have some formal employment. Close to 85% of the workforce have no employment related benefits. The low income and the absence of employment related benefits that characterize the sector in which majority of the workers find employment ensure that in the event of health-related emergencies, not only do they lose out on paid leave but also have to borrow for the expenses.

Uncontrolled dumping of wastes on the outskirts of towns and cities has created overflowing landfills, which have environmental impacts in the form of pollution to soil, groundwater, and air, and also contribute to global warming. Various factors influence the composition of the wastes. Those include geographic location, seasons, collection frequency, population diversity, salvaging and recycling, public attitude and legislation etc. The attitude of the population also influences the waste composition. Legislation of the land or state regulation will also affect the waste composition.

6.2.3 **Social Factors Influenced the Solid Waste Management**

Solid Waste Management (SWM) is one such activity, where public participation is key to success. The local body can never be successful in Solid Waste Management without active community participation, whatever may be the investments made from the municipal or government funds. The local bodies are the institutions of grass root democracy having elected members representing a small group of electorate. It also has an outreach service at the ward level through which it can easily interact with the people on almost all important issues.

6.2.3.1 **Population Growth**

The composition of municipal solid waste varies according to the cultural habits and economic status of the residents, urban structure, density of population, extent of commercial activity and climate. Information and data on physical components of the waste stream are important in the selection and operation of equipment and facilities, in assessing the feasibility of energy and resource recovery and in the design of a final disposal facility. Also, the physical component of household waste is always important for adaptation of further management practices.

6.2.3.2 **Increasing quantities and changing composition**

Due to growth in population, changing lifestyles and consumption patterns, and development is not only increased the quantity of waste generated, also increasing the quality and composition of waste and changing particularly more and more waste is being generated both because of industrialization as well as 'use and throw' kind of products..

6.2.3.3 **Increasing severity of adverse impacts**

The negative impacts of wastes on the local environment (air, water, land, human health etc.) are becoming more acute often resulting in public outcries and demands for action. The impacts of inadequate waste management are not just limited to local level but are now crossing boundaries and due cases like methane emission are even affecting global environment. The land under and around waste dumps are heavily polluted and will require tremendous efforts and resources for rejuvenation.

6.2.3.4 **Increasing cost of waste management**

Cost of waste management is increasing on several accounts. Firstly, because of the increase in quantity of waste being generated. Secondly, the changing composition of waste with increasing content of non-biodegradable and hazardous substances requires increasing complexity and sophistication in waste management techniques and technologies.

6.3 Rag – pickers

The role of rag-pickers is very important in Indian scenario for MSWM. However, their role in waste management stream had not been given any weightage. Even though rag-pickers save almost 14% of the municipal budget annually, their role is largely unrecognized and they are generally deprived of the right to work. According to an estimate, the rag-pickers reduce up to 20% load on transportation and on landfill[36].

In many developing countries, rag pickers find their livelihood through sorting and recycling of secondary materials. They have high occupational health risks, including risk from contact with human faecal matter, paper that may have become saturated with toxic materials, bottles with chemical residues, metal containers with residue pesticides and solvents, needles and bandages (containing pathogenic organisms)

[36] Joshi R, Ahmed S (2016) Status and challenges of municipal solid waste management in India: A review. Cogent Environmental Science, 2: 1139434

from hospitals, and batteries containing heavy metals. Exhaust fumes of waste collection trucks travelling to and from disposal sites, dust from disposal operations, and open burning of waste all contribute to occupational health problems.

Rag pickers are working in filthy environments, surrounded by crows or dogs under any weather conditions and have to search through waste without gloves or shoes. Besides compostable waste, the household solid waste consists of hazardous materials resulted from items like tube lights, dry battery cells used in radio and torch etc, nail polish remover, blades, sprays and other miscellaneous items. All activities in SWM involve risk, either to the worker directly involved or to the nearby residents.

6.4 Health issues

Health risks from the wastes are caused by many factors, including; the nature of waste as it decomposes, the handling of waste; the processing of wastes; the disposal of wastes. In developing countries, solid waste workers and waste pickers routinely touch the waste they collected and stepped on waste because they typically wore only sandals. Therefore, they are easily susceptible to various infectious diseases.

The most commonly experienced diseases among waste pickers are Tuberculosis, Bronchitis, Asthma, Pneumonia, Dysentery, Parasites and Malnutrition. The recycling of urban solid waste in India, similar to other developing countries, takes place partly with the involvement of an unorganized sector consisting of rag pickers, and scrap and waste traders, all together assisting in translocating waste to processing factories. The health hazards associated with rag picking were confusion, laceration, gastrointestinal problems, eye infections, lower back pain, skin disorders and malnutrition. It was inferred that the naked contact of the workers with waste without observing safety measures such as use of glove or mask was accountable for the state of ill health among them[37].

Inhalation of bio-aerosols and of smoke and fumes produced by open burning of waste can cause health problems. Toxic materials present in solid waste are determinants for respiratory and dermatological problems, eye infections and low life expectancy. The carbonaceous fractions and toxic elements like Chromium (Cr), Lead (Pb), Zinc (Zn), etc. dominate the fine particle range. As most of the fine particles can possibly enter the human respiratory systems, their potency for health damage is high. Also, these fine particles from open burning which constitute higher fractions of toxics are mostly released at ground level.

Some of the more commonly reported occupational health and injury issues in solid waste management:

- Back and joint injuries from lifting heavy waste-filled containers and driving heavy landfill and loading

[37] Sharholy M., Ahmad K., Mahmood G.et al. (2008). Municipal solid waste management in Indian cities – A review, Waste Management 28, 459–467

- Respiratory illness from ingesting particulates, bio-aerosols, and volatile organics during waste collection, and from working in smoky and dusty conditions at open dumps;
- Infections from direct contact with contaminated material, dog and rodent bites, or eating of waste-fed animals;
- Puncture wounds leading to tetanus, hepatitis, and HIV infection;
- Injuries at dumps due to surface subsidence, underground fires, and slides
- Headaches and nausea from anoxic conditions where disposal sites have high methane, carbon dioxide, and carbon monoxide concentrations; and
- Lead poisoning from burning of materials with lead-containing batteries, paints, and solders.
- HIV (due to handling of hospital waste)
- Tetanus (due to handling of jagged metals)
- Respiratory problems (due to exposure to smoke)
- Neural damage (due to lead)
- Injuries
- Premature drinking
- Stress
- Skin and gastric problems

6.4.1 **Injuries in Form of Cuts and Bruises**

Hazardous working conditions lead to frequent injury in the form of cuts and bruises from glass, metal sharps, broken bottles etc. 28% waste pickers reported experiencing such injuries often while 61% said that they got injured once in a while. Often proper medical attention is not given to these injuries, which leads to non-healing ulcers. Injuries sustained from medical waste are all the more dangerous because the waste pickers maybe unknowingly get infected by Hepatitis B and C or other bacterial infections through contaminated sharps and needles.

6.4.2 **Injuries Caused by Animals**

In search for saleable waste material waste pickers often visit landfills and open dump yards. There is a high prevalence of the waste pickers being bitten by rodents, snakes, dogs and bites and stings from other vermin. These animals transmit a variety of infections either by themselves or through the vectors they carry.

6.4.3 **Air Borne Diseases**

During long dry periods the surface of landfills and open dumping grounds becomes dry and very dusty. The waste pickers are exposed to air borne dust which makes their working conditions all the more unpleasant. Under these conditions infections and allergic disorders, especially of the respiratory tract, are common.

6.4.4 **Chemical poisoning**

It includes pesticide poisoning. Waste pickers often come across empty containers of chemicals, which they sometimes use for storing food or water or burning such

containers as source of heat in winter. Several anecdotal pesticide poisoning pesticide cases have been documented in children who have used discarded pesticide tins as glass for drinking water , lead poisoning in families where discarded lead battery containers were used as fuel have been documented.

6.4.5 **Other Diseases**

Tuberculosis, scabies, multi-system allergic disorders, asthma, respiratory infections, ophthalmic diseases, ulcers and stomach problems are other commonly reported diseases. The problem is acute because waste pickers are not protected by occupational health and safety measures.

6.4.6 **Mumbai Ragpickers**

A study of approximately 100 ragpickers in Mumbai quantified the medical problems faced by this community. Below Table describes the percentage of ragpickers who reported having certain medical problems.

Table 6.2 Ragpickers Ailments and Medical Conditions

Medical condition	Ragpickers reporting ailments (%)
Eye problems	80
Respiratory problems	73
Gastrointestinal diseases	51
Skin infections/allergies	40
Decreased vision	90

The Deonar dumping ground has caused health issues for the residents from Mumbai's neighborhood of Chembur, Govandi and Mankhurd. The dump at Deonar was opened in 1927 and is the oldest dump in Mumbai. Although the official area of the Deonar dump is 132ha (1.32km^2), the amount of land available for disposal is 110 ha (1.1 km^2) due to slum encroachment[38].

6.5 Aesthetic

The aesthetic value has also in danger to the surrounding environment due to the stray animals and scavengers invade the garbage dumps of roadsides and by lanes area. Obnoxious odours also pollute the air due to decomposition of organic solid waste. Sometimes the percolation of decomposed garbage dumps as contaminated leachates into soil may result into pollution of groundwater for unfit drinking water to the general public.

Accumulation of solid waste in open areas is an eyesore, diminishing real estate and property value, a breeding ground for insects and other vectors (rats and mice, wild and domesticated animals, as well as humans who may come in contact with contaminated wastes). It also cause odour nuisance, reflects the unorganized nature of the community, and creates a poor environment for growing children. Improper

[38] Uplap PA, Bhate K. (2014). Health profile of women ragpicker members of a nongovernmental organization in Mumbai, India. Indian J Occup Environ Med,18:140-4

disposal of MSW in open areas and landfills have negative impact on the living conditions of human beings as well as the overall environment. Foul odor is emitted at the disposal site due to continuous decomposition of organic matter and emission of methane, hydrogen sulphide, ammonia, etc. The uncontrolled disposal and open burning of wastes at the landfill sites create poor vision. Domestic rats, birds and other scavenging animals act as reservoirs for many organisms transmissible to people, including plague, forms of typhus, leptospirosis, trichinosis, psittacosis, salmonella infection and bovine tuberculosis.

Chemical control of both houseflies and rodents is not very effective because of widespread resistance. The essential basis of control remains denial of access to food and harborage, by covered storage and efficient removal. Aedes mosquitoes, vectors of dengue and yellow fever, breed prolifically in discarded containers that trap rainwater. Culex mosquitoes, vectors of filariasis, breed in polluted stagnant water. Such breeding sites often occur where drains are choked by solid waste. The social impacts faced by community related to solid waste can be categorized into following groups like direct, indirect impacts and also transport related problems.

Various studies show that about 90% municipal solid waste is disposed of unscientifically and unmannered way in open dump places which create problems to public health, the environmental problems and distort the surround aesthetic beauty. The improper solid waste disposal in urban center like Mumbai city has resulted in environmental deterioration and negative aesthetic value of this tourist destination[39].

Proper design and implementation of waste-to-energy facility and improved landscape site are helpful in improving the aesthetic value of an area. The emitted gases or smoke from chimneys having negative impact could be reduced or eliminated by installation of control equipments.

6.5.1 **Direct Impacts**

Some direct social impacts are raised from the garbage such as spreading of bad smell during transportation of waste, facilitation of breeding grounds for disease vectors due to the fallen garbage along roads during transportation and sitting landfill sites, reduction of the property value and production of unpleasant odor from landfill sites.

6.5.2 **Indirect impacts**

Some indirect social impacts are also faced by community from garbage such as increased frequency of floods during rainy season, improper personal safety raised during smoke and production of toxic gases from open burning of garbage, more vulnerability of children to diseases raised from improper solid waste disposal like skin diseases etc.

[39] Goel, S. (2008). Municipal solid waste management (MSWM) in India: a critical review. Journal of Environmental Science Engineering 50(4), 319-28.

6.5.3 **Transport related social issues**

The transport related social issues include road traffic congestion through solid waste transfer vehicles, aesthetic nuisance from improper cover of garbage bags on trucks may fall from trucks during its transportation along main roads, dust pollution and deterioration of roads due to heavy transportation which results an increase in the maintenance cost.

6.5.4 **Social and Cultural Resources**

As Waste Processing & Disposal project is planned on land which belong to Deonar dumping site, there is no social or cultural dependence on that land. There are various health clinics, hospitals along with schools in the slum located adjoining the Deonar dump site. But as the project has dedicated road access, these will not directly affect and so there is no risk of other impacts on such community assets.

As per ASI monuments and excavations list, there are no such sites/ structures in the project area which were having archaeological importance.

6.6 Social Impact of WtE Project

The social impact for proposed WtE project at Deonar can be summarized as below:

6.6.1 **Loss of Livelihood**

After implementation of WtE project, some activities like rag-picking and some recycling businesses would be impacted. However, at the same time, it will prevent the large scale un-organized labour, their un-hygienic condition of working and other exploitation. Most of the recycling businesses thriving on materials from rag pickers are also illegal in nature.

The WtE plant will generate lots of employment opportunities in which people from the areas can be employed.

6.6.2 **Health Impact**

Some concern is given that certain technologies for WtE may give rise to air emissions and water pollution. Such emissions will have health impact on the nearby areas.

Considering the present condition at Deonar dump-site, where fire happens very frequently, the health impact is much more than a WtE plant will emit. The modern WtE plants are equipped with very high efficiency emission control equipment and therefore, emissions would be much lesser than what is being prevailed in the area presently.

6.6.3 **Aesthetic and Overall Environment**

The aesthetic value has also in danger to the surrounding environment due to the stray animals and scavengers invade the garbage dumps of roadsides and by lanes area. Obnoxious odours also pollute the air due to decomposition of organic solid waste. Sometimes the percolation of decomposed garbage dumps as contaminated

leachates into soil may result into pollution of groundwater for unfit drinking water to the general public.

The improper solid waste disposal in urban center like Mumbai city has resulted in environmental deterioration and negative aesthetic value of this tourist destination.

Accumulation of solid waste in open areas is an eyesore, diminishing real estate and property value, a breeding ground for insects and other vectors (rats and mice, wild and domesticated animals, as well as humans who may come in contact with contaminated wastes). It also cause odour nuisance, reflects the unorganized nature of the community, and creates a poor environment for growing children. Improper disposal of MSW in open areas and landfills have negative impact on the living conditions of human beings as well as the overall environment.

Foul odor is emitted at the disposal site due to continuous decomposition of organic matter and emission of methane, hydrogen sulphide, ammonia, etc. Spreading of the waste in the area adjacent to the dustbin due to activity of ragpickers cause degradation of aesthetic quality. Uncontrolled disposal and open burning of wastes at the landfill sites create poor vision. Domestic rats, birds and other scavenging animals act as reservoirs for many organisms transmissible to people, including plague, forms of typhus, leptospirosis, trichinosis, psittacosis, salmonella infection and bovine tuberculosis.

Proper design and implementation of waste-to-energy facility and improved landscape site are helpful in improving the aesthetic value of an area. The emitted gases or smoke from chimneys having negative impact could be reduced or eliminated by installation of control equipments[40]. The suitability of WtE site is given in **Annexure 18**.

6.6.4 **Community Health and Safety**

Hazards posed to the public will be mainly during material movement, specifically during peak traffic hours. If vehicular movement is not planned for project, may cause traffic accidents and vehicle collision with pedestrians. Potential impact is negative but short-term and reversible by mitigation measures. The Concessionaire will be required to:

- Plan material movement in a way to avoid peak-pedestrian and traffic activities
- Drivers should be given proper training on speed limits and safe driving habits.
- Safety signage, speed limits, entry-exist routes, etc. should be displayed at all require locations in local language in visible manner
- If required traffic marshals should be involved during peak timings

[40] Weinstein, P. E. (2006). Waste-To- Energy as a Key Component of Integrated Solid Waste Management for Santiago, Chile: A Cost-Benefit Analysis Department of Earth and Environmental Engineering, Columbia University. Master: 1-57

6.6.5 **Greenhouse gases (GHGs) and clean energy production**

Waste-to-energy facilities contribute in the production of renewable energy from solid waste stream and make less dependent on non-renewable energy resources. So the material left over after the segregation of recyclables and organics for composting came from renewable sources, this derived component of waste stream could be used as clean, sustainable and renewable fuel for heat and electricity production. It has been confirmed by many independent studies that waste-to-energy facilities have capacity to generate electricity and avoid the greenhouse gases emissions and are more effective than landfills.

6.6.5.1 **Benefit of WtE Technology for reducing GHGs**

Waste to energy technologies are currently probably the best fit methods of municipal solid waste management, not only because they take the excess waste out of landfills and get rid of it in a non-polluting way, but it also becomes a source of renewable energy to generate electricity. WtE is expected to be a major option for many Indian cities. While self-reporting and regulating emissions is a must, WtE will become the right choice for India when it becomes more inclusive with increased public understanding.

Due to the socio-economic and environmental perspective landfill is not favourable waste treatment option. As various landfill in India will be overfilled near future, the waste to energy programs are becoming more important than ever. Landfill space is hard to find in and around urban centres.

The benefit of WtE technologies for reducing GHGs is also discussed in Section 3.3 of Chapter 3.

CHAPTER 7: Environmental Management Plan (EMP)

The Environmental Management Plan (EMP) is a site specific plan developed to ensure that the project is implemented in an environmentally sustainable manner where all stakeholders including the project proponents, contractors and subcontractors, including consultants, understand the potential environmental risks arising from the proposed project and take appropriate actions to properly manage that risk. Adequate environmental management measures need to be incorporated during the entire planning, construction and operating stages of the project to minimize any adverse environmental impact and assure sustainable development of the area. The EMP is generally:

- Prepared in accordance with rules and requirements of the Ministry of Environment and Forests (MoEF) and the State Pollution Control Board,
- To ensure that the components of the facility are operated in accordance with the design,
- A process that confirms proper orientation through supervision and monitoring,
- A system that addresses public complaints during construction and operation phase; and
- A plan that ensures that remedial measures are implemented immediately.

The key benefits of the EMP are that, it provides the organisation with means of managing its environmental performance, thereby allowing it to contribute to improved environment quality. The EMP includes four major elements:

- Commitment and Policy: Proponent will strive to provide and implement the Environmental Management Plan that incorporates all issues related to air, land and water.
- Planning: This includes identification of environmental impacts, legal requirements and setting environmental objectives.
- Implementation: This comprises of resources available to the developers, accountability of contractors, training of operational staff associated with environmental control facilities and documentation of measures to be taken.
- Measurement and Evaluation: This includes monitoring, corrective actions, and record keeping.

WtE Plant will be having some impacts on the surrounding environment. In order to mitigate and reduce the impact intensity, the EMP needs to be implemented.

7.1 Objective

The EMP shall aim to meet the following specific objectives:

- To adopt construction and operational methods which will limit environmental degradation
- To protect physical environmental components such as air, water and soil
- To conserve terrestrial and aquatic flora and fauna
- To incorporate the views and perceptions of the local inhabitants on the project
- To generate employment opportunities wherever possible and feasible
- To provide environmental guidelines and stipulations to the construction Contractors to minimize the construction related impacts
- To provide adequate safety systems to ensure safety of public at large
- To establish post construction monitoring program to monitor effects of the project on the environment

Once an EMP has been approved, it should provide the basis for environmental considerations of all the activities carried out on the site by the appointed Contractor.

7.2 Management of Impacts

7.2.1 Mitigation Measures during Construction and Operation Phases

The planning, implementation and management of the various project activities during these phases shall be undertaken in line with the best practices on environmental and social safeguards and the suggestions proposed in the present Environment Management Plan, so that most of the environmental impacts, which are of temporary in nature, will be easily mitigated. No potentially adverse, irreversible or long term negative impacts are envisaged due to the proposed project interventions. The potential impacts and mitigation measures during the construction and operation phases for the WtE Plant are discussed in **Table 7.1** and **Table 7.2**.

7.3 Occupational Health and Safety Measures (OHS)

Construction workers engage in many activities that may expose them to serious hazards, such as falling from rooftops, unguarded machinery, being struck by heavy construction equipment, electrocutions, silica dust, asbestos, noise and vibrations. It is also important to control and monitor the risk related to the safety of workers and to assess the same in order to mitigate it.

Choosing a control method may involve:

- Evaluating and selecting temporary and permanent controls.
- Implementing temporary measures until permanent (engineering) controls can be put in place.
- Implementing permanent controls when reasonably practicable.

7.3.1 Mitigation measure for safety of Construction Workers:

1. During the construction phase, contractors should be required to adopt and maintain safe working practices during
   - Construction works
   - Handling of large construction equipments and machineries, etc.

2. The Contractor should arrange the PPEs for workers, first aid and fire fighting equipments at construction site. An emergency plan should be prepared duly approved by the Engineer-In-Charge to respond to any instances of emergency and safety hazard.
3. By using Engineering controls such as designs or modifications to plants, equipments, ventilation systems, and processes, reduction in source of exposure can be achieved.
4. The Contractor will be required to appoint an Accident Prevention Officer (APO) who will conduct regular safety inspections at construction sites. The APO will have the authority to issue instructions and take protective measures to prevent accidents.

Table 7.1: Summary of Potential Impacts and Mitigation Measures for Construction Phase

Sr. No.	Environmental Components	Potential Impacts	Potential Source of Impact	Controls through EMP & Design	Impact Evaluation	Implementing Agency
1.	Surface water quality	Surface water contamination	Surface runoff carrying loose soil particles	- On site diversion ditched will be constructed to control any surface run-off during site development - Avoid excavation during monsoon season. - Care should be taken to avoid soil erosion. - All stacking and loading areas will be provided with proper garland drains to prevent run off from the site. - During construction, proper arrangements shall be made to dispose of any wastewater generated from the area. - Construction camps should be located away from water bodies.	No off site impact envisaged as there is no surface water receiving body in impact zone.	Contractor/ MCGM
2.	Ground water quality	Ground water contamination	Waste water generated during construction activity containing waste water, various chemicals, solvents etc.	- Careful handling of materials - Controlling spillage through better management - Provision of dykes for material storage units of material such as oil.	Minor negative impact as quality generated is small and execution of EMP will reduce the impact to acceptable level.	Contractor/ MCGM
3.	Storm water	Contamination of Storm water	- Diesel and oil spills in the diesel power generator and fuel storage area. - Waste spills in the	- Regular inspection and cleaning of storm water drains to ensure cleanliness. - Cover waste storage areas. - Provision of silt traps in storm water drains.		

Sr. No.	Environmental Components	Potential Impacts	Potential Source of Impact	Controls through EMP & Design	Impact Evaluation	Implementing Agency
			solid waste storage & dump area. - Oil spills and leaks in vehicle parking lots.			
4.	Ground water quality	Ground water depletion	Use of ground water for activity	- There is no ground water extraction for the project	No impact	Contractor/ MCGM
5.	Air Quality	Dust Emissions	Heavy construction activities.	- Emission control particle filters on Construction equipment - Rapid on site construction - Improved maintenance of construction equipment - Use of vehicles with valid Pollution Under Check (PUC) certificate - Apply water to at least 80% of the surface areas of all open storage piles on a daily basis when there is evidence of wind driven fugitive dust - Apply dust suppressants in sufficient quantity and frequency to maintain a stabilized surface - Downwash of trucks (especially tyres) prior to departure from site. - Water all roads used for any vehicular traffic once daily and restrict vehicle speed to 15 kmph. - Do not burn waste materials/ tyres on-site. - Take account of the wind conditions when arranging activities that are likely to emit	Not significant.	Contractor/ MCGM

Sr. No.	Environmental Components	Potential Impacts	Potential Source of Impact	Controls through EMP & Design	Impact Evaluation	Implementing Agency
				aerosols, fumes, odours and smoke.		
		Emissions of SPM, SO_2, NO_x and CO	Operation of construction equipment and vehicles during site development.	- Emission control particle filters on Construction equipment. Using electrically operated construction machinery is the best way to avoid external pollution produced by diesel engines - The diesel generators used on site, in case of power failure, are maintained properly - Rapid on site construction - Improved maintenance of construction equipment - Use of vehicles with valid Pollution Under Check (PUC) certificate	Not significant.	Contractor/ MCGM
6.	Noise Environment	Noise emissions	Operation of construction equipment and vehicles during site development.	- Use of well-maintained equipment fitted with silencers. - Providing noise shields near the heavy construction operations - Construction activity will be limited to daytime hours only - Anti honking sign boards will be placed in the parking areas and on entry and exit points - Strict Safety, Health and Environment (SHE) codes for construction shall be implemented. Any noise generating activity shall be avoided as far as possible.	Considering the present traffic flowing through the area, and existing commercial activities no noise increase expected from the project activities.	Contractor/ MCGM

Sr. No.	Environmental Components	Potential Impacts	Potential Source of Impact	Controls through EMP & Design	Impact Evaluation	Implementing Agency
				- Maintain all equipment, machinery and vehicles in good working condition at all times - Deliver materials/plant within daytime hours to reduce night-time vehicle movements. - Construction equipment producing the maximum noise level should be fitted with noise shields.		
7.	Land Environment	Soil contamination	- Disposal of construction Debris. - Inappropriate disposal of liquid waste, (lubricating oil and fuel spills, waste oil and lubricant and vehicle/ equipment washing effluent) and solid waste (fuel filters, oily rags)	- Contractors will be appointed for debris disposal & recycling as per rules. - Hazardous waste generated during construction phase shall be stored in sealed containers, labeled, and disposed of as required by the Hazardous Wastes Management and Handling Act Amendment Rules (MoEF, 2003) - Waste generated from labour camps, non-compostable and non-recyclable portion of the waste shall be collected and send to authorized agency. - The contractor shall take the top soil out separately and stockpile it. After the construction activity is over, top soil shall be utilized for landscaping activity	Not significant. Impact will be local, as any waste generated will be reused for construction activities. Not significant.	Contractor/ MCGM
8.	Biological Environment	Displacement of Flora and Fauna on site	Site development during construction.	- After completion of soil work, temporary vegetation preferably grass to be planted to minimize soil erosion.	Beneficial Impact.	Contractor/ MCGM

Sr. No.	Environmental Components	Potential Impacts	Potential Source of Impact	Controls through EMP & Design	Impact Evaluation	Implementing Agency
9.	Socio-Economic Environment	Employment opportunities	Construction activities.	- There will be generation of employment for local labour due to the ensuing construction activities	Beneficial Impact.	Contractor/ MCGM
10.	Traffic Pattern	Increase of Vehicular traffic	Heavy vehicular movement during construction.	- Heavy vehicular movement will be restricted to non-peak traffic hours only. - Adequate parking facility will be provided	No Negative Impact.	Contractor/ MCGM
11.	Occupational health and safety	Hazards to workers	Construction activities	- Occupational Safety and health measures - Provision of proper occupational safety and health conditions - Provision of safety equipments - Regular medical check-up and treatment - Operational status of fire-fighting	Beneficial Impact.	Contractor/ MCGM
12.	Spillage control	Environmental damage	Construction activities	- Ensure that all liquids are appropriately stored to prevent spillage (i.e. within a bunded area as necessary) and fuels/oils away from sensitive areas - Use absorbent pads or sand to spill clean up	Local Impact	Contractor/ MCGM

Table 7.2: Summary of Potential Impact and Mitigation Measures for Operational Phase

Sr. No.	Environmental Components	Potential Impacts	Potential Source of Impact	Controls through EMP & Design	Impact Evaluation	Implementing Agency
1.	Surface water quality	Surface water contamination	Discharge of domestic wastewater to surface water body.	- Waste water will be collected from all units by properly designed drainpipes and will be treated in Sewage Treatment Plant (STP) and from there discharged into sewer as per norms. - Waste water will be collected from all units by properly designed drainpipes and will be treated in Effluent Treatment Plant (ETP) and from there discharged as per norms. - Water consumption will be minimized by a combination of water saving devices and other domestic water conservation measures - Ensure that all liquids are appropriately stored to prevent spillage	No off site impact envisaged.	Contractor/ MCGM
2.	Storm water	Storm water contamination	- Waste spills in the solid waste storage area. - Oil spills and leaks in vehicle parking lots. - Silt from soil erosion in landscape area	- Regular inspection and cleaning of storm water drains to ensure cleanliness. - Cover waste storage areas. - Provision of silt traps in storm water drains. - Good housekeeping in the above areas		Contractor/ MCGM
3.	Ground water quality	Ground water contamination	- Sewage discharge on site or off site	- Only treated sewage will be discharged into the MCGM sewer line in accordance with the norms specified by CPCB/MoEF	No negative impact on ground water quality envisaged	Contractor/ MCGM
4.	Air Quality	Emissions of SPM, SO_2, NO_x and CO	- Emissions from vehicular traffic in operations.	- Use of good quality fuel with low sulphur content - Periodic maintenance of DG sets as per	No impact is envisaged.	Contractor/ MCGM

Sr. No.	Environmental Components	Potential Impacts	Potential Source of Impact	Controls through EMP & Design	Impact Evaluation	Implementing Agency
			- The main sources of pollution shall be boiler stack emissions, fugitive dust and odor emissions from waste handling and processing and emissions due to vehicular movement. Adequate mitigation measures shall be implemented.	defined schedule of manufacturer - Providing adequate stack heights. - Vehicle flow and traffic should be management in systematic manner - Vehicles carrying the construction material and sand shall be covered properly - Loading and unloading of construction materials has to be in covered area with provisions of water fogging around these locations - Regular maintenance of machinery and equipment is essential; vehicular pollution check should be made mandatory - The parking area should carry signs warning the vehicle driver against idling within the parking lot. - A team of trained staff should be appointed for monitoring traffic movement inside the parking space and at entrance and exit points of the premises. - During the waste processing the emission will have to meet the standards as prescribed by the SWM Rules 2016 and CPCB		
5.	Noise Environment	Noise emissions	- Noise from vehicular movement and DG sets. - Noise from Waste processing units	- Better acoustic control will be maintained by use of noise absorbent measures and DG sets will be acoustically enclosed. - Staff to use earplugs inside DG room. - Noise level monitoring during the day time near the sensitive receptors should also be	Not significant. The background noise levels are considerably high, thus noise mingling would	Contractor/ MCGM

Sr. No.	Environmental Components	Potential Impacts	Potential Source of Impact	Controls through EMP & Design	Impact Evaluation	Implementing Agency
				made mandatory - Anti honking sign boards will be placed in the parking areas and on entry and exit points.	occur in a few meters distance.	
6.	Land Environment	Soil contamination	The project is going to reduce the waste disposal on the ground; therefore, land contamination would reduce.	- This project is for managing waste disposal on the ground.	No impact on site.	Contractor/ MCGM
7.	Socio-Economic Environment	Employment opportunities	Plant operation.	- Project will provide employment opportunities to the local people in terms of service personnel during operations. - Providing comparatively better infrastructure.	Beneficial Impact.	Contractor/ MCGM
8.	Biological environment	Displacement of flora & fauna	Plant operation	- Enhancement of the current ecology at the proposed project site will entail the plantation and landscaping within the proposed development - For the purpose of pollution attenuation, the green belt shall be developed		Contractor/ MCGM
9.	Aesthetic Environment	Quality of Aesthetic Environment	Improvement of vegetation cover	- The project area would be aesthetically adorable due to green belt, plantation, good roads etc.	Beneficial Impact.	Contractor/ MCGM

5. Implementation of administrative controls should be included to alter the way the work is done, including timing of work, policies and other rules, and work practices such as standards and operating procedures (including training, housekeeping, and equipment maintenance, and personal hygiene practices). The Contractor should ensure good health and hygiene of all workers to prevent sickness and epidemics.
6. To avoid disruption of the existing traffic due to construction activities, comprehensive traffic management plan should be drawn up by the Contractor and get the approval from the MCGM.
7. At every workplace, the Implementing Agency/ Contractor in collaboration with local health authorities will ensure that a readily available first-aid unit including an adequate supply of sterilized dressing materials and appliances is made available.

7.4 Environmental Monitoring Plan & Implementation Arrangements

For the effective and consistent functioning of project, an Environmental Management System (EMS) should be established at the site. The EMS should include the following:

(a) An Environmental Management Cell.
(b) Environmental Monitoring.
(c) Personnel Training.
(d) Regular Environmental Audits and Corrective Action.
(e) Documentation – Standard Operating Procedures, Environmental Management Plans and other records.

7.4.1 **Environmental Management Cell**

Apart from having an Environmental Management Plan, it is also necessary to have a permanent organizational set up charged with the task of ensuring its effective implementation of mitigation measures and to conduct environmental monitoring. The major duties and responsibilities of Environmental Management Cell shall be as given below:

- To implement the Environmental Management Plan.
- To ensure regulatory compliance with all relevant rules and regulations.
- To ensure regular operation and maintenance of pollution control devices.
- To minimize environmental impacts of operations by strict adherence to the EMP.
- To initiate environmental monitoring as per approved schedule.
- Review and interpretation of monitored results and corrective measures in case monitored results are above the specified limit.
- Maintain documentation of good environmental practices and applicable environmental laws as ready reference.
- Maintain environmental related records.

- Coordination with regulatory agencies, external consultants, monitoring laboratories.
- Maintain of log of public complaints and the action taken.

7.4.1.1 **Organizational Structure of Environmental Management Cell**

A dedicated person who will report to the site manager should supervise normal activities of the EMP cell. The Environment Management Cell shall be consisting of a hierarchal structure having people from both the Contractor's and MCGM side which will coordinate and supervise the activities within the plan with respect to environment. With the systematic hierarchal structure, the managing and resolving of issues are faster and efficient. Further the Standard Operating Procedures (SOPs) supports in completing the respective activity in more planned and organized manner.

7.4.2 **Environmental Monitoring Program**

The purpose of environmental monitoring is to evaluate the effectiveness of implementation of EMP by periodically monitoring the important environmental parameters within the impact area, so that any adverse affects are detected and timely action can be taken. In consultation with Maharashtra Pollution Control Board (MPCB), the project will be monitored for ambient air quality, noise levels, groundwater quality and quantity, soil quality and solid wastes in accordance with an approved monitoring schedule. The monitoring protocol and location selection will have to done carefully. The monitoring sampling program should be discussed and approved by MPCB. A suggested monitoring protocol, based on the predicted impacts, is given in **Table 7.3**.

Table 7.3: Environmental Monitoring Plan

Sr. No.	Type	Locations	Parameters	Period and Frequency	Institutional Responsibility	
					Implementation	Supervision
Construction Phase						
1.	Ambient Air Quality	4 locations as selected during baseline study	PM_{10}, $PM_{2.5}$, Sulphur dioxide (SO_2), Oxides of nitrogen (NO_2), Carbon monoxide (CO), Hydrocarbon (HC), Volatile Organic Compounds (VOC's)	24-hr (8hr for CO) average samples every quarter	Contractor through MoEF & CC approved agency	Independent Engineer (IE)/ MCGM
2.	Ground Water	3 locations as selected during baseline study	pH, TSS, TDS, DO, BOD, Salinity, Total Hardness, Fluoride, Chloride and MPN (No. of coli forms / 100ml), Heavy Metals	Quarterly	Contractor through MoEF & CC approved agency	IE/ MCGM
3.	Surface Water	3 locations as selected during baseline study	pH, TSS, TDS, DO, BOD, Salinity, Total Hardness, Fluoride, Chloride and MPN (No. of coli forms / 100ml), Heavy Metals	Quarterly	Contractor through MoEF & CC approved agency	IE/ MCGM
4.	Drinking Water	5 samples from labour camps during construction phase	pH, TSS, TDS, DO, BOD, Salinity, Total Hardness, Fluoride, Chloride and MPN (No. of coli forms / 100ml), Heavy Metals	Quarterly	Contractor through MoEF & CC approved agency	IE/ MCGM
5.	Noise	4 locations as selected during baseline study	24 hrly Day and Night time Leq levels	Quarterly	Contractor through MoEF & CC approved agency	IE/ MCGM
6.	Soil	4 locations as selected during baseline study	Organic matter, C, H, N, Alkalinity, Acidity, heavy metals and trace metal	Quarterly	Contractor through MoEF & CC approved agency	IE/ MCGM
Operation Phase						
1.	Ambient Air Quality	4 locations as selected after consultation with SPCB	PM_{10}, $PM_{2.5}$, Sulphur dioxide (SO_2), Oxides of nitrogen (NO_2) Carbon monoxide (CO) Hydrocarbon (HC) Volatile Organic Compounds (VOC's)	24-hr (8hr for CO) average samples every quarter	MoEF & CC approved agency	IE/ MCGM

Sr. No.	Type	Locations	Parameters	Period and Frequency	Institutional Responsibility	
					Implementation	Supervision
2.	Ground Water	3 locations as selected after consultation with SPCB	pH, TSS, TDS, DO, BOD, Salinity, Total Hardness, Fluoride, Chloride and MPN (No. of coli forms/ 100ml), Heavy Metals	Quarterly	MoEF & CC approved agency	IE/ MCGM
3.	Surface Water	3 locations as selected after consultation with SPCB	pH, TSS, TDS, DO, BOD, Salinity, Total Hardness, Fluoride, Chloride and MPN (No. of coli forms / 100ml), Heavy Metals	Quarterly	MoEF & CC approved agency	IE/ MCGM
4.	Noise	4 locations covering the project site and in the surrounding areas to be identified in consultation with SPCB	24hrly Day and Night time Leq levels	Quarterly	MoEF & CC approved agency	IE/ MCGM
5.	Soil	4 locations as selected after consultation with SPCB	Organic matter, C, H, N, Alkalinity, Acidity, heavy metals and trace metal, Alkalinity, Acidity	Quarterly	MoEF & CC approved agency	IE/ MCGM
6.	Treated potable water quality	Water Treatment Plant	Parameters for horticulture use - BOD, pH, S.S, Coliforms	Half Monthly	MoEF & CC approved agency	IE/ MCGM
7.	Treated Sewage Water Quality	STP	Parameters for horticulture use - BOD, pH, S.S, Coliforms	Half Monthly	MoEF & CC approved agency	IE/ MCGM
8.	Treated Effluent Quality	ETP	As per IS 10500 – potable water standards	Half Monthly	MoEF & CC approved agency	IE/ MCGM

7.4.3 **Record Keeping and Reporting**

Record keeping and reporting of performance is an important management tool for ensuring sustainable operation of the proposed development. Records should be maintained for regulatory, monitoring and operational issues. Typical record keeping requirements for the proposed development is summarized in **Table 7.4**.

Table 7.4: Record Keeping Parameters with Particulars

Parameter	Particulars
Solid Waste Handling and Disposal	- Daily quantity of waste received - Daily quantity treated and recycled - Daily quantity sent for disposal
Hazardous wastes	- Quantity of waste generated - Quantity of waste sent out for treatment/ disposal - Waste manifests as per regulations
Sewage treatment plant	- Daily quantity of raw and treated sewage - Quantity and point of usage of treated wastewater - Treated wastewater quantity
Regulatory Licenses (Environmental)	- Environmental permits/ Consents from MPCB/ MoEF - Copy of waste manifests as per requirement
Monitoring and survey	- Records of all monitoring carried out as per the finalized monitoring protocol
Accidental reporting	- Date and time of the accident - Sequence of events leading to accident - Name of hazardous waste involved in the accident - Chemical datasheet assessing effect of accident on health and environment - Emergency measure taken - Step to prevent recurrence of such events
Other	- Log book of compliance - Employee environmental, health and safety records - Equipment inspection and calibration records, where applicable - Vehicle maintenance and inspection records

7.4.4 **Environmental Audits and Corrective Action Plans**

Environmental Audit is a management tool comprising systematic, documented, periodic and objective evaluation of how well environmental organisation, management and equipments are performing with the aim of helping to safeguard the environment by facilitating management control of practices and assessing compliance with company policies, which would include regulatory requirements and standards applicable. To maintain the WtE plant efficiency and maintain its capacity,

Environmental Audits on periodical basis will require to be done by the Contractor in consent with MCGM. To assess whether the implemented EMP is adequate, periodic environmental audits will be conducted by the proponent. These audits will be followed by Corrective Action Plans (CAP) to correct various issues identified during the audits. The Environmental Management Cell will be performing the above said activities and shall be maintaining the record as well.

The key concepts of the Environmental Audit are

- Verification: audits evaluate compliance to regulations or other set criteria.
- Systematic: audits are carried out in a planned and methodical manner.
- Periodic: audits are conducted to an established schedule.
- Objective: information gained from the audit is reported free of opinions.
- Documented: notes are taken during the audit and the findings recorded.
- Management tool: audits can be integrated into the management system (such as a quality management system or environmental management system).

The Environmental Management Plan (EMP) is a site specific plan developed to ensure that the project is implemented in an environmentally sustainable manner where all stakeholders including the project proponents, contractors and subcontractors, including consultants, understand the potential environmental risks arising from the proposed project and take appropriate actions to properly manage that risk. Adequate environmental management measures need to be incorporated during the entire planning, construction and operating stages of the project to minimize any adverse environmental impact and assure sustainable development of the area. The EMP is generally:

- Prepared in accordance with rules and requirements of the Ministry of Environment, Forests and climate change (MoEFCC) and the State Pollution Control Board,
- To ensure that the components of the facility are operated in accordance with the design,
- A process that confirms proper orientation through supervision and monitoring,
- A system that addresses public complaints during construction and operation phase; and
- A plan that ensures that remedial measures are implemented immediately.

WtE Plant will be having significant impacts on the surrounding environment. In order to mitigate and reduce the impact, the EMP needs to be implemented.

Once an EMP has been approved, it should provide the basis for environmental considerations of all the activities carried out on the site by the appointed Contractor.

CHAPTER 8: Project Risk Management

This is important to identify various risk scenarios for the project and to prepare adequate mitigation plan. On the basis of different component of the project, following risk areas have been identified:

1. Legal Risk
2. Environmental Risk
3. Social Risk
4. Design basis Risk
5. Technological Risk
6. Fire and Explosion
7. Disaster Risk
8. Financial Risk
9. Non compliance of Contractors
10. Non-performance of Contractors

Assessment and management of the above mention risks are presented in **Table 8.1**.

Table 8.1 Risk and Mitigation Measures

Sr. No.	Risk	Categories	Management
1.	Legal Risk	Environmental Clearance (EC)	• The present project site is on active dumping site and having many environmental constraints. Therefore, EC for the site is very important. • The project category as per EIA Notification 2006 is given in Chapter 4.
		Forest and CRZ Clearance	• The site boundary for WtE is identified considering CRZ areas. Still, it fringes into some CRZ areas and require clearance from Coastal Zone Management Authority. • The project is near to mangroves, therefore, Forest clearance is also required. • CRZ and Forest clearance is also required for 3.5 Km long water pipeline from Ghatkopar Lagoon to the project site, which will pass through mangroves and CRZ areas.
		Clearance from Civil Aviation Authority	• The project requires clearance from Civil Aviation Authority considering the flight funnel zone

Sr. No.	Risk	Categories	Management
2.	Environmental Risk	Emission Control	• The WtE projects has risk of emissions like Dioxin and Furan, which needs to be controlled by adequate emission control devices
		Noise & Odor	• Noise and odor control to be managed by adequate tree fencing and adequate acoustic measures.
		Ecological	• The project is near the creek area and mangroves. Any large scale fire or hazard may culminate in destruction to mangroves and associated flora and fauna. • Adequate measures are required to save the mangroves and creek area during construction as well as operation phases of the project.
		Rejects disposal	• Large amount of rejects would be generated from the WtE plant. Scientific disposal is required like use in cement plant and brick manufacturing.
3.	Social Risk	Employment	• There would be loss of employment to rag-pickers, however, this can be compensated by employing them in WtE plant.
		Livelihood	• There could be issue of livelihood for rag-pickers and the same should be rehabilitated.
4.	Design basis Risk	Foundation	• The project site is on dumping site and adequate design consideration should be taken for foundation. This may have cost implication.
		Subsidence	• Flexible structures and roads are recommended to deal with subsidence issue at the site.
		Stack	• Stack design should consider wind and seismic issues. Also, clearance is required from Civil Aviation Authority.
5.	Technological Risk	Feedstock characteristics	• The waste (Feedstock) has large variation, which may have impact on downstream process, emission and power generation. • Apart from pre-processing of waste,

Sr. No.	Risk	Categories	Management
			certain measures should be there for collection and transportation of waste for good feed stock.
		Pre-treatment of waste	• Pre-treatment of waste is important for better quality of feedstock and in turn reliable power generation and lower maintenance requirement.
		Power generation	• Uniform power generation will depend on feed-stock quality and pre-treatment. This needs to be ensured
		Breakdown and maintenance	• There are many technological factors, which are required for minimizing the shutdown time, like pre-treatment of waste, feedstock maintenance etc.
		Reject Management	• Discussed under Point 2, above.
6.	Fire & Explosion	Fire in waste bunker	• This can be mitigated by manual surveillance during waste tipping. Apart from this, proper management is required during waste collection and transportation.
		Fire in feedstock	• Adequate fire protection should be employed around the feedstock storage.
7.	Disaster	Flood	• Strom water drains should be maintained and cleaned on regularly.
		Wind	• Facilities at site to be design considering wind and cyclone hazard zone.
		Earthquake	• Structural design should be considering seismic parameters.
		Landslides	• Proposed site is surrounded by 35 - 37m high garbage heaps. Its slope stability to be ensured through gentle slope covered with good soil and vegetation.
8.	Financial Risk	For MCGM	• Safeguard of Capital investment can be ensured through – Security deposits – Milestone based payments – Retention from monthly bills – Penalties on non compliance of norms
		For Operator	• Operator should analyze their risk for

Sr. No.	Risk	Categories	Management
			recovery of their investment through tariff and funding. This needs to be included in their agreement.
9.	Non-compliance by Contractor	Environmental Non-compliance	• Compliance can be supervised by MCGM or an Independent Engineer (IE) (appointed by MCGM) on regular basis. Any deviation should be brought to the notice immediately and penalty to be levied to operator.
		Future Environmental Norms	• The environmental norms all over the world is becoming more stringent. Therefore, any futuristic change in the environmental emission norms will have very high impact on the project sustainability.
		Business non-compliance	• Monitoring by MCGM through 3rd party audit and reporting on regular basis.
10.	Non-performance of Contractor	Quality and quantity of power generation	• To be ensured through proper sizing of the plant and machinery and their maintenance. • Quality control devices to ensure quality.
		Plant maintenance	• Regular inspection and record keeping.

CHAPTER 9: Quantity and Cost Estimation

9.1 Quantity Estimates

Quantity estimation of items has been worked out as per the drawings and unit basis.

9.2 Cost Estimates

The Cost estimates for the proposed WtE project at Deonar site includes capital investment for Pre-processing unit, MSW Processing Plant, Pollution Control Equipment, Continuous Emission Monitoring System, Information Communication Technology, Auxiliary Power Supply System and Allied Infrastructure. It is summarized in below table. This cost is worked out on the basis of MCGM Schedule of Rates and standards reference documents. This forms the basis of the present financial evaluation. Entire cost of the project is considered in Indian Rupees.

Table 9.1: Summary of Block Cost Estimate of Waste to Energy Project

Component	Description	Cost (Rs.Crores)
Component-A	Cost Centre A1.1: Site & Periferal Preparation including 1.Site Survey, 2.Geotechnical Investigation, 3.Waste Physico-chemical Characterization Study 4.Site Clearance, Excavation, Filling & Compaction 5. Compound Wall 6. Pipeline & Pumping Station 7.Preparation of Eastern Periferal area slope 8. Landscaping 9. Storm Water Drain	146.95
Component-B	Cost Centre A1.2: Design including all approvals	28.64
Component-C	Cost Centre A1.3: Pre-Processing Plant	138.00
Component-D	Cost Centre A1.4: Processing Plant (Electric Power Plant) including Civil, Electrical, Mechanical, I&C, Water System, Construction, Supervision, Pollution Control Equipments, etc.	469.09
Component-E	Cost Centre A1.5: Allied Infrastructures including Internal Road, Storm Water Drainage, Fire Ring main, Weighbridge, Water Treatment Plant and Storage, Leachate Treatment Plant, Sewage Treatment Plant, Effluent Treatment Plant, Truck Parking area, Security Booth, Administration/ Laboratory Building, Pile Foundation Car Parking, Material Entry/ Exit Gate, Visitor Entry/Exit Gate, Workers Area, Canteen, Landscape area with irrigation system complete, Pile Foundations, Continuous Emission Monitoring System (CEMS), Information Communication Technology (ICT), Auxiliary Power Supply System, Laboratory Equipments, Safety and security arrangement including electronic surveillance, etc.	54.53
Component-F	Cost Centre A1.6: Power Evacuation Line	21.17
Component-G	Cost Centre A1.7: Process by-product Management and Disposal (Ash/ Sludge/ Rejects/ other) Plant	4.99
Component-H	Cost Centre A1.8: Tests on Completion and Training	9.38
Component-I	Cost Centre A1.9: Provisional Sums – General	5.00
	Total (Rs. Crores)	**877.76**

Note:
Above estimate is subject to change based on following considerations
1. MCGM Schedule of Rate (SoR): 2014, Standard Manuals, Reports and Market Rates.
2. Site clearance, excavation and filling are calculated considering complete removal of legacy waste from the proposed plant area. There is scope for the Contractor to propose innovative technology which may lead to reduction in cost and time of site preparation.
3. Some of the sub-components considered for above estimate may not be applicable or may get replaced depending on the selection of the pre-processing and processing technology.
4. Above cost estimates are inclusive of prevailing taxes.

9.3 Financial feasibility of the Project

The project cost is higher than similar other projects elsewhere. The higher cost of the project is mostly due to following reasons;

1. Land development cost: The project is being developed at dumping site, having waste dumping of about 10 - 12m. Removal of the dump and re-filling to the standard of construction (with partly good quality earth and re-using existing waste material) will incur about 147 crore.
2. Construction .requirement, i.e. higher standard of construction is required considering the corrosive environment and land stability condition.
3. Ash pond development: The land parcel is not adequate and therefore ash pond is planned for comparatively heigher
4. Emission control: There are habitations in close vicinity of the project, therefore all the emission control measures needs to be of higher standard to maintain the pollution level within the stipulated norms. Cost is also incurred towards emission monitoring system like Continuous Emission Monitoring System (CEMS).
5. Pipeline and treatment of wastewater: The water for the project is to be taken from Ghatkopar Lagoon site with laying 3.5km pipeline. Also, water treatment plant to be provided for treating the water to the standard for using in WtE process. This is an additional cost.

Considering the above requirements for the project, the cost is comparatively higher. However, considering the environmental and social benefits in long run as detailed in Chapter 6, the project is beneficial to the city.

CHAPTER 10: Funding Scenarios and Financial Model

The most important aspect for Solid Waste Management (SWM) is its processing in environmentally safe manner and at the same time, deriving useful products including energy. There are many examples worldwide for thermal processing of Municipal Solid Waste (MSW) for energy production. The advantage of thermal processing is that about 90% of volume and about 80% of weight can be reduced of MSW[41]. The final residual ash can further can be utilized for brick making and filling of low lying areas. Another important advantage of thermal processing is recovery of energy from waste, i.e. Waste to Energy (WtE) projects.

The WtE projects are cost intensive due to higher inputs for Plant & Machinery and later on pollution control equipment required during plant operation. However, WtE projects still a viable option considering the long term waste management.

The Ministry of Non-Conventional Energy (MNRE) is promoting all the technology options available for setting up projects for recovery of energy from urban wastes. In developed countries, environmental concerns rather than energy recovery is the prime motivator for waste-to-energy facilities, which help in treating and disposing of wastes. Energy in the form of biogas, heat or power is seen as a bonus, which improves the viability of such projects.

10.1 Project Funding Models

The WtE projects can be implemented by way of different financial models. The two most preferred models are Design Built and Operate (DBO) model and Design, Built, Finance, Operate and Transfer (DBFOT) also known as Public Private Partnership (PPP).

The important features of these two models are given below:

Design, Built and Operate (DBO) Model:

In this model, Contractor is responsible for Design, Construction and Operation of the project for a specified period. Financing is done by Owner. In this model, the Owner retains the total ownership of the facility and thus has control over unexpected changes in performance requirement. The control on design, build and asset quality can be better kept in this model.

This model requires intensive effort from the owner to define project requirements and risks prior to bidding of the project. Extensive administration over the Life of the project is also required.

The Contractor operates the plant for an agreed period of (say) 20 or 25 years for which they get the operation service charges.

Design, Build, Finance, Operate and Transfer (DBFOT)

In this model, the project is developed, financed by a private Developer and the Municipality or Urban Local Bodies(ULB) provide the land at nominal cost and waste

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for processing. Developer shall operate the Plant for an agreed period of (say) 20 or 25 years and then the asset will be transferred to the Municipality or ULB.

The developer gets his return on investment in terms of (a) Tipping Fee or b) Tariff, or (c) both by selling of power generated to Power distribution company (DISCOM) along with Tipping fee. This model is popularly known as Public Private Partnership (PPP).

Model suited for WtE project for MCGM

DBO and DBFOT have certain level of advantages and disadvantages. The model to be selected considering the project requirement and risks involved.

The WtE project for Mumbai is very important project for efficient waste management. This is also going to be the largest project (3000TPD) in India. The other important constraints for the project are land availability (carved out from existing dumpsite) and water (treated waste water from Ghatkopar STP). The project location has environmental and social sensitivities.

The main objective of the WtE project is to process the waste. The power generation is a secondary objective. In PPP mode, usually the objective is shifted from waste processing to power generation. Considering the several constraints and objective of the project, it is important that MCGM should develop this project in DBO model, in which they have better control and monitoring. MCGM is in a position to fund this project.

The matrix for comparison of DBO vs. PPP mode is given in Table 10.1.

Table 10.1 Comparison Matrix DBO Vs PPP Model

Criterion	PPP	DBO
Financial Procedure	• SPV formation is required	• MCGM is in a position to fund the capital cost, hence can expedite the project. • MCGM can use the power generated for its own purpose, hence project is not dependent on tariff finalization.
Maximizing Revenue	There is incentive to the Developer to maximize revenue. (Operator may compromises on compliances *or uses supplementary fuel.)*	The model can include sharing of benefits of the additional power generated beyond guaranteed power to the Contractor. MCGM has adequate control over the plant operation.
Financial Risk	In case the contractor gets bankrupt then project may get shelved. The project objective of waste processing gets jeopardized.	MCGM owns assets, hence can exercise alternate strategies to mitigate financial risk, in case of stressed financial situation of the contractor.
Case flow	Any issue in arranging finance timely project execution.	Assured Cash flow for the Bidder enables timely completion of the project

Criterion	PPP	DBO
	Only financially strong parties can bid, and may limit the role of technology partner.	also is considered to be attractive proposition for reputed parties.
Incoming waste	Financial viability significantly depends on Waste characteristics and quantity. Any downside variation can lead to legal issue/non performance.	Financial risk/ benefit is with MCGM, so variation in the Waste can be accommodated.
Functional Risk	Redundancies for critical equipments may not ensure continuous processing of waste.	Redundancies can be specified for critical equipments for ensuring continuous processing of waste.
Technology Risk	In case of non performance of the plant the project revival is relatively difficult.	In case of non performance of the plant the remedial measures are relatively easier.

Note: Apart from the above two models, another model is for DBO with partly deferred payment. However, it is similar to PPP mode to the large extent.

The Operation service for the present WtE plant is considered for 20 years period considering CERC guidelines and similar project execution in many places.

The project implementation in DBO mode is shown in **Figure 10.1**.

10.2 Levelized Tariff

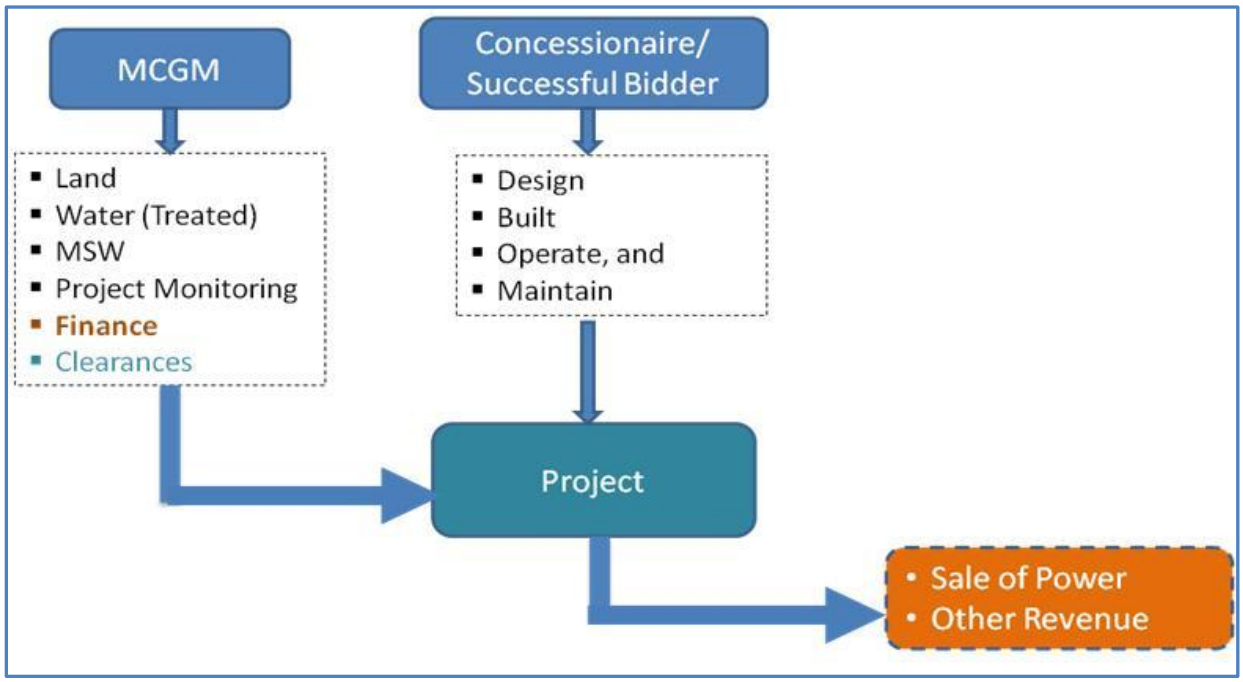
The project cost is arrived at Rs. 877.76 crores as given in Chapter 9.

In order to encourage setting up of the waste generation plant, concessions are given by Government of India and the State Government for this type of project;

a) Central Sales Tax @ 2% shall be levied on equipments
b) Excise duty is Nil and concessional custom duty.
c) Works contract tax for civil works at @ 6%
d) Sales Tax/ VAT exemption as given by the State Government

Further, the other particulars required for arriving at the levelized tariff has been obtained from the CERC website. The particulars are listed in Table 10.2.

Figure 10.1: Project in DBO Mode



Note: *Clearances (Statutory clearances like Environmental, CRZ etc.) shall be in the scope of Contractor, supported by MCGM.*

Table 10.2: Data input for Levelized Tariff

Sr. No.	Particulars	Unit	Value	Remarks
1.	Installed capacity	MW	25	
2.	Auxiliary power consumption	%	15%	CERC Oct'15 order
3.	Project Cost	Rs. Cr.	877.76	
4.	Interest During Construction(IDC)	Rs. Cr.	60.79	
5.	Total project cost including IDC	Rs.Cr.	938.55	
6.	Project financing			
(a)	Equity	30%	281.56	
(b)	Debt	70%	656.98	
7.	Long term interest rate	%	13%	CERC Oct'15 order
8.	Working capital interest rate	%	13.5%	CERC Oct'15 order
9.	Depreciation	%		
(a)	Upto 12 years	%	5.8%	
(b)	13 years onwards	%	1.54%	
10.	Return on equity			
(a)	First 10 Years	%	20%	CERC Oct'15 order
(b)	Next 10 Years	%	24%	CERC Oct'15 order
11.	Annual O&M cost (ARF Inclusive)	%	15%	of the O&M Expenses

Sr. No.	Particulars	Unit	Value	Remarks
12.	O&M expenses	Rs. lacs/ MW	90	CERC Oct'15 order
13.	O&M escalation	%	5.72%	Per annum
14.	Operation life	Years	25	
15.	Discounting factor	%	10.8%	CERC Oct'15 order
16.	Plant load factor	%	65%	1st Year Operation
17.	Plant Load factor	%	75%	2nd Year Operation onwards
18.	Income tax	%		Not considered in the tariff
19.	Repayment period	Years	12	
20	Construction Period	months	24	

The levelized tariff comprises of two parts:-

a) Variable Cost: The raw material required i.e. municipal waste would be given as free issue to the developer. The cost for the same has not being considered while arriving at the variable cost.

b) Fixed Cost: It is arrived based considering:

i) Return on Equity
ii) Interest on loan capital
iii) Depreciation
iv) Interest on Working Capital
v) Operation and maintenance expenses

The fixed cost is the sum of the above.

10.3 Cost of Generation of Power

(b) PPP Model

The levelized tariff is calculated considering the plant life as 25 years

The levelized tariff (sum of fixed + variable cost) is arrived at considering the discount factor for time value of money.

The levelized tariff considering the taxes and duties is as under:

Table 10.3: Tariff Calculation as per 75% PLF

Sr. No.	Particulars	Value
1.	Capacity - MW	25
2.	Total Project Cost- Rs. Crore	938.55
3.	Levelized Tariff Rs./ kwh	**13.74**

(a) With the project being financed by MCGM, considering 20 Years Operation Service period the levelized is arrived at considering:

(i) Only Capital recovery during the project life
(ii) Operation Service charges considered @ 5% per annum of the Capex Cost with an annual escalation of 5.72% and
(iii) Asset Replacement Fund considered at 1% per annum of the Capex cost

The levelized tariff work out to **Rs. 7.42/ kWh**

(c) Considering only Operation Service carried out by the Contractor for a period of 20 Years the levelized tariff is arrived at taking:

a. Operation Service charges considered @ 5% per annum of the Capex Cost with an annual escalation of 5.72% and
b. Asset Replacement Fund considered at 1% per annum of the Capex cost

The levelized tariff works out to Rs. 4.20/kWh.

The above cost may vary in case of any additional securities are sought on the project.

10.3.1 In house consumption of power generated

Considering internal usage of the total power generated by MCGM

- Charges per Unit including wheeling charges Rs. 3.04/kwh
- Power consumption by MCGM for street lighting and office (drawn from DISCOM) at Rs. 6.16/ kwh (average) for 100 Million units (approximate) is Rs. 61.6 crores.
- The saving in terms of power being consumed internally is (115*3.12) = Rs.36 Crores.

10.3.2 Sale of Power Vs Internal Consumption

Two option for MCGM

- Sale of Power to Discom
- Internal Consumption

The comparison between Sale of power to Discom Vs internal consumption is shown in **Table 10.4**.

Table 10.4 Comparison between sale of power to Discom Vs internal consumption

Comparison	
Sale of Power to Discom	**Internal Consumption**
Requires Power Purchase agreement with utility	MCGM has large in-house demand. Presently it is incurring charges of @ Rs. 6.16 per Unit. Requires Energy Purchase agreement with Utility.
High Commitment Level	Wheeling charges and banking charges will be attracted.
Tariff fixed by MEDA/ MERC	

The present scope for the project limits the scope for connecting to the nearest grid. Decision about using power for internal consumption by MCGM or to sell it to

DISCOM as part of their Renewal Purchase Obligations (RPO) will be taken at later stage.

CHAPTER 11: Project Implementation Strategy

It is proposed that the Waste to Energy project to be bided out as a Design, Build, and Operate and Transfer basis for a period of 25 years with O&M 15 years. The private operator would be required to complete the commissioning work within a given time frame and then operate and maintain the Plant for the balance period for which he would be paid fees based on the generated power.

A transparent and competitive bidding process will be adopted for selection of the Contractor.

It is proposed to award a comprehensive contract to Commission Waste to Energy project and its operation and maintenance thereafter for a period of 20 years to a pre-qualified and competitively selected private operator through an International Competitive Bidding (ICB) process.

The contract with the Contractor would provide for conditions related to achievement of specific milestone linked to defined timeframe and performance criteria to operate and maintenance of the Waste to Energy Plant as per the desirable standards.

11.1 Maintenance Requirements

Operation and Maintenance of the WtE Plant is a very important aspect. The maintenance requirements are enumerated below:

- Preventive maintenance of the plant
- Detailed inspection and record keeping
- Repair and maintenance record
- Reject management
- Periodic environmental monitoring to ascertain ground water and air quality as prescribed by the Maharashtra Pollution Control Board
- Regular maintenance of all the equipment, machineries, pumps, treatment units procured under this Project
- Monthly detailed inspection of WtE plant components
- Regular reporting of Continuous Emission Monitoring System (CEMS) data
- All the equipment shall be maintained per manufacturer's specification and recommended frequency.
- Ensure security and safety of the facilities.
- Asset replacement for maintain the WtE Plant for its optimum capacity and efficiency
- Penalties for non-compliance
- Performance guarantees - minimum power generation, maximum auxiliary power usage, emissions Safety aspects
- Corrections during operation for waste characteristics

11.2 Project Milestone

The project milestone with schedule is given in **Table 11.2**.

11.3 Issues Requiring Attention of MCGM

In India, under the provisions of Air and Water Act, for running or establishing any industry or process and discharging effluent/ emitting pollutants into any water resource or on land/ air and polluting thereby the environmental water/ air is required to obtain consent to establish and consent to operate from the concerned Pollution Control Board. The Maharashtra Pollution Control Board (MPCB) shall be the governing agency to release the consents. The prerequisite documents to be considered for the WtE plant are as follows,

- License for manufacturing and trading of compost
- Pollution control boards NOC for manufacturing and trading of refuse derived fuel
- DIC (District Industries Centre) registration.
- NOC from PCB (Pollution Control Board).
- NOC from Labor Commissioner

The below table describes in detail the various project stages and the required compliances/ requirements to be attained concerned agencies for the proposed WtE plant at Deonar, List of Approvals and Regulatory Compliance to be obtained for Waste to Energy Project[42]: The compliances/requirements and respective agency is shown in **Table 11.1**.

Table 11.1: Compliances/ requirements and Agency

Sr. No.	Project Stage	Compliances/ Requirements	Remarks	Agency
1.	Project Development Stage	Approval for setting up the project	Statutory	State & Local Administrative Authority
2.	Project Development Stage	Town Planning & Building Plan Approval		Local Administrative Authority
3.	Project Development Stage	Environmental Clearance (EC) from State Pollution Control Board under Environment Protection Act 1986	Statutory	SEAC/ SEIAA
4.	Project Development Stage	Coastal Regulation Zone (CRZ) Clearance	Statutory	SCZMA
5.	Project Development Stage	Change of Land use		Concerned authority

[42] Referred to Indian Renewable Energy Development Agency Ltd

Sr. No.	Project Stage	Compliances/ Requirements	Remarks	Agency
7.	Pre Construction	Consent to Establish (CTE) from State Pollution Control Board under Water Act 1974 & Air Act 1981	Statutory	MPCB
8.	Pre Construction	NOC from FIRE dept.		Fire Dept.
9.	Construction	Registration under The Contract Labour (Regulation & Abolition) Act, 1970 as Principal Employer	Statutory	State Labour Department
10.	Pre Construction	Central Ground Water Board NOC for ground water extraction	Statutory	CGWB
11.	Pre Construction	Airport Authority of India (AAI) Clearance/NOC	Statutory	AAI
12.	Pre Construction	Building Plan Approval from ULB	Statutory	MCGM
13.	Pre Construction	Other Site/Location Specific Clearances Required: - Forest Dept. Clearance - CRZ Clearance	Statutory	SEAC/ SEIAA
14.	Pre Construction/ Operational Phase	Consent to Operate from State Pollution Control Board under Water Act 1974 & Air Act 1981	Statutory	MPCB
15.	Pre Construction	Authorization under MSW (M&H) Rules 2016 (State Pollution Control Board)	Statutory	MPCB
16.	Operational Phase	Value Added Tax (VAT & CST) Registration	Statutory	
17.	Operational Phase	Service Tax Registration	Statutory	Income Tax Dept.
18.	Operational Phase	Registration under Employees Provident Fund Act	Statutory	
19.	Operational Phase	Registration under Employees State Insurance Act	Statutory	
20.	Operational Phase	Power Purchase Agreement (PPA)		Electricity transmission board
21.	Operational	Storage of biogas/ RDF/ Compost (if applicable)		

1. Demarcation of land on the proposed site as shown in the Interim Site Management Plan
2. Daily MSW should not be dumped in the area as shown in the Interim Site Management Plan
3. Water pipeline concurrence from relevant MCGM department and fund allocation
4. Clearance from MoEF and DISCOM for laying pipeline from Ghatkopar STP Lagoon to the proposed site
5. Communication with DISCOM for power purchase

11.4 Interim Plan for Site Management

MCGM should ensure that till the appointment of Operator/ Contractor for the development of Waste to Energy Project, daily MSW disposal at site should be avoided in the area as earmarked for WtE Project in the drawing. This will help in expediting the execution activities.

Following action points are suggested to achieve the above strategy:

1. It is recommended that area in and around the proposed land parcel marked as **"No Dumping Zone"** in the map in **drawing no. TCE. 10176A-2024-GA-6003**. should not be used for further dumping of MSW.
2. It is recommended that maximum MSW is to be processed at the other SWM facilities of MCGM to reduce the load at Deonar site.
3. Do not dump waste on or near partial closure area
4. It is recommended that waste lying inside No Dumping zone but outside of Land parcel A, B and C should be profile and gentle slope of 1:4 to be given, cover with soil cover and compacted by MCGM. Storm water flow to be channelized at the toe of the profile waste in order to avoid collection of storm water in the proposed land parcels.

Table 11.2: Project Milestone for Development of Waste to Energy (WtE) Project at Deonar, MCGM, Mumbai

Sr. No.	Project Milestone	Year																																							
		2016											2017												2018												2019							
		F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
1	Project Feasibility and DPR																																												
2	Tender preparation																																												
3	Publishing Tender																																												
4	Pre-bid meeting																																												
5	Suggestions & objections reply to be uploaded																																												
6	Tender submission																																												
7	Tender Evaluation																																												
8	Placing of Work Order																																												
9	Selection and Appointment of Contractor/ Operator																																												
10	Selection and Appointment of Independent Engineer																																												
11	Detail design																																												
12	Construction																																												
13	Site Preparartion																																												
14	Water pipeline and allied Infrastructure																																												
15	Foundation and Civil Work																																												
16	Plant Erection																																												
17	Procurement of Plant and machinery																																												
19	Commissioning of plant																																												

Note: Above Schedule is dependent on clearances and approvals

CHAPTER 12: Literature Review

1. Abhimanyu Singh et al. (2014). Municipal solid waste management challenges and health risk problematic solutions at Agra city, U. P., India. Advances in Applied Science Research, 2014, 5(3):397-403
2. Bandara, N. J. G. J., Hettiarachchi, P. J. (2003). "Environmental Impacts Associated with Current Waste Disposal Practices in a Municipality in Sri Lanka – A Case Study." Sustainable Landfill Management 19-26.
3. Bhave, N. L. (2014). Study of Noise Pollution During Deepawali. International Journal of Innovative Research in Advanced Engineering, 1-11.
4. Brihanmumbai Mahanagarpalika Air Quality Monitoring & Research Laboratory Data
5. Development of Solid Waste Management Project at Mumbai (Jan 2015) Draft Project Report, by Infrastructure Development Corporation (Karnataka) Limited (iDECK), Infrastructure Development & Finance Company (IDFC) and SENES Consultants India Pvt. Ltd.
6. Dube, R., Nandan, V., Dua, S. (2014). Waste incineration for urban India: valuable contribution to sustainable MSWM or inappropriate high tech solution affecting livelihoods and public health?. International Journal of Environmental Technology and Management, Vol.17,No.2/3/4, 199.
7. EIA Report for Modernization of Existing Unit #6 (500 MW) for Trombay Thermal Power Station (TTPS), Mumbai (Year 2013)
8. Goel, S. (2008). Municipal solid waste management (MSWM) in India: a critical review. Journal of Environmental Science Engineering 50(4), 319-28.
9. India: 1000 TPD Waste to Energy Project at Deonar, Mumbai, IEE Report Deonar
10. Jain P, Handa K and Paul A (2014). Studies on Waste-to-Energy Technologies in India & a detailed study of Waste-to-Energy Plants in Delhi, International Journal of Advanced Research, 2(1), (2014).
11. Joshi R, Ahmed S (2016) Status and challenges of municipal solid waste management in India: A review. Cogent Environmental Science, 2: 1139434
12. Kalyani, K.A. and Pandey, K.K. (2014). Waste to energy status in India: A short review. Renewable and sustainable energy reviews, 31, 113-120
13. Lemieux, Lutes & Santoianni (2004). Emissions of organic air toxics from open burning: a comprehensive review. Progress in Energy and Combustion Science, 30 (1), 1-32
14. MCGM Report on Waste characterization-2007.
15. Mwanthi, M., and Nyabola, L. (1997). Solid waste management in Nairobi City: Knowledge and attitudes. Journal of Environmental Health, 60(5), 23.
16. NEERI Revised Final Report on Waste characterization of Mumbai- 2015 (Deonar Site- Freshly dumped waste values considered).
17. NEERI's study on "Assessment of Status of Municipal Solid Wastes Management in Metro Cities and State Capitals" in 2004-2005.

18. NHAI to use Municipal solid waste for construction of highways By Express News Service, Published: 24th June 2016
19. Pappu, A., Saxena, M., & Asolekar, S. R. (2007). Solid wastes generation in India and their recycling potential in building materials. Building and Environment, 42, 2311–2320.
20. Planning commission report (WTE) under the chairmanship of Dr. K Kasturi Rangan (Vol – I & II)
21. Refsgaard K., and Magnussen K., (2009). Household behaviour and attitudes with respect to recycling food waste experiences from focus groups, Journal of Environmental Management,90, 760–771
22. Refsgaard, K. and Magnussen, K., (2009). Household behavior and attitudes with respect to recycling food waste experiences from focus groups, Journal of Environmental Management, 90, 760–771.
23. Report of the Task Force on Waste to Energy Volume I & II (May 2014), by Planning Commission.
24. Roos, C., Clean Heat and Power Using Biomass Gasification for Industrial and Agricultural Projects, U.S. Department of Energy, 2010,1-9.
25. Sangodoyin A.Y., and Ipadeola S.F. (2000). Hazardous wastes: assessing the efficacy of structures and approaches to management in Nigeria, Environmental Management and Health,11, 39–46
26. Sangodoyin, A.Y. and Ipadeola, S.F., (2000). Hazardous wastes: assessing the efficacy of structures and approaches to management in Nigeria, Environmental Management and Health, 11, 39–46
27. Sarkar, P. (2003). Solid Waste Management in Delhi – A Social Vulnerability Study. Proceedings of the Third International Conference on Environment and Health, Chennai, India.
28. Sarkar, Papiya “Solid Waste Management In Delhi – A Social Vulnerability Study” in Martin J.Bunch, V. Madha Suresh and T. Vasantha Kumaran, eds., Proceedings of the Third International Conference on Environment and Health, Chennai, India, 15-17 December, 2003.
29. Sethna SF (1999) Geology of Mumbai and surrounding areas and its position in the Deccan Volcanic Stratigraphy, India. J Geol Soc India 53:359–365
30. Sethna, S. (1999). Geology of Mumbai And Surrounding Areas and its Position in the Deccan Volcanic Stratigraphy, India. Journal Geological Society of India, 359-365.
31. Shankar & Rao (2002) Impact of Air Quality on Human Health: A Case of Mumbai City, India IUSSP Regional Conference on Southeast Asia’s Population in a Changing Asian Context,10-13 June 2002
32. Sharholy M., Ahmad K., Mahmood G.et al. (2008). Municipal solid waste management in Indian cities – A review, Waste Management 28, 459–467

33. Singh, A. (2014). Municipal solid waste management challenges and health risk problematic solutions at Agra city, U. P., India. Advances in Applied Science Research, 5(3):397-403.
34. Status of solid waste generation, collection, treatment and disposal in metro cities, (CPCB, 2000) for Mumbai.
35. UNEP / Bloomberg New Energy Finance (2012): Global Trends in Renewable Energy Investment 2012. Frankfurt, Germany
36. Uplap PA, Bhate K. (2014). Health profile of women ragpicker members of a nongovernmental organization in Mumbai, India. Indian J Occup Environ Med,18:140-4
37. Waste composition for city more than 5 lakh population, Background material for Manual on SWM, NEERI 1996.
38. Weinstein, P. E. (2006). Waste-To- Energy as a Key Component of Integrated Solid Waste Management for Santiago, Chile: A Cost-Benefit Analysis Department of Earth and Environmental Engineering, Columbia University. Master: 1-57
39. Weinstein, P.E. (2006). Waste-to-Energy as a Key Component of Integrated Solid Waste Management for Santiago, Chile: A Cost-Benefit Analysis Department of Earth and Environmental Engineering, Columbia University
40. World Bank (2012). What a waste: a global review of solid waste management. Urban development series knowl- edge papers.
41. World Bank Report on Solid Waste in India, considering India as a Lower middle income country, 2012.
42. Zaman, A.U. (2010). Comparative study of municipal solid waste treatment technologies using life cycle assessment method. International Journal of Environmental Science & Technology, 7(2), 225.
43. World Energy Council 2013: http://www.worldenergy.org/news-and-media/news/22nd-world-energy-congress-reflects-concerns-about-shifting-energy-agenda/
44. Stengler, E. 2005. The European position – Where is waste-to-energy, and where is it going? Waste Management World. Nov/Dec 2005.
45. Guideline for safe and eco-friendly biomass gasification Intelligent Energy – Europe (IEE), 2009.

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