JINDAL URBAN WASTE MANAGEMENT (VISAKHAPATNAM) LTD.

DETAILED PROJECT REPORT

FOR

MUNICIPAL SOLID WASTE TO ENERGY FACILITY, VISAKHAPATNAM, (A.P.)

Project No. 1638
30th November 2016
Updated 12.05.2018

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00 EXECUTIVE SUMMARY

00.01 Background & Objective Of The Project

As a part of Swachh Bharat Mission, Government of Andhra Pradesh has adopted strategy for implementation of Solid Waste Management (SWM) Rules. Solid waste management plans have already been made for all the 110 local bodies in the state and the state government has plans to set up at least one model MSW-to-Energy (WtE) project in each district of the state.

New and Renewable Energy Development Corporation of Andhra Pradesh Limited (NREDCAP), on behalf of 53 Urban Local Bodies have already awarded Waste to Energy Projects for 10 clusters with total Power generation capacity of 63 MW.

JITF Urban Infrastructure Limited (JUIL), a subsidiary of Jindal Saw Limited (JSL)have received letters of award for three clusters-Guntur, Tirupati and Visakhapatnam through competitive bid process.

As per the conditions laid down in Letter of Award No. NREDCAP/BM/MSW/EOI/2015-16/1379 dated 03.12.2015,JUIL has promoted **Jindal Urban Waste Management (Visakhapatnam) Ltd.** for execution of the for 15 MW capacity WtE Project at Visakhapatnam

Following activities have also been completed for start of project :

1. Concession Agreement with Greater Visakhapatnam Municipal Corporation was signed on 17th February 2016.

2. Power Purchase agreement has been signed with AP Eastern Power Distribution Company Ltd. (APEPDCL) on 17th Feb. 2016.
3. Resource assessment and basic engineering of the project defining the configuration of the project has also been completed.
4. Techno Economic study covering Project cost estimates and financial viability has been completed.
5. Social and Environment Risk Analysis studies have also been completed.

This Detailed Project Report has been prepared to enable Jindal Urban Waste (Visakhapatnam) Ltd proceed with Financial Closure, obtain other statutory clearances and go ahead with further work for project implementation.

00.02 Project Configuration

Waste to Energy Project will process Municipal Solid Waste (MSW) received from the areas under Greater Visakhapatnam Municipal Corporation (GVMC).

The Project includes :

- MSW receipt, storage and segregation facility with design capacity of 1250 TPD of MSW
- Power Plant of 15 MW capacity using combustion technology for steam production and Power generation using Steam Turbine – Generator.
- Balance of plant and other auxiliary facilities required for the project.

17.08 Acres of land is already identified by GVMCin Centralized Waste Treatment Facility (CWTF) being developed at Kapuluppada as a part of overall Municipal Solid Waste Management Plan for the city.

Technological aspects and details of equipment and facilities are covered in Chapters 03 to 06 of this report.

00.03 Environmental & Social Aspects

Measures to be adopted for meeting the statutory requirements related to Environment Pollution have been studied in detail and covered in Chapter 07. Issues related to Health and safety of manpower engaged are also addressed in addition to social impact and management of related aspects.

00.04 Organisation Structure & Manpower

Requirement of manpower during project execution stage and for Operation & Maintenance have been assessed and organisation structure required for project planning and implementation has been presented in Chapter 08.

00.05 Implementation Schedule

Project implementation schedule in form of Bar Chart along with strategy for implementation and quality assurance are presented in Chapter 09. Financial closure is targeted by May 2017 and plant commissioning by October 2018.

00.06 Project Cost

The Capital Cost Estimates for the project are presented under differentexpenditure heads and are based on :

- Cost for major equipment such as MSWhandling, boiler, air pollution control and turbo generator are taken from historical estimates and validated on conservative basis by interaction with vendors

- Cost of balance of plant equipment, buildings,development & civil works, etc. are taken as per basic engineering and consultant data base

The Capital Cost of the Plant is estimated at Rs220.77 Lakhs as detailed in Chapter – 10.

00.07 Project Financials

The revenue for the project has been estimated based on sale of power and recyclables during operation of Plant for 25 years.

Assumptions made for calculations of financials are as per norms followed by lenders.

The project IRR (post tax) has been computed taking into account the capital cost and revenue generated during tenure of the concession period of 25 years.

Computed figure for IRR is 16.44 (Pre Tax) and 14.84(Post Tax)

The debt service coverage ratio (DSCR) of the project works out to 1.87.

Details are presented in Chapters 11 and 12.

Considering the analysis of IRR, the project is considered technically feasible andcommercially viable.

01. INTRODUCTION TO THE PROJECT

01.01. Background & Objective Of The Project

Municipal Solid Waste (Management & Handling) Rules were framed by Govt. of India in year 2000. The Rules provided guidelines for collection, storage, transportation, sorting and segregation, processing and disposal of solid waste. After launching of Swachh Bharat Mission in 2014, these rules have now been updated and replaced by Solid Waste Management (SWM) Rules 2016. As per Rules, States have the responsibility of framing Waste Management Policy & Strategy and conforming to the State Policy, Urban Local Bodies (ULB) are responsible for making waste management plan for implementing SWM Rules.

Andhra Pradesh Govt. has been very proactive and Strategy on Andhra Pradesh Integrated Municipal Solid Waste was formulated in 2014 which provided framework for ULBs to implement SWM Rules. The Andhra Pradesh government has been aggressively promoting generation of power from MSW. The state government has plans to set up at least one model MSW-to-Energy (WtE) project in each district of the state. The state of Andhra Pradesh has 110 urban local bodies (ULBs), including 13 municipal corporations and 17 municipal councils.

Andhra Pradesh Urban Finance and Infrastructure Developmentcorporation (APUFIDC) engaged agencies for preparation of Detailed Project Reports (DPRs) for Municipal Solid Waste management in areas covered by various ULBs in the state. For areas covered under Greater Visakhapatnam Municipal Corporation DPR has been prepared by M/s Feedback Infra Private Limited.

Note on Swachh Bharat Mission

Urban India is facing an ever increasing challenge of providing for the incremental infrastructural needs of a growing urban population. With increasing population, municipal solid waste management (MSWM) in the country has emerged as a challenge not only because of the environmental and aesthetic concerns, but also because of the huge quantities of municipal solid waste (MSW) generated every day.

Municipal Solid Waste (Management & Handling) Rules were formulated in 2000 which required all urban local bodies (ULBs) to establish a proper waste management system including a timeline for installation of waste processing and disposal facilities by the end of 2003, not only for metro cities and class I cities but also for all ULBs in the country. However, despite encouraging pilots and achievements, most ULBs continue to face challenges not only in the areas of appropriate and advanced collection and transportation systems, technology selection, and disposal methods, but also in sustainable financial management of MSWM. The non-compliance issue is still true after 16 years of the notification of the MSW (M&H) Rules, 2000.

In order to give a push to the municipal solid waste management in cities, the ministry of Urban Development launched the Swachh Bharat Mission (SBM) in 2014.

SBM seeks to promote cities as engines of economic growth through improvement in the quality of urban infrastructure, with assured service levels and efficient governance. SBM aims to address the challenges in management of municipal solid waste and to support cities in developing modern and appropriate systems.

(Complied from MSW Management Manual by CPHEEO)

New and Renewable Energy Development Corporation of Andhra Pradesh Limited (NREDCAP), on behalf of Urban Local Bodies started process for selection and appointment of concessionaires for development of WtE projects. Some of the projects have already been awarded. **Swachha Andhra Corporation,** which was incorporated on 1st May 2015 with a goal to achieve the campaign "Swachh Bharat Mission" has been given the responsibility of monitoring of all WtE projects in Andhra Pradesh.

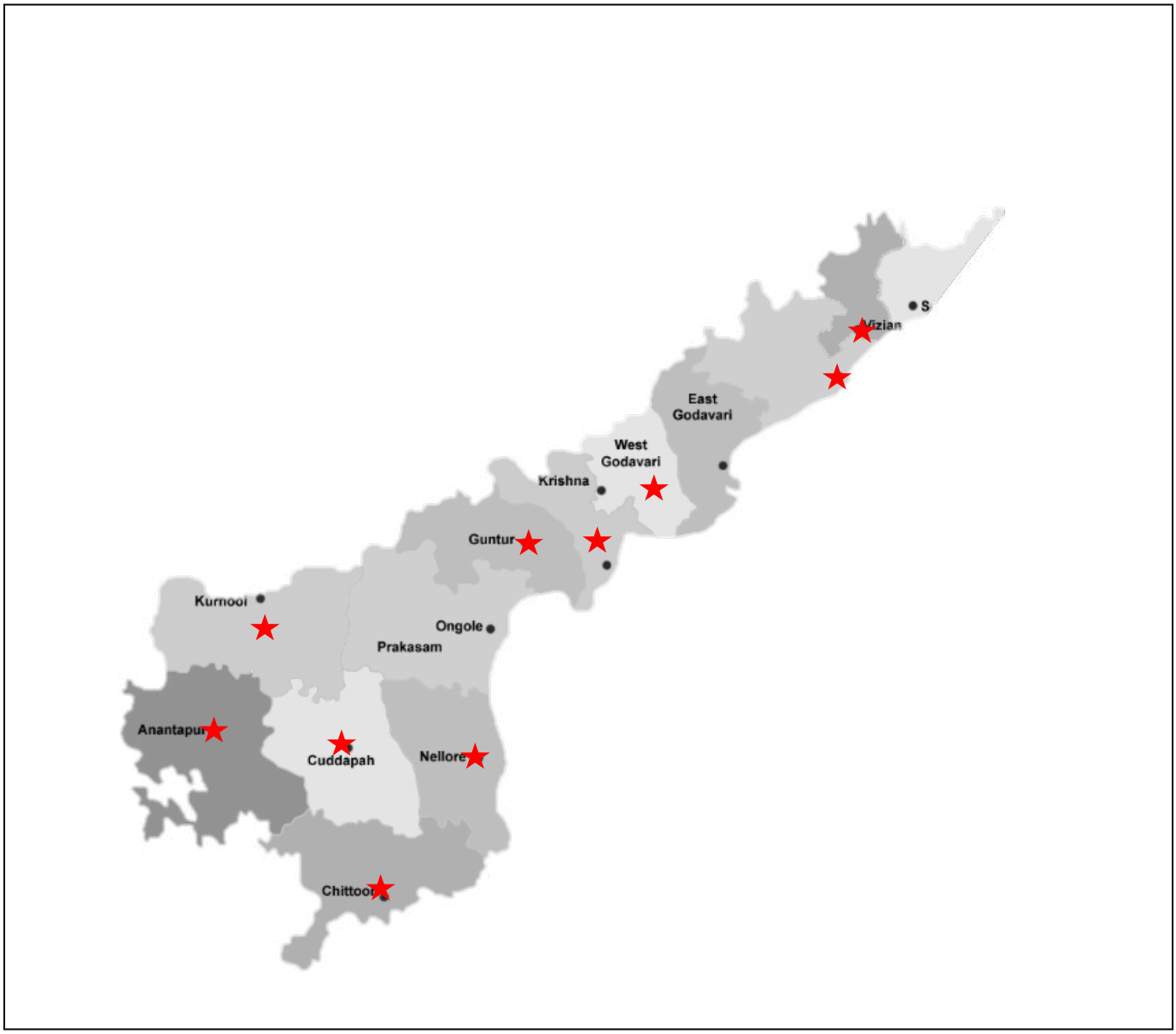
For 53 ULBs generating ~4471 Tonnes/day of Municipal Solid Waste as of 2015-16, Waste to Energy Projects have been awarded with total Power generation capacity of 63 MW in addition to other useful products.

Table 1: Waste to Energy Projects in Andhra Pradesh

Cluster Name	MSW Capacity TPD (as of 2015-16)	Capacity (MW)	Name of Developer
Visakhapatnam	952	15	JITF Urban Infra. Ltd.
Guntur	1202	15	
Tirupati	374	6	
Ananthapur	283	4	Essel Infra Projects.
Tadepalligudem	342	5	
Kadapa	317	5	
Machilipatnam	196	4	
Vizianagaram	208	4	
Kurnool	316	1	Nexus Novas
Nellore	296	4	Envikare LLP

(Details as per Letters of Award circulate by Swachh Andhra Corporation Dt. 31.03.2016)

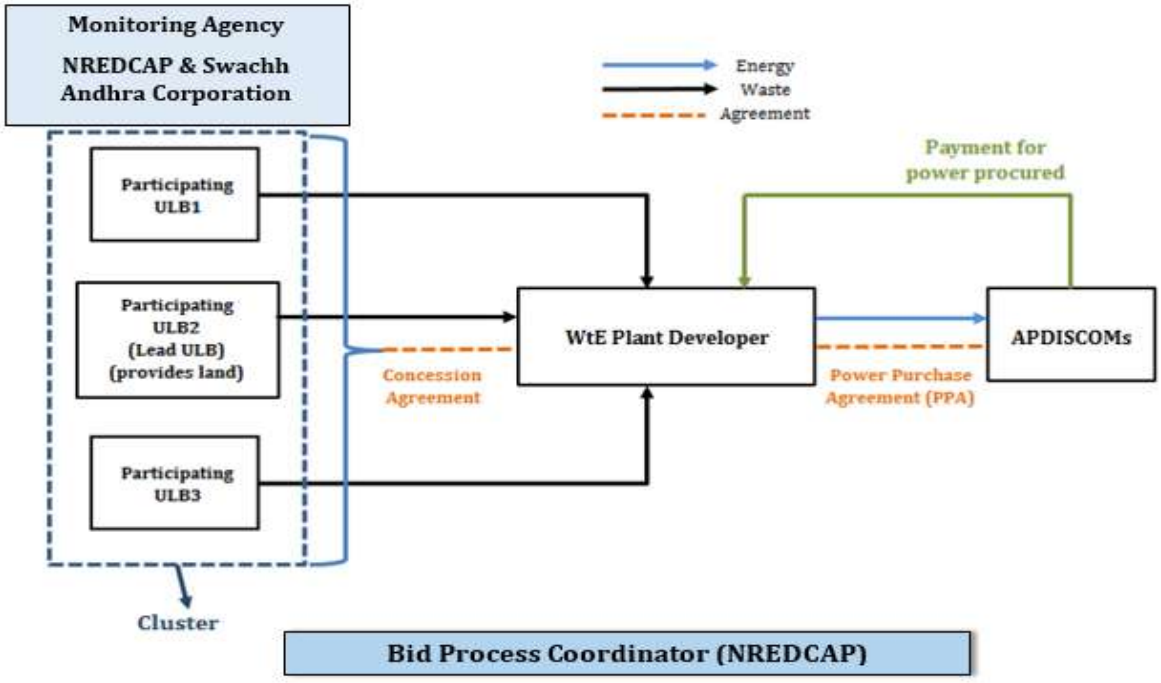
Figure- 1:Location of Waste to Energy Projects in Andhra Pradesh



Jindal Group, through its wholly owned subsidiary JITF Urban Infrastructure Limited (JUIL), participated in the competitive bidding process carried out by NREDCAP and succeeded in winning the bid for three clusters-Guntur, Tirupati and Visakhapatnam.

Projects are to be executed on Design, Build, Finance, Operate and Transfer (DBFOT) basis for converting waste to energy. Letter of Award No NREDCAP/ BM/ MSW/ EOI/2015-16/ 1379 was issued by NREDCAP to JUIL on 3rd Dec., 2015 for setting up of Waste to Energy Project of 15 MW capacity at Visakhapatnam covering area under Greater Visakhapatnam Municipal Corporation.

Figure- 2: Operating Structure of WtE Projects



In pursuance to the letter of award, JUIL has constituted separate companies for developing the three projects, JIUL being the holding company. **For executing Visakhapatnam WtE Project, Jindal Urban Waste Management (Visakhapatnam) Ltd.has been formed**.

Objective of this Report is to investigate and project Technical Feasibility and Commercial viability of the project to enable Jindal Urban Waste (Visakhapatnam) Ltd proceed with Financial Closure, obtain other statutory clearances and go ahead withfurther work for project implementation for 15 MW WtE Facility

The Detailed Project Report has been prepared for 15 MW capacity Waste to Energy Project by processing MSW received from Visakhapatnam Cluster covering the area under Greater Visakhapatnam Municipal Corporation.

01.02. Group Corporate Profile

O.P.Jindal group was Founded in 1952 by Shri O. P. Jindal, a first-generation entrepreneur, the group today is a leading steel producer with interests spanning across the spectrum from mining iron ore to manufacturing value-added steel products. Group has grown to US$ 18 billion global business conglomerate

PR Jindal Group was created post demerger of assets of OP Jindal Group. Mr. P.R. Jindal is Chairman of PR Jindal Group of companies.

PR Jindal Group has diverse business interests viz., manufacturing of steel pipes, pellets, infrastructure development and mining. The group recorded turnover of Rs.7971 Crores during FY 2015-16 and net worth of Rs.5116 Crores as on March 31st, 2016. Jindal SAW Limited (Jindal SAW), founded in 1984, is the group flagship company and is leading global manufacturer and supplier of Iron & Steel pipe products, fittings and accessories with manufacturing facilities in India, USA, Europe and UAE (MENA).

PR Jindal group's journey in infrastructure sector

PR Jindal Group forayed into infrastructure sector in 2007 and incorporated Jindal ITF Limited (JITF) as a subsidiary of Jindal SAW. Activities of JITF span across infrastructure, transport and fabrication solutions addressing the varied needs of the industry. JITF is engaged through its subsidiaries in various infrastructure businesses namely waste to energy, rail wagon fabrication, ship building, coastal and inland water transportation business, water infrastructure EPC business.

PR Jindal Group has identified municipal solid waste processing and power generation, water infrastructure, rail manufacturing as high potential businesses. In order to achieve faster growth and unlock shareholder value it was decided to demerge these high potential business into a separate infra vertical. This infra vertical is housed in Group's entity namely Jindal Infralogistics Limited (JIL).

Municipal Waste Management and Waste to Energy Projects are looked after by JITF Urban Infrastructure Ltd. (JUIL).

Figure- 3: Structure of Infrastructure Business before Restructuring

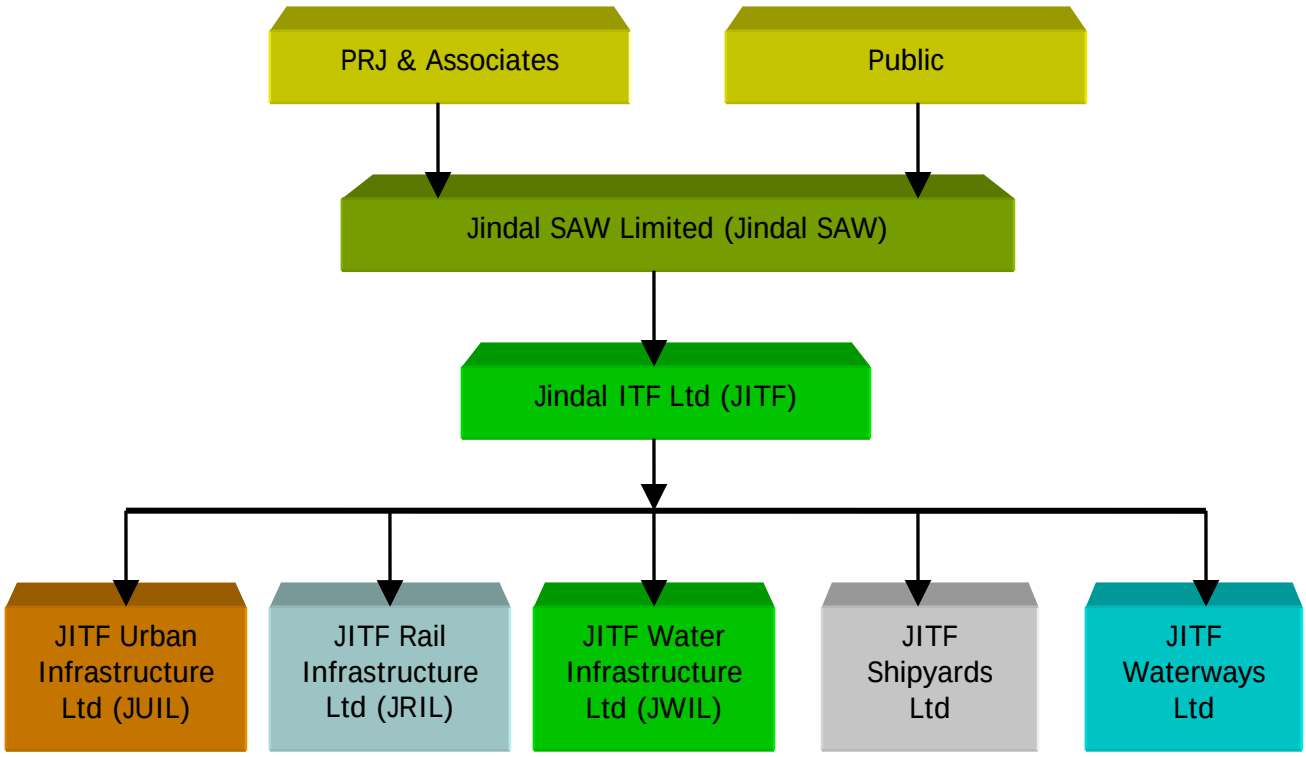
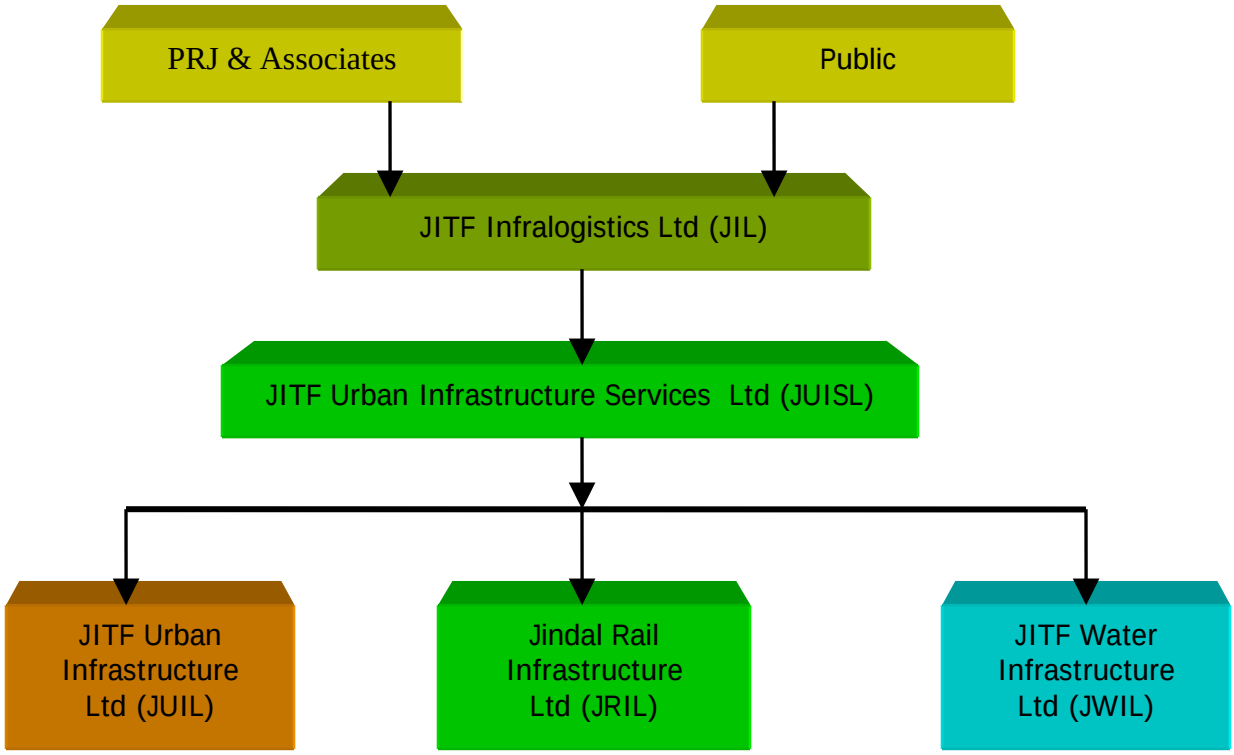


Figure- 4: Structure of Infrastructure Business after Restructuring



Group Flagship Company

Jindal SAW Limited (Jindal SAW), incorporated in 1984, is the flagship company of PR Jindal Group and is the largest steel pipe producer in India. In addition to pipes, pellets and value added products like pipe coatings, bends and connector castings, Jindal SAW also owns low grade iron ore mines in Rajasthan. The Company operates manufacturing facilities in India, the United States, Europe and United Arab Emirates. Its products find applications in energy, petrochemicals, oil and gas exploration, engineering, water transportation, and sanitation and sewage transportation. Jindal SAW is one of the largest steel pipe exporters from India with exports contributing around 35%-40% of the company's total revenues. Jindal SAW recorded turnover of Rs.6384 Crores during FY 2015-16 and had Net worth of Rs.5302 Crores as on March 31st, 2016.

Table 2: Particulars of Flagship Company

Company	Jindal SAW Limited (Jindal SAW)
Promoter	PR Jindal group
Registered Office Address	A-1, UPSIDC Industrial Area, Nandgaon Road, Kosi Kalan, Mathura, Uttar Pradesh – 281403
Date of Incorporation	October 31st, 1984
CIN Number	L27104UP1984PLC023979

Details of Key Management personnel is given in Table 3

Table 3: Profile of Key Personnel

Name	Designation	Qualification	Experience
Mr.Prithviraj Jindal	Chairman	Bachelors of Arts	Mr. Jindal pioneered the production of SAW pipes three decades ago. He has been at the helm of affairs of Jindal SAW and was associated in the setting up of SAW Pipes Limited (Jindal SAW, now) in 1984. Mr. Jindal Guides Company's global ambitions.
Ms. Sminu Jindal	Managing Director	MBA	Ms. Sminu Jindal has experience in the Steel, Oil and Gas sectors in India and is currently appointed as the Managing Director of Jindal SAW.
Mr. Neeraj Kumar	Group CEO	Masters in Physics and Masters in Business Management	Mr.Neeraj Kumar has wide experience with large Indian business houses, top multinationals and financial institutions across infrastructure, commodity, service and financial sectors. Mr. Kumar also worked as Director (Finance) & CFO of Jindal SAW.
Mr.Narendra Mantri	CFO	F.C.A.	Mr. NarendraMantri is the CFO of Jindal SAW. He was earlier associated with Dalmia Bharat Sugar & Industries Ltd as CFO. He has close to 30 years of Work Experience.
Mr. Sunil Kumar Jain	Company Secretary	B.Com & CS	Mr. Sunil Jain has more than 30 years of experience in Corporate Secretarial and Legal field. He has handled varied matters in court cases and arbitration including matters related to forming of JV, cross border merger, domestic amalgamation/ demerger, issue of securities in international market both GDRs & FCCBs and their listing on London, Luxembourg and Singapore Stock Exchanges.

01.03. Promoter Company Profile

JITF Urban Infrastructure Limited (JUIL) is the holding company for all the Urban Infra Projects of the PR Jindal Group. JUIL has promoted various SPVs for implementing Waste management and Waste to Energy projects.

JUIL has completed the following projects and these are in operation:

1. Waste to Energy Project – 16 MW at Okhla, New Delhi
2. MSW Management with RDF Plant at Bathinda, Punjab : 300TPD
3. MSW Management Project in Daman : 100 TPD
4. MSW Management Project at Firozpur, Punjab : 300 TPD (Commissioning trials are completed, Commercial operation is yet to begin.)

Three Projects in Andhra Pradesh, one in Gujarat and two in Rajasthan are in pipeline.

Table 4: Particulars of Promoter Company

Company	JITF Urban Infrastructure Limited (JUIL)
Promoter	JITF Urban Infrastructure Services Limited (JUISL)
Registered Office Address	A- 1-, UPSIDC Industrial Area, Nandgaon Road, KosiKalan, Distt, Mathura (U.P.) -281403
Date of Incorporation	March 28th, 2007
CIN Number	U70102UP2007PLC069540

Structure of JITF Urban Infrastructure Limited (JUIL) is shown in Fig – 5 below :

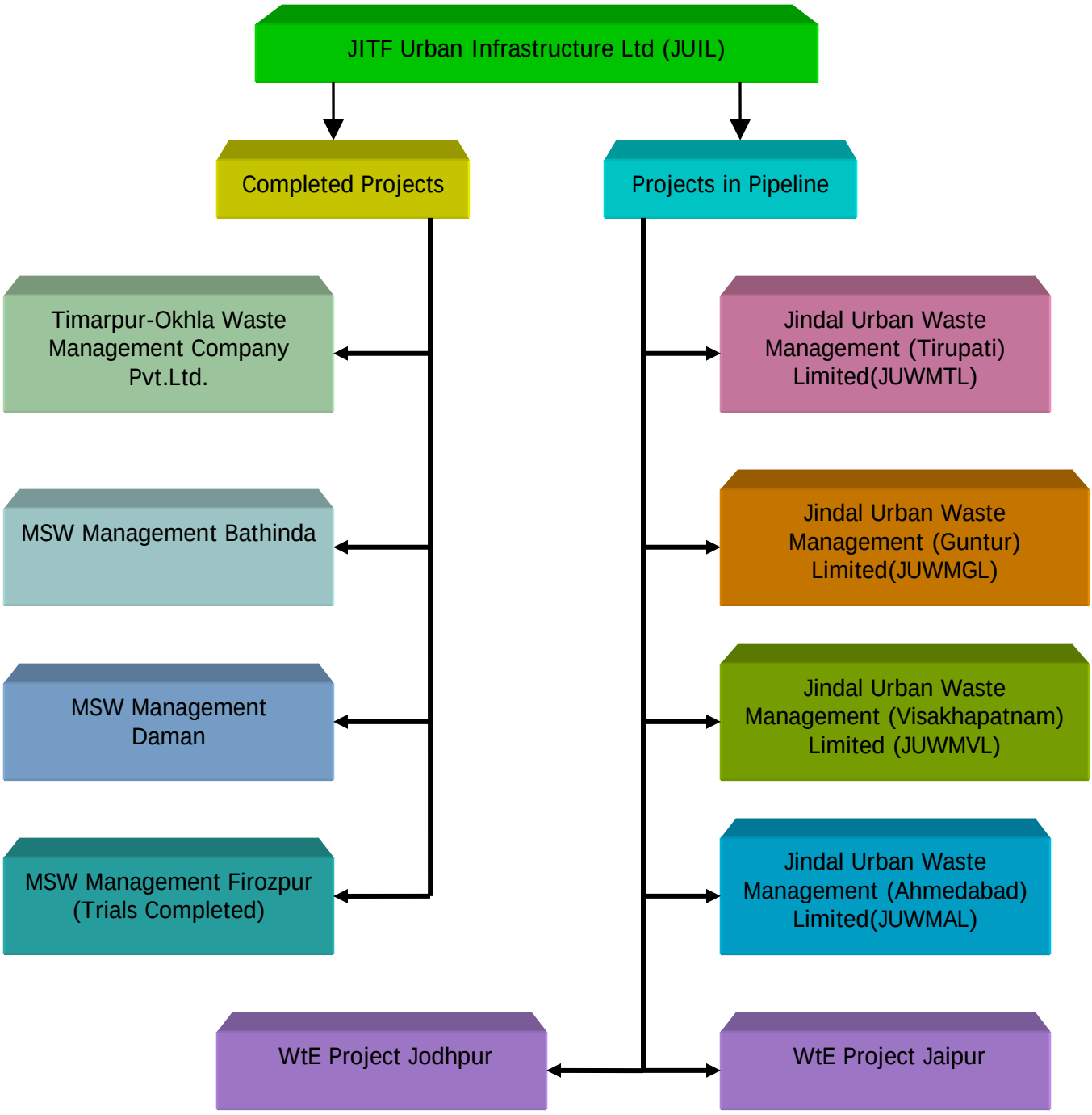


Figure- 5: Structure of JUIL

Snapshots of some completed Projects

WtE PROJECT AT OKHLA – NEW DELHI

MSW PROCESSING FACILITY AT BATHINDA

COMPOST AND RDF PRODUCED AT BATHINDA

01.04. The Project

The Waste to Energy Project will be anintegrated facility for processing Municipal Solid Waste (MSW) delivered by Visakhapatnam Municipal Corporation at the door of the facility. Simple Segregation System will be designed for segregation of chlorinated plastics, metallic recyclable material and Inerts. In some cases if, ULB's supplies unsegregated waste, to fulfill the NGT order simple segregation will be taken place. Processed MSW will be used in a Power Plant to produce 15 MW of Power.

Plant Location :

- Village	:	Kapuluppada
- Mandal	:	Bheemali
- District	:	Visakhapatnam (Andhra Pradesh)
Nearest Railway Station	:	Visakhapatnam -23km
Nearest Airport	:	Visakhapatnam – 27 km
Nearest Access Road	:	NH-16, 1km
Nearest Highway	:	Chennai – Kolkata National Highway (NH-16) – 1km
Source of Water	:	Treated Waste Water from STP – 2.5km from site.
TotalLand Area of Existing Plot	:	17.08 Acres
Power Connectivity	:	Grid Sub-station of APEPDCL – 5 km

Plant Capacity :

MSW Handling Capacity	:	1620 TPD
Power Generation	:	15 MW

Figure- 6: Location Map WtE site Visakhapatnam

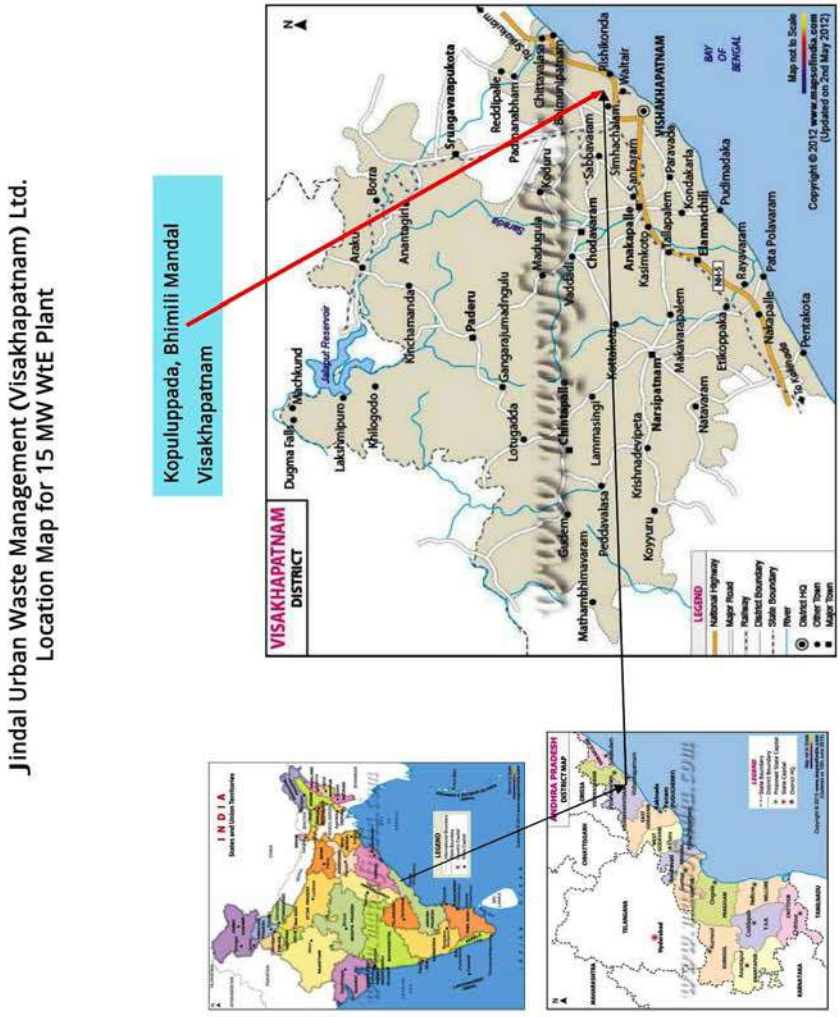


Figure- 7: Google Earth Image of Site

01.05. Consultants and Assignment

Consultants Profile

KORUS – a multidisciplinary consultancy organization was established in 2005 by a group comprising experts of highest professional caliber and repute with a mission to provide world class professional services at local cost for the steel industry from project conceptualization to commissioning.

KORUS has assembled a team of more than 150 highly qualified and experienced professionals in all the relevant Technical and Engineering Disciplines in a short span and the organization is growing at a rapid pace.

KORUS team has the added advantage that its leading members have acquired hands-on shop floor experience in reputed public and private sector steel plants during the early years of their careers and then spent over three decades in providing Technical Consultancy and Project Design & Engineering Services.

The KORUS Approach

KORUS works closely with its clients to develop concepts and deliver design solutions with maximum impact on functionality, efficiency and life cycle cost of the plant. Because of this approach KORUS engineers have a reputation for being innovative. The well-knit team working under one-roof ensures that proposed solutions not only meet diverse requirements of the client but are also delivered on time and within budget.

Commitment to Quality

KORUS recognizes the importance of achieving global quality standards. It has developed a quality culture, which permeates every aspect of its activities. Quality improvement is a CONTINUOUS PROCESS and KORUS keeps it updated with worldwide best practices.

Key Personnel

The Key Personnel who are the brain trust of KORUS have acquired extensive experience, first by working on shop floor in reputed public and private sector steel plants in India and abroad during early stages of their careers and then by providing Technical Consultancy and project engineering services for over three decades in India, Indonesia, Kuwait, Malaysia, Nepal, Nigeria, Pakistan, Sri Lanka, Thailand, UAE and USA.

Range of Services

KORUS renders comprehensive services including requirement analysis and project conception to implementation. The services include:

- Project identification and conceptualization.
- Field surveys / investigation / assessment of production potential and market VALUE of old plant and equipment; requirement of additional equipment, geotechnical considerations etc
- Preparation of Bankable Techno-Economic Feasibility Reports & Detailed Project Reports
- Preparation of preliminary designs and project engineering drawings for field activities.
- Preparation of Technical Specifications & Tender documents for procurement of production and Auxiliary Equipment and civil & structural construction works.
- Assistance in procurement of equipment.
- Preparation of detailed design and field execution drawings for utilities & services such as power, water, compressed air, fuel oil, gasses, maintenance workshops, testing laboratories, pollution control equipment, sheds, buildings, foundations, roads and

drainage and other infrastructure facilities.

- Project management services, monitoring and scheduling.
- Construction supervision and Quality Control / Assurance.
- Inspection, erection and commissioning of production and auxiliary equipment.
- Technology support for Sintering, Pelletizing, Ironmaking, Steelmaking, Rolling technology, Waste to Energy and Power Projects

Strengths of KORUS

With all the engineering disciplines under one roof, KORUS is able to provide end to end services for project implementation from concept to commissioning. Detailed engineering of Civil, Structural, Utility systems & piping, material handling and other services is carried out in house which ensures quality as well as timely delivery. Co-ordination between site team and design office team also takes care of modifications as required due to actual site conditions in a shortest possible time.

Key strength lies in integrating the complete plant by proper co-ordination of engineering activities carried out by different package suppliers. Responsibility of Interface management and filling the gaps is taken by KORUS for smooth completion of the project in totality.

Waste to Energy

Having associated with Iron & Steel industry, KORUS has gained vast experience in Energy systems and Power Plants based on Waste/ surplus energy available from technological processes. Captive Power Plants are integral to all Iron & Steel Plants with Power generation capacity from 4 MW to few hundred MW. KORUS has been associated with Jindal Group Companies since its inception and have successfully executed projects in wide range of technological fields.

Having gained expertise in Captive Power plants based on waste energy, KORUS has been associated by Jindal Group in its Endeavour to produce Energy (Fuel & Power) from Municipal Solid Waste. Korus is also providing Process & Technology upgradation and optimization for current expansion of Okhla WtE Plant. Pit extension and expansion is being done for better segregation and processing of MSW generation. To further strengthen the WtE group, KORUS has taken on board experts in the field of MSW processing and WtE projects.

The Assignment

JITF Urban Infrastructure Ltd. have assigned to KORUS Detailed Engineering, Consultancy and Project Management Services from concept to commissioning for their upcoming MSW process plants for projects in Andhra Pradesh, Gujarat and Rajasthan.

01.06. Structure of the Report

Detailed Project Report (DPR) has been prepared with a view to present the total plant configuration along with Techno Economic Evaluation for the purpose of getting approvals from various statutory bodies as well as for financial closure with lenders. The Reports is covered in various chapters as listed below :

1. Background and Introduction to the Project
2. Rationale for Project
3. Selection of Technology and sizing of main plant units
4. Selection of Plant & Equipment
5. Plant Location and Layout
6. Requirement of Land, Sheds, Buildings and other Civil Works

7. Environment, Health, Safety & Social Management
8. Organisational Structure Manpower Requirement
9. Project Implementation & Construction Schedule
10. Project Cost estimates & Means of Finance
11. Operating Costs, revenue generation & working results
12. Financial Projections and Project Appraisal

Executive summary is presented at the beginning of the Report.

02. RATIONALE FOR THE PROJECT

02.01. Municipal Solid Waste Scenario

Solid Waste Management Rules, 2016 have laid down Framework for Solid Waste Management. Duties & Responsibilities of all stake holders are covered in these Rules. All Urban Local Bodies (ULBs) are required to put in place complete Solid Waste management systems within a time frame. In Andhra Pradesh, Integrated Solid Waste Management Strategy is already in place since 2014 and most of ULBs have also prepared Solid Waste Management Plans. DPR for Solid Waste Management for Greater Visakhapatnam Municipal Corporation (GVMC) has been prepared by M/s Feedback Infra Private Limited.

As per SWM Rules 2016, following provisions have been made:

- It has been made mandatory to segregate the waste at source with Processing of Waste into usable products to the extent possible.
- De-centralized facilities for composting of bio- degradable waste are to be created.
- Non bio-degradable and non recyclable waste with CV more than 1500 kCal/kg is essentially to be sent to processing plant.
- Only inert material which cannot be recycled or converted into compost or energy is to be sent to the landfills.

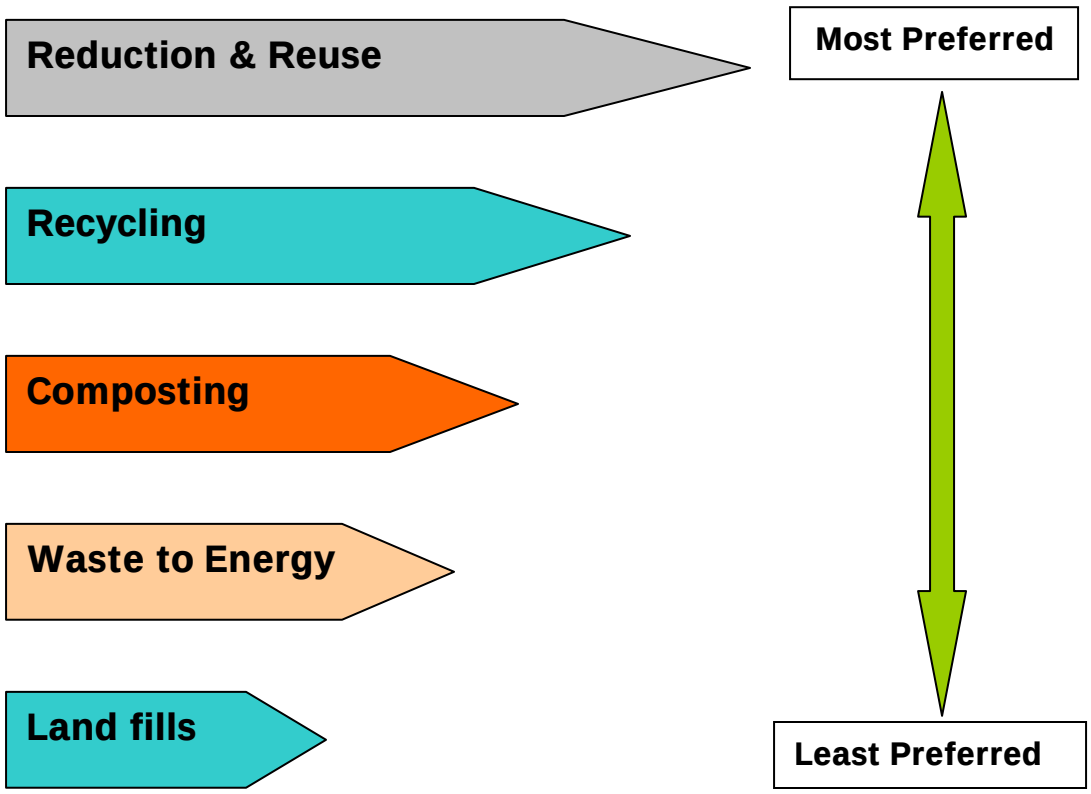
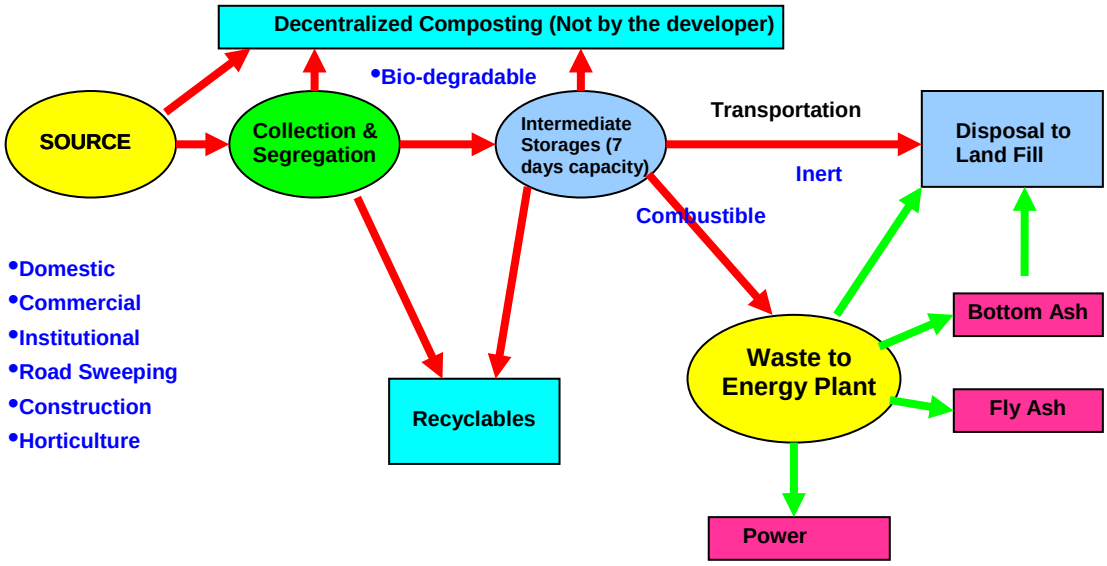


Figure- 8: Integrated Solid Waste Management Hierarchy

Fig- 8 shows the Integrated Solid Waste Management Hierarchy which is the guideline for the plans.

Waste to Energy Plants, therefore, have become essential part of SWM Plans. However, quality of feedstock directly impacts the performance, production rate as well as availability of steam generator for Power generation. At present MSW received at WtE facilities is without any segregation except recyclables collected by informal pickers. Moisture content ranges from 30 to 60%.

Figure- 9: Integrated Solid Waste Management System



Over the years, there has been steady growth in quantum of waste generation in towns / cities. Composition of waste has also undergone change. Adoption of MSW management plans by all stake holders as per SWM Rules 2016 is likely to bring major changes in the quality of waste received at processing facility over a period of time. Facilities being planned should be suitable for present quality and also perform with expected quality in future. Moreover, part of investment made now should not become redundant in near future.

Once segregation at source or intermediate storage and de centralized composting is adopted, only part of the waste containing non compostable combustibles having minimum CV of 1500 kcal/kg is to be supplied by ULB (Urban Local Bodies) to the WtE facility. This may result in reduction in percentage of MSW available for WtEplants, however, overall growth in MSW generation in ULB clusters will compensate the net availability. Quality and GCV of waste is also expected to improve

thereby Power Generation capacity will not have any adverse impact. On the other hand performance of Material Recovery Facility and incinerators will improve.

02.02. MSW Scenario for Greater Visakhapatnam Municipal Corporation

Visakhapatnam, popularly known as Vizag is a multi faceted city located in south east India and is also one of the largest ports in the country. GVMC was formed in 2005 and by addition of other areas under its jurisdiction, GVMC has evolved as second largest urban agglomeration in Andhra Pradesh. Its population was 9.85 lakhs in 1991 which increased to 13.45 lakhs in 2001 and 18.83 lakhs in 2011. GVMC has been divided into six zones consisting of 72 wards. The per capita waste collection is in the range of 0.45 to 0.47kg/per capita/day based on the quantity received at dump site. It is also estimated that out of total waste, about 75 – 80% only reaches the dump.

Presently segregation and Door to-Door garbage collection is being carried out in 72 wards and Bheemli. Waste is collected from the Households, recyclables are sold away by the workers and the organic waste is collected into the plastic baskets in the trolley.

In GVMC, waste stored in open spaces is either loaded manually or with the help of loaders (in case of huge accumulations) in trucks. The vehicles involved in the solid waste transportation in Visakhapatnam include dumper placers, tractors, mini vans and tippers (big & small). Dumper placers carry the bin and unload the waste at the transfer station and will perform on an average of 4-5 trips per day. Mini tippers transport the waste from the open secondary collection points to transfer stations located in each of the six zones. About 70 vehicles ranging from Mini Tippers to Big Tippers and Dumpers are engaged for Transport waste from transfer stations in six zones to Kapuluppada dump yard.

GVMC has a plan to upgrade the system and large compacter trucks will be used for long haul from transfer station to processing facility.

Collection from various areas of GVMC was about 920 TPD in 2015 as per information presented by M/s Feedback Infra in the DPR. All the waste generated is not being transported to dump yard so far.

Primary transportation

Secondary Transportation

Proposed Compactor Transport

02.03. Project Rationale

With the ever increasing volume of Municipal Solid Waste being generated all over India and the problems associated with its disposal, importance of Solid Waste Management can not be over emphasized. Waste to Energy Project at Visakhapatnam is a part of Integrated Solid Waste Management Plant conceived by GVMC. Plant is to be set up at Centralized Waste Treatment Facility (CWTF) being developed at Kapuluppada.

Having identified the immense potential offered by Solid Waste Management, JUIL has ventured into the SWM business with focus on creation of a sustainable ecosystem for future generations. It is inline with this strategy of the group that JUIL has been increasingly playing a defining role and proving that the WtE can be a good and sustainable business too. JUIL has successfully developed and been operating the most successful 16 MW WtE project in Delhi and 300 t/d RDF project in Bathinda.

Based on its technical and financial strengths and tariff bid, JUIL has succeeded in winning the bid for development of WtE projects in the three largest clusters (Visakhapatnam, Guntur and Tirupati) amongst the ten clusters awarded in AP. Letter of Award No. NREDCAP/BM/MSW/EOI/2015-16/1379 dated 03.12.2015 was issued by NREDCAP for 15 MW capacity WtE Plant at Visakhapatnam. Accordingly Concession Agreement has been signed between Greater Visakhapatnam Municipal Corporation and Jindal Urban Waste Management (Visakhapatnam) Ltd on 17th Feb, 2016. Project is to be set up on Design, Build, Finance, Operate and Transfer (DBFOT) basis.

03. SELECTION OF TECHNOLOGY AND SIZING OF MAIN PLANT UNITS

03.01. General

Several technologies and process route options are available for processing of MSW and recovery of useful energy from the same. However, Waste to Energy Plant to be established as a part of overall Solid Waste Management Plan must adhere to the Rule, Guidelines and Policies of Govt. of India, State Govt. and ULBs. Technology to be adopted should comply with:

1. SWM Rules 2016
2. Central Pollution Control Board Regulations
3. Andhra Pradesh Pollution Control Board
4. Municipal Solid Waste Management Manual of MoUD (Prepared by CPHEEO)
5. Concession Agreement with GVMC
6. Rules and guidelines of Central & Andhra Pradesh Electricity Regulatory Commissions.

In addition to compliance with statutory provisions, Reliability and Techno-economic viability are also key guiding factors.

Quantity and characteristics of Solid waste are expected to vary over a wide range on daily as well as seasonal basis. WtE processing facility is to be designed to take care of mixed waste under variable conditions.

03.02. Availability of Waste

Quantity and quality of waste generated in any urban area changes over time due to change in demographic profile, economic growth and lifestyle changes. As per various studies conducted MoUD Manual on MSW Management have concluded that per capita waste generated ranges from 200-300 grams for smaller town to close to 600 grams for larger cities. For area under GVMC jurisdiction present level of waste reaching the dump site is estimated as 470g/capita per day with total availability at collection levels as 920 T/day as per DPR prepared by Feedback Infra Pvt. Ltd for APUFIDC. Out of total waste, only 75 – 80% reaches the dump site at Kuppulupadda.

As per assessment made in MoUD Manual, per capita waste generation is increasing by about 1.3% per year. With an urban growth rate of 3.0%–3.5% per year, the annual increase in waste quantities may be considered at 5% per year. Impacts of increasing ULB jurisdiction should also be considered while assessing future waste generation rates.

Projected population growth and waste generation for year 2018, when plant will be commissioned, is given in Table 5 below:

Table 5: Estimate of waste generation

Particulars	Estimate
Population (2001 census)	13.45 Lakhs
Population (2011 census)	18.83 lakhs
Projected population (2018)	22.00 lakhs
Per capita waste generation-gram/day	590
Estimate of waste generation (2018) TPD	1,298 say 1,300
Maximum availability over project lifecycle@ 125% (TPD)	1,620
Plant Sizing - TPD	1,620

As per the terms of concession agreement, provision can be made to process MSW quantity in excess of the obligated quantity based on growth potential of MSW availability. Processing plant capacity is therefore selected as 1620 TPD considering the growth potential.

03.03. Waste Characteristics

As per DPR prepared by Feedback Infra Pvt. Ltd for APUFIDC, survey was carried out inVisakhapatnam in May 2015 as per guidelines given in Manual on MSW Management by CPHEEO and circulated by MoUD. Results of samples are given in Table 6:

Table 6: Characteristics of Samples of MSW

Sl. No.	Item	Unit	Result
1	pH (5% solution)	-	8.01
2	EC(5% solution)	μ siemens/cm	1108
3	Total Waste Soluble	mg/gm	3.4
4	Moisture content	%	38.9
5	Total organic Carbon	%	18.4
6	C/N Ratio (Dry)	-	25.5
7	Calorific Value	Kcal/kg	1220
8	Total Phosphorus	%	0.76
9	Total Potassium as K	mg/gm	0.92
10	Total Nitrogen as N	%	0.72
11	ArsenicasAs2O3	mg/kg	BDL
12	Cadmium as Cd	mg/kg	2.3
13	Chromium as Cr	mg/kg	16.4
14	Nickel as Ni	mg/kg	8.6
15	LeadasPb	mg/kg	17.2
16	Zinc as Zn	mg/kg	36.8
17	Copper as Cu	mg/kg	91.6

Testing was done by SV Enviro Labs, Visakhapatnam

Highlights of the sample analysis reports is summarized as :

1. Moisture content : 38.9%
2. Calorific Value : 1220 Kcal/Kg
3. C/N ratio : 25.5

Data as per DPR of Feedback Infra Pvt. Ltd is considered authentic as the sampling methodology is exhaustive and broad based.

In view of the above, for the purpose of calculations following assumptions have been made in the Report :

- Average moisture level in mixed waste : 30 - 40 %
- Moisture reduction during storage : 18% (Leachate + Evaporation)
- Net weight of MSW available for boilers is taken after removal of moisture, inerts and recyclables as presented in Annexure 10.1 of financial chapters.
- GCV of MSW in 2016 : 1220 Kcal/kg
- Improvement in GCV of waste 1% per year.
- Cap on the value of GCV of fuel feed to boiler : 2100 Kcal/Kg to be on conservative side.
- Sensitivity analysis is also carried out assuming no increase in GCV over years.

Seasonal variations are possible wherein moisture in waste is higher than average in rainy season. Excess moisture will get removed during processing as leachate. This will not effect the GCV of MSW feed to boilers. Boilers will be capable of handling feed CV in wide range.

03.04. Technological Options for Waste to Energy Projects

Rule No. 21.1 of SWM Rules 2016 defines the Criteria for waste to energy process as:

"*Non recyclable waste having calorific value of 1500 Kcal/kg or more shall not be disposed of on landfills and shall only be utilised for generating energy either or through refuse derived fuel or by giving away as feed stock for preparing refuse derived fuel."*

Chapter 3.3 of MSW Management Manual states:

Waste to energy (WtE) refers to the process of generating energy in the form of heat or electricity from MSW. Energy from MSW can be achieved through:

1. *thermal processes like incineration or combustion of MSW fuel; and*
2. *biological processes like bio methanation and further conversion into electrical power or automotive fuel (compressed biogas).*

In addition to the above, Gasification and Plasma technologies for recovery of energy from waste are also available. However, these are not fully mature and are also capital intensive.

All WtE facilities require some degree of simple segregation of MSW for segregation of unwanted material. The quality requirement of Fuel for different WtE technologies is illustrated in the following Table 7.

Table 7: Quality Parameters of MSW for WtE Processes

Parameters	Requirement			
	Bio-methanation	**Combustion**	**Gasification**	**Plasma**
Moisture	>50%	<30%	<20%	<10%
Volatile/ organic	>40%	>40%	>40%	>40%
Fixed carbon	<15%	NA	<15%	<15%
Total inert	<5%	<20%	<10%	<10%
GCV (kcal/kg)	NA	>1,200	>2,000	>2,000
C/N ratio	25-30	NA	NA	NA

As seen from the characteristics of the waste available, Bio-methanation is not recommended due to low C/N ratio. Waste is suitable for combustion for production of electrical energy.

As per the criteria laid down in MSW Management Manual Power Production by incineration of waste is suitable when supply of waste is stable and amount to be processed is at least 500 TPD. Minimum LCV of 1450 kcal/kg and minimum yearly average LCV of 1700 kcal/kg is recommended. In view of this Visakhapatnam project qualifies for Power Production using processed MSW which will have higher LCV than mixed raw MSW.

GVMC and participating ULBs have a goal that the MSW management system shall be a 'model system' for the country, which would scientifically collect, transport, process and dispose of MSW, have maximum recycling and recovery, and create public awareness.

As per scope defined in Concession Agreement the technology adopted forWtE facility whichshall ensure:

- a suitable technology is used for Processing of combustible content of the MSW
- a suitable technology is used for, recovering and processing recyclable content of the MSW,
- not more than 25% of the MSW received at the Processing Facility is disposed off in the Scientific Landfill.
- not less than 2% of waste measured at Processing Output Weighbridge shall be disposed off in the Scientific Landfill

To meet the requirements of SWM Rules and MSW Management Manual, and Concession Agreement following technological consideration are made:

- Processing of mixed MSW in Simple Segregation System using suitable technology for separation of recyclables and inerts and making MSW suitable for incineration.
- Selection of furnace which ensures stable and continuous operation and complete burnout of waste and flue gases using MSW as fuel.
- Flue gas emissions must meet the CPCB norms and standard referred in Schedule – II of SWM Rules-2016
- Leachate disposal should also meet the requirements of the SWM Rules.

03.05. Simple Segregation System (SSS)

Mixed MSW received at WtE facility has high level of moisture content and composition is also heterogeneous in terms of content and size. Raw waste also contains metals and inerts in various sizes in addition to finer organic matter. The processing of MSW involves segregation of material into following components to fulfill the NGT order:

- Segregation of hard chlorinated plastic, batteries, etc;
- Inert material for disposal to landfills or conversion to paver blocks.
- Metals for disposal by sale;
- Segregated MSW for use in Boilers of Power Plant.

Mechanical Segregation process (magnetic separator, Ballistic Separator) is suitable only when moisture level is reduced and material is no longer sticky. Most of the equipments used in MSW segregation plants have relatively long performance track records in different types of industrial applications. Even then, these equipments including the ones imported from highly developed countries seem to have failed to perform in an integrated manner in the various MSW processing facilities installed in the country.

The DST TIFAC technology follows more or less similar process. This involves the conversion of MSW into RDF through homogenization, size reduction, drying and segregation. Hot air dryers, conveyors, feeders, rotary screens, etc are used in the process. Process is in use at some of the installations in the country. However, several operational and maintenance constraints are faced due to high level of moisture. Hot air generators used for drying also are to be designed for RDF fuel. Most of plants using this process are facing operation and maintenace problems due to high level of moisture and hetrogenous waste material.

JUIL has been successfully operatingWtE plant at Okhla by partially drying the MSW using bio-drying process followed by mechanical segregation to the extent required. **Boilers selected are having combusion system suitable for wide variations in fuel cheracteristics. Threfore production of dry RDF as input to boilers is not essential.**

The proposed project has been designed based on MSW suitable as feed to the combustion based power generation plant having 15 MW Power Generation Capacity with a margin of 20% to take cate of future availability and quality of waste.

Process Flow Diagram for the Simple Segregtion System proposed is shown in Drawing No. 1636-002 Sh 01 enclosed with Report.

MSW HANDLING:

Municipal Solid Waste (MSW) arriving at the facility in trucks will be weighed in weigh bridge and unloaded into MSW storage pits near the Tipping floor. Tipping floor will be elevated up for effective unloading of waste. Tipping floor will have four gates to enable dump trucks to unload material in to storage pit.

EOT crane with orange peel type grab will move the received material to storage heaps after addition on inoculums to accelerate bio digestion of organic material. Periodic shuffling of material will allow moisture to settle down and get removed from pit bottom as leachate.

Initially mesophilic bacteria is added which oxidizes carbon to CO_2, which liberates large amount of heat. Temperature up to 50^{o}C is reached within 2 days. After this, thermophilic bacteria is added due to which temperature rises to 65^{o}C, thus releasing

CO_2, moisture etc. Moisture reduction leads to free flowability of waste and loosening of material for easy separation.

Partially dried material can be fed to hopper for mechanical segregation for removal of inerts and fines. Unacceptable material can also be separated manually from conveyor system.

Mechanical Segregation:

After manual sorting, conveyors feed the material to Mechanical separator. Magnetic separator is installed to remove the ferrous scrap before feeding.

Ballistic separator performs screening action as well as gravity separation segregates the waste into following fractions:

- Material above 80-100 mm size is retained on top screen and is sent to shredder for size reduction.
- Middle fraction (10 to 100mm) is feed for the boiler which is transported to Boiler Feed storage. EOT crane with grab will make separate heap and also feed the stored material in to feed hoppers of boilers.
- Heavy inert material is separated by gravity/ inertia separation and is fed to inert material conveyor for disposal.

Output from shredder and crusher for coconut is also mixed with boiler feed.

Proposed Simple Segregation System Drawing – 1638 – 002 Sh. No. 11

Ballistic Separator & Shredder Commissioned at Okhla

03.06. Combustion & Steam Generation

Mass Incineration of unprocessed waste has been the most commonly used technology for WtE projects globally. More than 500 such projects are operating in USA, Europe, China and many other countries. However, this is suitable where MSW is pre segregated at source itself.

Different types of combustion technologies such as travelling grate, reciprocating grate, reciprocating forward feed grate and circulating fluidised bed have been used globally including in India. Travelling grate is the lowest cost option and simple to operate. However, it requires fuel to be of consistent quality having low level of moisture and inert and relatively higher GCV. This technology was used in some projects in India but has not been able to perform resulting in closure of those projects as has been reported in the planning commission report. Few projects have been set up recently in India on circulating fluidised bed technology. This technology is fairly versatile and can accept low grade fuel with varying consistencies. However, feeding low bulk density fuel such as MSW in a pressurised furnace has remained a major challenge resulting in unstable operation of these projects.

The figure below illustrates a typical configuration of a well-designed and environment friendly power project based on MSW fuel.

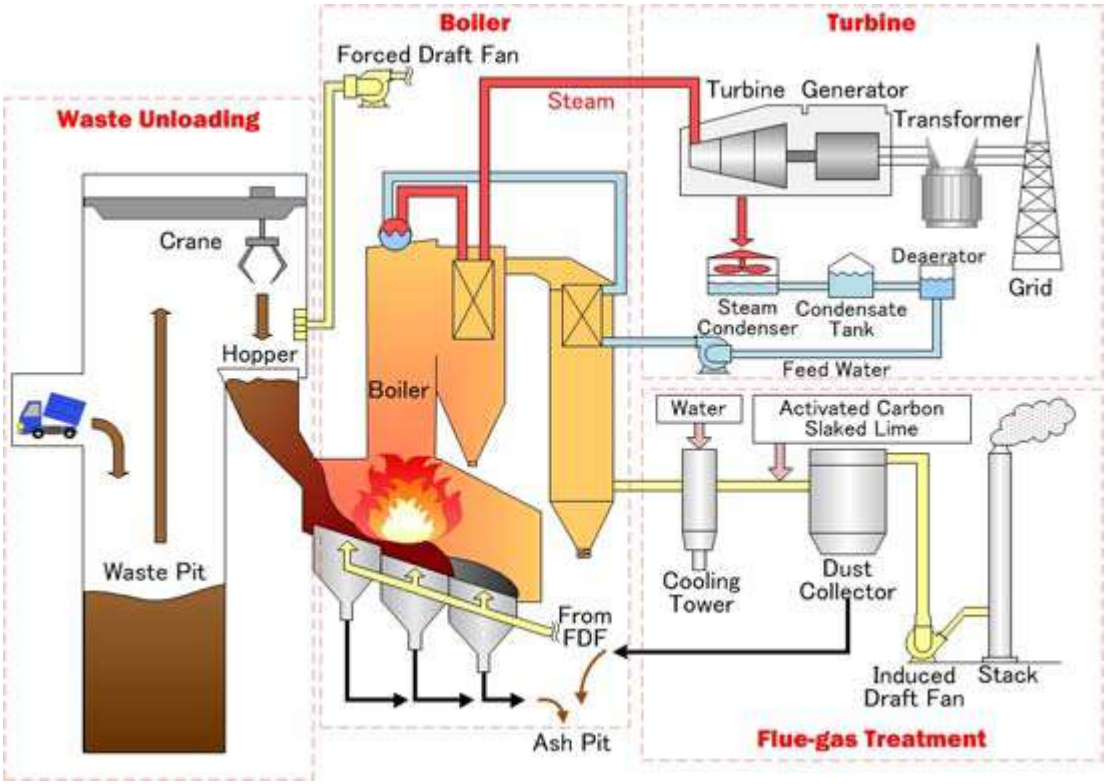


Figure- 10: Schematic –Combustion& air pollution control

Reciprocating forward feed grate has performed most successfully in WtE projects under different fuel conditions all over the world. Fuel is slowly propelled through the combustion chamber (furnace) by a hydro- mechanically actuated grate. Fuel continuously enters one end of the furnace and ash is continuously discharged at the other after going through several to and fro movement within the chamber. The plant is configured to enable complete combustion as Fuel moves through the furnace. Process conditions are controlled to optimize the feed moisture by steam heated air pre-heaters and control the residence time of the fuel in the furnace for complete combustion. Boilers are provided with sophisticated instrument, control and monitoring system to ensure stable operation of the furnace all the time. These include cameras for flame monitoring and temperature gauges for the various sections in the boiler.

The cost of this technology is high. But until other cheaper alternatives are technically proven under Indian operating conditions, this remains the best option for sustainable performance of WtE projects.

03.07. Flue Gas Treatment

Pollution from WtE projects remain a area of high concern both for the regulators and society at large. There is high level of dissatisfaction with the current status of waste management in India. At the same time, there are also apprehensions about likely environmental fall out from the better alternative of WtE projects.Combustion based projects are considered one of the most environment friendly technology provided due care is taken for control of air pollution. Air pollution control technology has been developed to take care of all concerns through elaborate arrangement of multi stage treatment and control and monitoring system.

Provisions are made in the design of the combustion system of boilers to minimize the level of pollutants present in the flue gas coming out of the boiler. Further treatment is required to bring the levels below the prescribed values as per SWM Rules and CPCB norms. Since norms become stringent over a period of time, care is to be taken to select treatment section so that future requirements are also met without much modifications.
Flow Diagram for Combustion boiler and Flue Gas Treatment is shown in Drg. No. 1638-002 Sh02

The flue gas treatment system consisting of lime and activated carbon injection system, quenching chamber and reaction tower followed by bag filters ensure total compliance with the most stringent regulation anywhere in the world. Process control for the flue gas treatment facility consists of three loops, in which the first loop continuously controls the flow of re-circulated absorbent to the reactor by continuously monitoring the quantity of flue gas. The second loop is controlled by a

temperature measurement of the outlet gas, which ensures that the flue gas is cooled down by controlling the quantity of water sprayed. The third loop is used to control the adding quantity of lime milk through acid gases (HCl, SO_2) of the outlet loop. Flue gas flowing out from the reactor then goes into the bag filter removal of micro particles including hazardous substances. The purified flue gas is discharged by ID fan and vented into the atmosphere. The number of components and their footprints and quite large, requiring large amount of land area. Both capital and operating costs are fairly high and have to be specifically factored for financial viabilityanalysis of such projects.

03.08. Ash Handling

Combustion of MSW produces fly ash and bottom ashjust, as is the case when coal is combusted. The total amount of ash produced by municipal solid waste combustion ranges from 4 to 10% by volume and 15–20% by weight of the original quantity of waste and the fly ash amounts to about 10–20% of the total ash.Volume reduction of MSW by upto 90% is possible with combustion plants, thereby almost eliminating the requirement of landfill.

03.09. Odor Pollution Control

Odor pollution can be a problem with old-style plants, but odors and dust are extremely well controlled in newer WtE plants. They receive and store the waste in an enclosed area with a negative pressure with the airflow being routed through the boiler which prevents unpleasant odors from escaping into the atmosphere. However, not all plants are implemented this way, resulting in inconveniences in the locality.

03.010. Effluent Treatment

Effluent is generated due to draining of leachate from the waste bins and waste water from air pollution control and cooling water system. Technology is available for minimising the water requirement in various processes and recycling the waste after treatment for applications such as floor washing, gardening and brick plant, cooling in FGCS, etc.

Leachate collected from MSW storage pit is treated in treatment plant for recovery of water. Rejected part is used for ash quenching.

03.011. Power Generation

Rankine Steam Cycle is used for power generation. Efficiency of the Rankine cycle depends upon the pressure and temperature of the superheated steam. With a view to contain the corrosion impact at higher temperatures, steam temperature for MSW based power plants is maintained at around 400^{o}C and consequently the pressure at around 42kgf/cm^{2}(a).

JUIL has successfully implemented the 16 MW WtE project based on reciprocating forward feed grate and Rankine technology at their Okhla plant. The project has been operating at desired PLF level since then.

Proposed configuration for this project will ensure that the fuel quality available for combustion in boilers using bio drying process will be better than the fuel used in existing Okhla plant resulting in efficient operation as well as better availability of plant for power generation.

More detailed description has been provided at Chapter 4 of the report including proposed flow diagrams for each process.

04. SELECTION OF PLANT & EQUIPMENT

04.01. General

The project consists of the following main units:

MSW Receipt

- Weigh bridge
- Tipping Floor

Simple Segregation System

- Common MSW pit for storage and drying (7 days capacity)
- Material Segregation (Magnetic Separator, Ballistic Separator)

Power Plant

- Boiler including auxiliaries
- Air pollution control system
- Ash handling and Disposal
- Turbo generator
- Condensing plant

Balance of Plant

- Water system
- Compressed air system
- Electrical system
- Control & instrumentation system
- HVAC
- Fire fighting
- Effluent treatment
- Environment monitoring system
- Sanitary Landfill

04.02. Material Receipt

04.02.1. Weigh Bridges

Two weigh bridges (1-input & 1-output) of minimum 40 tons weighing capacity will be installed on approach road from main vehicle entry gate to the material recovery facility. Salient features of the weigh bridges proposed are:

- Recording facility for complete details of vehicles using close circuit cameras.
- Platform scales have the capability of accurately measuring tare and net weights of range of vehicles.
- Recording facility for tare, gross and net weight and volume of each consignment.
- Computerized system for billing and tracking vehicle movement.
- The weigh bridge will be a permanent structure furnished with appropriate space to maintain and operate the computerized weight recording system, store historical records and have sufficient room for two weigh bridge operators.
- Maintain an electronic database for each delivery with time stamp and provide a print out of the specifications and details for each consignment received at the Project Site with provision for on line monitoring and transmission of data.

Table 8: Technical Parameters for Weigh-bridge

Weigh-bridge type	:	Electronic type with load cells
Material handled	:	MSW trucks, compactors and other vehicles
Weigh-bridge capacity	:	40 MT
Accuracy	:	± 5 kg
Weigh-bridge construction	:	Pit less with approach ramps on both sides and non-skid type steel plates
Platform size	:	9m x 3m
No. of load cells for weighing	:	Minimum four number
Nominal load	:	23 MT per load cell
Max. load without damage	:	150% of rated capacity
Destructive load	:	225% of rated capacity
Weighing console	:	Microprocessor based with suitable memory device for storing data of 90day with 250 trucks per day transactions.
Area classification	:	Safe
Corrosion Allowance for fabricated items	:	3mm
Material of Construction	:	IS 2062, for fabricated structure / component
Control Console Room	:	The console shall be provided on suitable table with the operator chair at a convenient location in the control room. The control room shall also be provided with window air- conditioner(s). UPS for 2 h. rating, required for the system shall be supplied.
Design Standard:		Indian Standard IS-1436 (1991): Weighbridges – Specification IS-9281 Part 1 of 4 (1979) : Specification for Electronic Weighing System

Weighbridges shall conform to the Indian Standards for Weights and Measures certified by statutory authorities.

04.02.2. Tipping floor

MSW shall be delivered at the plant premises by respective ULBs. Each truck carrying the municipal solid waste will be visually inspected before it goes to a weighbridge. If the MSW vehicle contains a high percentage of unwanted materials, then it shall not be accepted in the plant. After weighing , the trucks will proceed to the tipping floor, where the driver unloads the waste in the designated dumping pit . This tipping floor is elevated for effective unloading of waste in to the pit.

Sufficient quantity of decomposing microbial cultures (inoculums & sanitizer) will be inoculated at this point with sprayer to reduce odor and enhance digestion process.

04.03. MSW Storage and Handling

It has been estimated that about 1,326 t/d waste would be available in 2018, the first year of operation of the proposed WtE project at Guntur. Considering the committed quantity at 125%, the fuel preparatory system has been designed for 1,650t/d. The details of the system and components are described as follows.

SSS consists of MSW unloading, manual / mechanical segregation and shredding and crushing of Coconut shells. SSS of waste will be done in the 2 shifts (16 hours) and one shift will be for maintenance and cleaning of section. Equipment sizing will be done accordingly to handle the waste in this stipulated time. Proper redundancy will be designed for critical equipment's to reduce the breakdown time.

The detailed process flow and material balance diagram for SSS is included as Drawing No. 1636-002 Sh.04

04.03.1. MSW Pit

There will be a common pit for receipt and Storage of MSW. MSW will be stored in heaps for moisture removal. Hoppers will be provided to feed the material to SSS and segregated material will also return to same pit In some cases if, ULB's supplies unsegregated waste, to fulfill the NGT order simple segregation will be taken place. Separate heaps will be made for storage of processed MSW for charging in to boiler feed hoppers.

Area including tipping floor and pit will be in a closed shed with adequate provision of natural lighting. Air from shed will be sucked by Primary air fans of the boilers to create a negative pressure in pit so that foul smell does not affect the surroundings.

Two EOT (Electric Overhead Travel) cranes with orange peel grab will be provided for handling of material.

04.03.2. Manual & Mechanical Segregation

Manual Segregation:

Dried material is fed by grab crane with 8 m^3 capacity grab into hopper (FH-1). Hydraulically operated Ram feeder feeds the wide horizontal conveyors (BC-1). Manual sorting will be done on conveyor platform. Unwanted material like hard chlorinated plastics, batteries, etc., oversize items and inerts are manually sorted and loaded on to conveyor (BC-2) and discharged at one end of conveyor into a collecting open bin for subsequent disposal by pay-loaders and dumpers.

Mechanical Segregation:

After manual sorting, the material moves through the Magnetic separator installed above horizontal conveyors (BC-1) to remove the ferrous scrap before feeding into the Ballistic Separator.

04.03.3. Disposal of Rejected Material

All rejected materials are sent to landfill sites through vehicles. The weighbridge operator weighs the tare vehicle as well as loaded vehicle after the rejected material is loaded.

04.03.4. Overall Parameters of SSS

MSW received from Municipal Corporations is heterogeneous and its characteristics change with source of collection, season and other factors. SSS is to be designed to take care of wide variation in quality of waste.

Estimated physical characteristics of MSW to be considered for design are as follows:

- Inert Material : ~20%
- Metals : < 0.5 %
- Sand & fine soil : ~ 1 %
- Moisture : 20-40 %

Table 9: Capacity of Simple Segregation System

Handling capacity (MSW)	TPD	1650
Number of parallel streams	No.	1(Working)+1(Future)
Handling capacity of each stream	TPH	50
Operating Hours for each stream	Per day	~16
Capacity of common conveyor for Boiler Feed	TPH	100

Table 10: List of equipment for Simple Segregation System

Equipment	Quantity
Feeding Hoppers	1
Ram Feeders complete with hydraulic arrangement.	2 nos. (Working in tandem)
Magnetic Separator	1
Ferrous Material Bin	1 for manual sorting belt at discharge of magnetic separator.

Equipment	Quantity
Ballistic Separator	1
Structure	1 Lot (Open gantries with both side walkway, trestles and transfer tower for belt conveyor.)
Chutes	All interconnecting chutes

Table 11: List of Belt Conveyors for Simple Segregation System

Purpose	Quantity
Horizontal Feed Conveyor (BC-1)	1
Rejects Conveyor from manual sorting (BC-2)	1
Ballistic Separator discharge to Inert Conveyor (BC-3)	1
Ballistic Separator discharge to fines Conveyor (BC-4)	1
Ballistic Separator discharge to Boiler feed Conveyor (BC-5)	1
Fuel Conveyor (BC-6)	1
Processed MSW Conveyor (BC-7) to Boiler Feed Storage Pit	1

04.04. Power Plant

04.04.1. Boilers including auxiliaries

Reciprocating forward feed type technology has been selected as this has been proven under Indian condition and versatility in terms of fuel quality. Steam requirement has been computed by developing heat and mass balance (HMBD, included as Drawing No. 1638- 001 Sh05). Two number boilers with MSW throughput equivalent of 600 t/d MSW each has been considered. This would help in reducing the project cost (standard module) and improving operational reliability taking into account the periodic stoppages required for cleaning of boilers operating on biomass fuels. The following three parameters have been taken onto account while carrying out basic engineering design of the boilers:

- Air temperature for combustion
- GCV of the fuel
- Exit flue gas temperature

- Boiler combustion system would be designed to operate on MSW of GCV ranging of 1,100 to 2,000 kcal/kg. This would ensure operation sustainability even under uneven drying conditions, fire safety of the plant and storage bin and safety of the reciprocating grate. The grate has three sections, first one for drying, followed by combustion & the last for conveyance of ash. Provision has been made for supply of pre-heated air to take care of flame stability under varying moisture content in the MSW fuel. This would ensure maintenance of appropriate furnace condition ensuring output, efficiency and environment performance all the time.

Heat & Mass Balance for steam system is given in Drawing No. 1638-002 Sh.5

04.04.2. Auxiliary Fuel and Firing System

There shall be a dedicated oil firing system for each boiler, these burner system comprises set of start-up and auxiliary burners. The main purposes of these burners are:

Start-up burner, it will support during refractory dry out for gradually heat up the furnace during start-up for drying and baking of the refractory lining. This system is also used to start the boiler from cold condition for preheating (if necessary) of the furnace during normal start up procedure of the furnace.

Auxiliary burner

- The auxiliary burners have been designed to maintain the required temperature and retention time.
- These burners are used during startup and shutdown condition to achieve certain combustion temperature in controlled way when there is no fuel so as to avoid any damage in installation due to sudden temperature variations.

There is limit of flue gas exit temperature(190^0C) from the perspective of reaction in SNCR. This limits the waste heat recovery potential in the air pre-heater. Further, it is very difficult to control the temperature of pre-heated air in an air pre-heater. It has therefore, been considered necessary to install steam coiled air pre-heater (SCAPH). Two-stage SCAPH-the 1^{st} one based on low pressure steam from bleed of STG and the 2^{nd} one from high pressure saturated steam from steam drum, with appropriate control system would be used. This would help in regulating the final temperature of air as per requirement of the boiler corresponding to the moisture level in the MSW and at the same time optimize the overall thermo-dynamic efficiency of the system along with sustainable environment performance.

Broad specification of the boiler is tabulated below:

Table 12: Specification of the boilers

Particulars	Unit	Value / Description
Number of boilers	No.	2
Boiler grate		Reciprocating forward feed-air cooled
Boiler type		Vertical
Boiler steam capacity (MCR)	t/h	45
Superheated steam pressure	kgf/cm^2 (a)	42
Superheated steam temperature	^{0}C	400
Feed water temperature economizer inlet	^{0}C	130
Fuel density	kg/m^3	150-250
GCV limit-operational stability & safety	kcal/kg	1100-2100
Excess air	%	30 – 70 %
Primary air temperature	^{0}C	220 - 240
Secondary air temperature	^{0}C	150
Efficiency on GCV basis	%	72
Exit flue gas temperature economizer	^{0}C	190
Peak capacity	%	110 MCR
Steam Quality at MSSV outlet		
Conductivity measured at 25 °C	µS/cm	< 0.2
Silica as SiO_2	ppm	< 0.02
Hardness as $CaCO_3$	ppm	Nil
Bottom ash (Grate ash, Bank, Economizer)		Water cooled Extractor
Fly ash		Dense Phase Pneumatic Conveyor

Table 13: Boiler Auxiliaries

Particulars	Description
De-aerator	Common for both boilers
Boiler feed water pump	2W+1S, for two boilers with VFD control
PA fan	1W+1S, for each boilers with VFD control
SA fan	1W+1S, for each boilers with VFD control
ID fan	1W+1S, for each boilers with VFD control
FGCS	Two set, one each for each boiler
SCAPH	LP & HP SCAPH in cascade for each boilers

04.04.3. Flue Gas Pollution Control

Sources of pollution & potential impact

In addition to particulates, certain harmful chemicals can get generated from solid waste during the process of combustion that requires treatment/removal to prevent their harmful impact on human health and environment in general.

Sulphur dioxide (SO_2), hydrogen chloride (HCl), hydrogen Fluoride (HF) and nitrogen oxides (NOx) are acid gases. Solutions of acid gases and water have a low pH-value, thus acidic, and can have negative impacts on vegetation. Acidic gases released into atmosphere are converted into sulphuric acid, hydrochloric acid and nitric acid as they dissolve in water droplets and precipitate onto soil and into water basins. Emission of acidic gases can result in acid rain impacting vast amounts of vegetation and areas of the natural habitat by acidification. The deposition of acid gases can also have corrosive effects on buildings.

Sulphur dioxide (SO_2) health concerns include effects on the respiratory system. People with asthma or bronchitis are most vulnerable to these adverse health effects. Combustion processes that lead to high concentrations of sulphur dioxide (SO_2) generally also lead to the formation of sulphur trioxide (SO_3). This in turn leads to the formation of fine sulphate aerosol particles in the atmosphere, imposing health risks, as they penetrate into the lungs and over time causing potential respiratory disease.
Hydrogen chloride (HCl) is gaseous and forms hydrochloric acid when in contact with humidity or water droplets and deposit on to the ground. Flue gas treatment measures to reduce sulphur dioxide (SO_2) emissions also lead to a significant reduction in hydrogen chloride (HCl) emissions.

Exposure to highly concentrated hydrogen chloride (HCl) may affect human health; causing throat irritation and in extreme cases severe swelling of the throat. Inhalation of hydrogen chloride (HCl) can also lead to asthma. However, hydrogen chloride (HCl) at normal background levels is unlikely to have any adverse impacts on human wellbeing.

The components nitric oxide (NO) and nitrogen dioxide (NO_2) are together termed nitrogen oxides (NOx), because over time nitric oxide (NO) is transformed into nitrogen dioxide (NO_2).Nitrogen dioxide (NO_2) can contribute significantly to the formation of ozone near ground level and contribute to the formation of photochemical smog. Excess ozone (O_3) concentrations are believed to cause increased respiratory symptoms and asthma. Nitrogen dioxide (NO_2) is in itself toxic and reacts with ammonia, moisture, and other compounds to form small particles. The health effects of nitrogen dioxide (NO_2) are similar to that of sulphur oxides. Other oxides of nitrogen include nitrous oxide (N_2O). Nitrous oxide (N_2O) is not a direct hazard to health, but a greenhouse gas with a significant global warming potential.

Ammonia (NH_3) is a volatile gaseous component originating as excess from the injection of ammonia water or urea in the nitrogen oxide (NO_x) cleaning processes. Ammonia (NH_3) deposition to ground has effects on biological conditions through nitrification.

Heavy metals are metallic elements with a greater density than iron and are generally of environmental concern. These metals, with the exception of mercury (Hg), are released in their oxidized form during combustion. They are discharged from the plant with either boiler bottom ash, fly ash or the residual FGT products. Heavy metals from fly ash can leach into a watery phase and thereby enter the environment. Therefore, fly ash is sent to safe/hazardous landfills.

Mercury (Hg) is the most prominent heavy metal and a naturally occurring element that is found in air, water and soil. The tendency of mercury to stick to fly ash particles is low. Mercury (Hg) may have toxic effects on the nervous system and organs. Even at low concentrations mercury (Hg) can cause serious health problems and is a threat to the child development. Human activity is the main cause of mercury release. Once in the environment mercury (Hg) can be accumulated in the food chain. Mercury must be specially taken care of in the flue gas treatment plant, either by application of activated lignite coke as an adsorbent or by absorption in an acidic reactor.

Organic compounds, as a rule, are only generated when there is incomplete combustion e.g. lack of combustion air or insufficient combustion temperatures. Organic compounds are molecules that contain carbon (C) and typically hydrogen (H), oxygen (O) and other elements. Simple molecules like carbon dioxide (CO_2) are regarded as inorganic, whereas methane (CH_4) is classified as organic. Organic molecules can form long molecule chains, rings, and combinations hereof. A well-known class of such molecules are polycyclic aromatic

hydrocarbons (PAH´s) which can be toxic and can influence hormonal balance. Organic compounds and PAH´s are unlikely to form or survive under normal combustion conditions.

Dioxins and furans are highly toxic and relatively stable organic compounds with a polycyclic structure. The presence of chloride (Cl) is a precondition for the formulation of dioxins. During typical waste combustion processes dioxins and furans can get generated in the boiler in trace amounts under certain furnace conditions and mostly segregated and conveyed away with fly ash. In the FGT dioxins are further reduced by injection of activated carbon or lignite coke or alternatively by catalytic reduction. Dioxins entering the environment are persistent pollutants and can accumulate in the food chain, mainly in the fatty tissue of animals. Dioxins can cause reproductive and development problems, damage to the immune system, interfere with hormones and also cause cancer. Human exposure is mainly through food consumption, thus food supply is monitored by relevant agencies/organisations to detect concentrations and prevent human consumption.

Particulate matter and dust mainly originates as fly ash from the combustion process. The introduction of powdery reagents and reaction products in FGT plants also adds to particulate matter presence in the flue gas. Particulate filters limit particulate matter and dust emissions from incinerators.. The absence of a particle filter at anincinerator would result in a dark exhaust plume from the stack.

There are various technologies for the reduction depending upon the type of the emissions level required & emissions available.

Pollution Control

Prevention of generation of hazardous chemicals by maintaining proper and stable furnace operating conditions followed by installation of state of art emission control technology have been adopted for control of emission. Fuel processing section has been designed to maintain fairly consistent with GCV of fed fuel to the boiler. The reciprocating forward feed type technology with fully automatic combustion control system has been selected to maintain the furnace operating condition. This would ensure that minimum temperature of 850 ^{0}C is always maintained in the combustion chamber and with a gas residence time not less than 2 (two) seconds. Reciprocating movement of the burning fuel mass and supply of proper quantity of preheated air would ensure complete combustion maintaining total organic carbon (TOC) content in the slag and bottom ashes less than 3%, or their loss on ignition at less than 5% of the dry weight.

Various technologies have been developed for flue gas emission control taking into account the potential formation of such chemicals due occasional operational instability. A comparative assessment of these technologies is illustrated in the following table.

Table 14: Comparative evaluation-emission control technologies

Evaluation particulars	Dry	Bi-carbonate	Semi-dry	Combined (wet & dry)	Wet
Operational reliability					
Performance history of reliable operation	√√ √	√√√	√√√	√√	√√
Capability					
Ability to handle changes in raw gas composition	√	√√	√√	√√√	√√√
Flexibility					
Ability to meet more stringent future emission limit	√	√	√√	√√√	√√√
Health and safety					
Reduced contact with hazardous material	√√	√√√	√√	√√	√√
Sensitivity to local conditions					
Limited plume visibility	√√ √	√√√	√√√	√	√
Discharge of treated waste water	N/A	N/A	N/A	N/A	√
Other environmental issues					
Low chemical consumption	√	√√√	√√	√√√	√√√
Low electricity consumption	√√ √	√√√	√√√	√√	√√
Low residue production	√	√√√	√√	√√√	√√√

The semi-dry FGT system is the most attractive option. A wet flue gas treatment system can reduce some emission limits to lower levels. However, this system produces effluent requiring treatment at the plant and its discharge as wastewater.

However, it is recommended to go with semi-wet type of system.

'Advanced' SNCR systems can achieve NO_x emission guarantees of around 100 mg /Nm³. This corresponds to 50% of the current daily average emission limit set in the IED. SCR systems can reduce NO_x emissions to 25 mg NO_x/Nm³ or lower. Air quality modelling should consider the emission limits that can be achieved with SNCR 100 and SCR systems to facilitate an informed consultation and decision on the de-NO_X system choice. Furthermore, financial considerations should also form part of the decision making process.

The key components of the combined system, flue gas and material flows together with conditions such as typical flue gas temperatures at various stages of the plant are shown in the following figure.

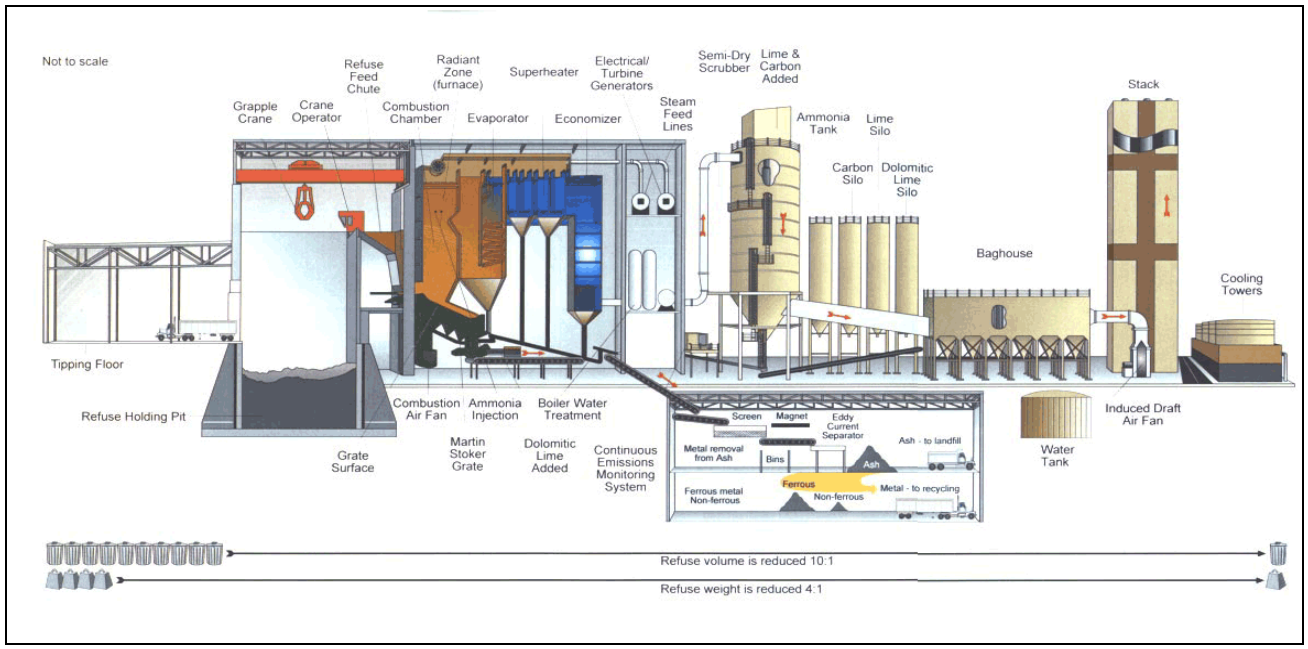


Figure- 11: General Process of Emission Control System

The system consists essentially of the following major components:

- Flue Gas System inlet Duct
- Reactor and Product Recirculation System
- Bag House Filter
- Sorbent Handling System
- End Product Handling System
- Process Water System
- Auxiliary Systems (Compressed Air System, Nitrogen Inserting System)

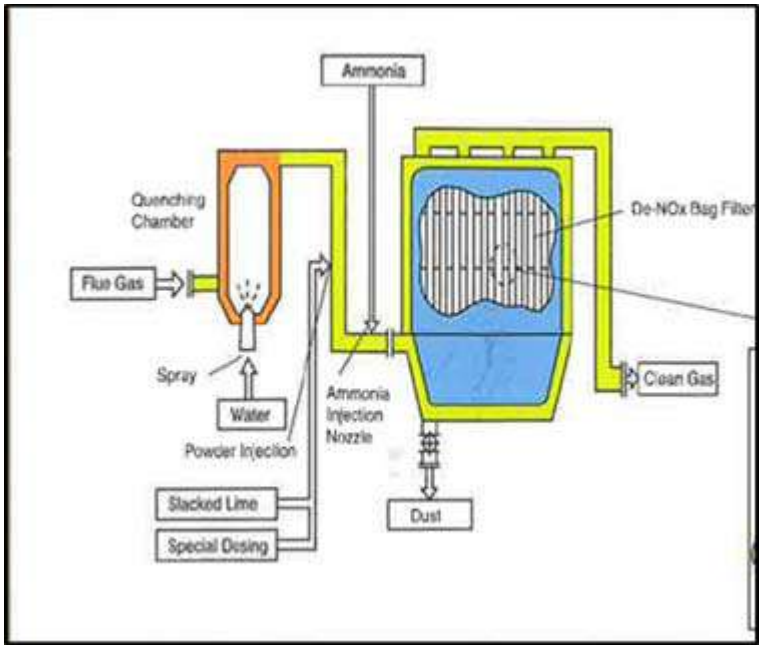


Figure- 12: Schematics Flue Gas Treatment System

Outlet emissions are monitored through sophisticated continuous emission measuring instruments. The system measures following parameters: CO_2, HCI, NO, NO_x, O_2, SO_x and SPM. Gas temperature and the pressure are also analysed continuously to regulate the dosing of sorbents. However, all other parameters would be monitored on weekly basis.

By means of the Reactor and the externally circulating fluidized bed it is possible to adjust extremely long solids retention times which enhance the pollutant collection efficiency and the utilization of the sorbent. Besides this fact the good effectiveness of the process is obtained by a high-turbulent flow of the solids in the Reactor and by the resulting maximum mass and heat transfer.

Dioxins/Furans and Mercury removal by adsorption

The control of the dioxins/furans and heavy metals – especially mercury – is performed by means of adsorption on pulverized activated carbon (HOC). The HOC is injected into the Reactor together with the slaked lime.

Due to the high specific surface of the adsorbents combined with an ideal pore size distribution the HOC-dust excellently removes the above mentioned pollutants. An adequate residence time for the adsorption of the pollutants is available due to the entrained flow phase within the Reactor and the filter cake on the filter bag surface and due to the external recirculation of the whole sorbent. As the flue gas penetrate this homogeneous layer at the filter bags from the outside to the inside, heavy metals, dioxins/furans and traces of the acid gas components are physically and chemically adsorbed and thus removed from the flue gas. The particulate pollutants are removed using the bag house filter.

The effectiveness of the selected pollution control technology has been very well established in the 16 MW WtE TOWML project as would be seen from the monitoring result compared against the norm below.

Table 15: Emission norms as per CPCB, MoEF

Parameters	Unit	Emission standard	TOWMCL Okhla Plant	Sampling Duration
Particulate matter	mg/Nm^3	50	30	30 min
HCl	mg/Nm^3	50	30	30 min
SO_2	mg/Nm^3	200	100	30 min
CO	mg/Nm^3	100 50	100	30 min Standard refers to daily average value
Total organic carbon	mg/Nm^3	20	20	30 min
HF	mg/Nm^3	4	4	30 min
NOx	mg/Nm^3	400	350	30 min
Total dioxins & furans	$ngTEQ/Nm^3$	0.1	0.1	6-8 hours sampling
Cd +Th + their compounds	mg/Nm^3	0.05	0.05	2 hours
Hg and its compounds	mg/Nm^3	0.05	0.05	2 hours
Sb + As + Pb + Cr + Co + Cu + Mn + Ni + V+ their compounds	mg/Nm^3	0.5	0.5	2 hours

04.04.4. Ash Handling & Disposal

Inerts are partially removed in the SSS plant. Balance amount of inert present in the fuel along with inherent ash in various combustible materials would constitute the total ash content in the fuel fed to the boilers. The generated ash in the boiler would be in two forms-bottom ash and fly ash. Bottom ash is discharged by the grate to the ash system designed for the purpose. Fly ash is formed by the fine inert and product of combustion carried away by the flue gas.

The fly ash content ranges from 2 to 3% of the fuel and bottom ash content ranges from 11 – 15% of the fuel, depending upon the quality of the fuel and separation (source segregation) it may increases to 20%. Accordingly, the estimates for the bottom and fly ashes are as shown below.

Table 16: Ash generation

Particular	Unit	Value
Fuel	t/d	1,100
Ash	%	19.25
Ash	t/d	212
Bottom ash	t/d	168
Fly ash	t/d	44

Bottom ash from grate & ash form the bag house filter & economizer is hot & generally water quenched, whereas the ash form the flue gas handling is conveyed to the silo by dense phase pneumatic conveying system. Considering the fly ash from bag house filters & economizer is assumed to 50%, same is used to compute the following capacities.

Table 17: Ash handling capacity

Particulars	Unit	Value
Ash extractor	t/d	200.00
Bed ash temperature	^{0}C	800.00
Temperature of discharge	^{0}C	35.00
Water required	t/h	2.93
Factor of margin	%	20.00
Water required	t/h	3.50
Vibrating conveyor	t/d	280.00

Water is required for the ash quenching. It is proposed to utilize treated effluent for the same with a view to achieve the set objective of zero discharge from the plant.

Table 18: Water requirement for ash quenching

Particulars	Unit	Value
Average temperature of ash	^{0}C	800.00
Temperature of discharge	^{0}C	35.00
Water required	t/h	2.93
Factor of margin	%	20.00
Water required	t/h	3.50
Available water from treated effluent	t/h	4.50

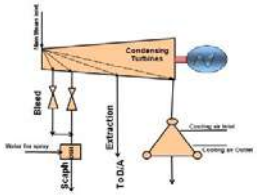
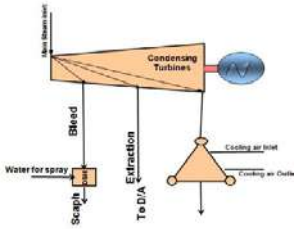
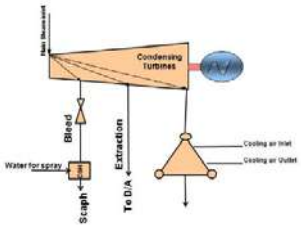
The entire requirement of ash quenching water will be met from effluent. The quenched ash would be discharged into vibratory conveyors for onward disposal. Fly ash is conveyed to the silo by a pneumatic system, which has been proven to be the best option. It is transported out from the silo for onward processing/disposal (landfill/ brick manufacture).

04.04.5. Turbo-Generator

Turbo-generators convert the thermal energy of steam into mechanical work (Turbine) & then convert the mechanical energy to the electricity (Alternator). Depending upon the size of the machine and operating parameters, the alternator can be either directly coupled to the turbine or mechanically connected through a gear box in between, later is mostly the case in case of smaller capacity machines such as the ones for WtE projects.

High pressure steam is admitted into the chamber of the turbine and then expanded in fixed and moving nozzles depending upon the turbine configuration. During the process of expansion (adiabatic in ideal case), the nozzles/blades thermal energy is converted into mechanical work. Low pressure steam at the end of the expansion can be either extracted for processes and/or preheating of feed water for improving the overall thermodynamic efficiency of the plant or condensed directly at lowest possible pressure (related to the absolute atmospheric pressure) for generating maximum power from the available steam. Steam is required in the WtE plant for the SCAPH as well as feed water de-aerator. This steam can be extracted from the turbine under different modes, the relative merits and demerits are as shown in the following table.

Table 19: Comparative of bleed & extraction

Design consideration	Extraction (Wander bleed)	Controlled Extraction	Uncontrolled extraction
Most efficient load range	50-80%	80-100%	Design Set point
Generally preferred	Process is important. Power production is not so important.	Constant pressure at outlet at all loads range.	Where steam pressure & temperature at outlet is not so relevant to process.
Controlling	HP steam bleed taken into account at low load, where as the MP steam bleed is taken at full load	Pressure is constant but outlet temperature varies, as isentropic efficiency varies with load.	No controlling- as the outlet temperature & pressure is the function of the load.
Used	Mainly for process rather than power generation.	Where constant pressure & temperature is required.	Where the steam parameters can vary with load.
Overall STG efficiency	Moderate	High	Function of steam properties at design point.
Schematic Representation			

As stated above, maintaining outlet air temperature from the SCAPH is vital for stable operation of the boilers. Temperature of the steam from the bleed from the turbine would fluctuate with load making it difficult to control the air temperature. Maintaining de-aerator temperature on the other hand would be possible with bleed steam under all conditions. Wander bleed (extraction) provides the compromise solution. The turbine has been accordingly configured so that both the operational requirement of the SCAPH and overall performance requirement are optimally met.

Table 20: Specifications of turbine

Parameters	Unit	Value/ Description
STG		1 x 15 MW
Type		Impulse + reaction
Steam pressure inlet	kgf/cm^2	39.00
Steam temperature inlet	^0C	395.00
Steam flow inlet	t/h	80.00
Exhaust steam pressure	kgf/cm^2	0.18
Exhaust steam flow	t/h	80.00
Mechanical efficiency	%	>95%

Table 21: Specifications of Alternator

Parameters	Unit	Value
Codes and standard		IS/IEC
Design ambient temperature	°C	50.00
Design relative humidity	%	60.00
Frequency	Hz	50 (-5% to+3%)
Generating voltage	kV	11±10%
Quantity	No.	1.00
Rating	MVA	18.75
Power factor		0.80 (lag)
No. of phases	No.	3
Speed	rpm	1500
No of Poles	No.	4
Short circuit ratio		> 0.50
Connection		Star
Insulation type		Class F for both rotor and stator
Temperature rise		Class B for both rotor and stator
Excitation type		Brush less excitation
Cooling method		CACW
Control Panel		AVR (2A +2M), Synchronizing panel , Generator Relay and Metering Panel, LASC&PT Panel, NGR Panel

Table 22: Specifications of Gear box

Parameters	Unit	Value/ Description
Standard		AGMA 2
Efficiency	%	>98%

04.04.6. Condensing Plant

High pressure steam is expanded in the turbine and condensed in the condenser at the lowest possible pressure for extracting maximum possible work from the thermal energy contained in the steam. Generally the water cooled condensers are most favourable for condensing steam. Hot water is cooled by the cooling tower & heat is rejected to atmosphere by evaporation of water. Thus over the time span the concentration of the salt level in the cooling water sump increases. This requires periodic blow down to maintain the concentration of total dissolved solids (TDS) within limit. Higher concentration of the TDS in circulating water will lead to the scaling on the surface of condenser thus decreasing the performance. TDS in the circulating water is normally not allowed to exceed the range of 2,500-3,000 ppm for circuiting water. The amount of blow down is governed by the concentration of the dissolved salts in the make-up water. It is proposed to use the sewage water for the power generation. Based on experience of past projects ,treatment cost of the sewage water for use in the cooling tower becomes non-techno viable. The comparative evaluation of water system compared for air cooled condenser (ACC) and water cooled condenser (WCC) which is shown in the following table.

Table 23: Comparison between ACC & WCC

Particulars	ACC	WCC
Cooling media	Air	Water
Vacuum at STG exhaust	>0.17	>0.10
System efficiency	Lower	higher
Application	Scarcity of water	Abundant water
	High treatment cost of water (Sewage water/ Bore well with high TDS)	Water quality good
Investment	High	Low
Operating cost	Low	High
Auxiliary power	Low	High

Table 24: Water requirement

Parameters	ACC	WCC
Cooling tower water make up (t/d)	200	2,980
Effluent (t/d)	~100	833
Effluent TDS (ppm)	3,200	3,800

In past projects it has been studied that the life cycle costing for similar type of the water properties yields more attractive for air cooled condenser than water cooled condenser. It is therefore, proposed to deploy ACC for the project. The specification of the ACC has been developed as shown in the following table.

Table 25: Specifications of Air Cooled Condenser

Parameters	Unit	Value / Description
Heat to be rejected	Mcal/h	~38,000
Type		Finned coils
Cells	No.	6
Temperature of condensate outlet	^{0}C	~58
Flow of steam to be condensed	t/h	75
Enthalpy of the steam at STG outlet	kcal/kg	566
Temperature of air	^{0}C	35
Ambient temperature for Design	^{0}C	40

Different types of fins are available for ACC. The comparative analysis is tabulated below:

Table 26: Comparatives-ACC types

Criteria	KL Type	Extruded Type	G-Type
Corrosion	Tube Protected against corrosion	Tube protected against corrosion	Provides perfect fit between fin & tube
Vibration	Resistant against vibration	Fins have extra rigidity	Comparatively Lower
Thermal Performance	High thermal performance and stress resistance with atmospheric corrosion protection	Heat transfer remains constant	Varies have comparative less performance than other
Temperature Operation	KL can be replaced by any other type of fins (Can be used up to 320^{0}C)	Can be used up to 300^{0}C	Can be used up to 400^{0}C

As it can be seen from the table that the KL type of fins are more corrosion resistant, having high thermal performance & resistant against vibration. Considering all above points it KL option has been recommended.

The auxiliary power required for MRF processing facility and the power plant have been estimated at about 1100 kW and 1500 kW respectively constituting about 7.5% for MRF and 10%for power plant. The processing plant has been designed to operate only for 16 hour a day. Therefore the plant would consume about 17.5% as auxiliary for 16 hour and 10% for rest 8 hour. Accordingly peak power export would be at 13.5 MW. With a view to determine the exportable power the overall auxiliary consumption has been computed as follows.

Table 27: Requirement of Auxiliary power

Particulars	Unit	Value
Power generation	MW	15.00
Only power plant operation	H	8.00
Process operation	H	16.00
Only power plant auxiliary load	%	10.00
Power plant auxiliary load only	MW	1.50
Energy required for only power plant operation	MWh/d	12.00
Auxiliary load when process is in operation	%	17.50
Power required during hours when process is in operation	MW	2.63
Energy required during process operation	MWh/d	42.00
Auxiliary average during 24 hours	%	15.00
Auxiliary power average during 24 hours	MW	2.25
Energy required	MWh/d	54.00

04.05. Balance of Plant

04.05.1. Water Systems

Water is required in a power plant for different applications; largest requirement is for cooling followed by other processes including boiler and smaller quantity for drinking and sanitation. Natural water can be used for cooling but it is preferable to use soft water for maintaining high cycle efficiency of the power plant. Demineralised water is required as make up for boiler feed whereas specifications of drinking water are as per the standard laid down for the same.

The detailed water balance diagram is included as Drawing No. 1638-002 Sh 07.

The quantitative and treatment requirement are primarily governed by availability and quality of the raw water. Properties of the raw water at the project site as per test report are tabulated below:

Table 28: Water properties

Particulars details	Unit	Raw Water Quality
(Treated Water STP)		
Total Suspended solid (TSS)	mg/l	200.0
Total Dissolved Solids (TDS)	mg/l	1200.0
Calcium (as Ca)	mg/l	78.0
P.Alkalinity (as $CaCO_3$)	mg/l	21.2
Total Alkalinity (as $CaCO_3$)	mg/l	500.0
Nitrate (as NO_3)	mg/l	12.0
sulphate (as SO_4)	mg/l	124.0
Sodium as Na	mg/l	174.0
Iron (as Fe)	mg/l	1.76
Zinc (as Zn)	mg/l	< 1.0

Particulars details	Unit	Raw Water Quality
Chloride (as Cl)	mg/l	250.0
Chemical Oxygen demand (COD)	mg/l	250.0
Biochemical Oxygen Demand (BOD)	mg/l	50.0
Dissolved Oxygen	mg/l	5.9
Bore Well Water		
pH		7.3
Total Dissolved Solids at 105^0C	mg/l	2310
Chlorides	mg/l	587
Total Hardness as CaC03	mg/l	1217
Nitrates as NO3	mg/l	31
Sulphates (as SO4)	mg/l	334
Iron as Fe	mg/l	0.45
Zinc as Zn	mg/l	0.23

TDS concentration in Bore well water is high and yield of water from bore wells is also low.GVMC has assured that water from STP will be made available .STP is located about 2 km from the project site.

Water Requirement

For the purpose of this report treated water available from STP is taken as input. Total requirement of water for the project is estimated as 500 m3/day as per water balance.

It would be desirable to soften the water required for make up in the auxiliary cooling tower. The capacity of the auxiliary cooling tower hasbeencomputed at 350 m3/h assuming 10% design margin. The specification for the same is as presented in the following table.

Table 29: Parameters of Cooling tower

Particulars	Unit	Value/ Remarks
Flow	m^3/h	350
Cells	No.	2
Type		Induced draft counter flow
Fills		PVC
Basin		RCC
Fans		With VVVFD & angle control
Temperature of hot water inlet to cooling tower	^0C	42
Temperature of cold water outlet of cooling tower	^0C	32
Dew Point	^0C	23
Wet bulb	^0C	28
Range	^0C	10
Approach	^0C	4

Accordingly the broad requirement of the clariflocculator, softening and DM water plant has been computed as shown in the following tables.

Table 30: Specifications of Pretreatment plant

Particulars	Unit	Value
Capacity	t/d	600
Hardness inlet	PPM	200
TDS inlet	PPM	1200
TSS	PPM	200
BOD	PPM	250
COD	PPM	50
BOD outlet	PPM	< 10
COD outlet	PPM	<20
TSS	PPM	< 50

Table 31: Specification of Treatment plant

Particulars	Unit	Value
Capacity	t/d	500
Hardness inlet	Ppm	200
Hardness outlet	Ppm	<10
TDS inlet	Ppm	1200

DM water system would consist of Primary sand filter→Activated carbon filter → Ultra-filtration→ reverse osmosis→ De-gases→ De-mineralized plant

Table 32: Parameters for DM Plant

Particulars	Unit	Value
Capacity	t/h	10.0
Hardness inlet	Ppm	200
Hardness outlet	Ppm	Nil
TDS inlet	Ppm	1500
TDS outlet	Ppm	<0.20
TSS	Ppm	Nil

Flow Diagram for water treatment is shown in Drawing No. 1638-002 Sh06

04.05.2. Compressed Air System

Compressed air is required for services such as pneumatic ash handling system and for instrumentation. The requirement of compressed air has been calculated based on normative consumption and proposed configuration of the project.

Table 33: Compressed air requirement (Nm3/h)

Applications	Instrument air	Service air
Boilers	205	378
Flue gas cleaning system	200	1100
STG set	15	-
Air cooled condenser	20	-
Ash handling system	15	150
Others BOPs and actuators	12	15
Sum Total	467	1534
Design at 15% margin	650	1725

The quality requirement for the service and instrument air is different as shown in the following table.

Table 34: Quality requirement for Compressed air

Particulars	Unit	Service air	Instrument air
Moisture content	Dryness [°C]	Saturated	-40.0
Oil content	ppm	<2	< 0.0003
Minimum pressure	kgf/cm^2	6.5	8.5

It is proposed to install common compressors to supply both instrument and service air. The dryer and filters will be used only for the quantity of air required for Instruments application. For rest of the air, dryers and filters will be bypassed. This air will be used for meeting the requirement of conveying air and service air.

The total air required is 2,380 Nm^3/h considering the standard capacities; we propose to install 3 x 800 Nm^3/h screw type compressors (2W+1S) along with VFD. The compressed air system would include all the required ancillaries such as filters, coolers, dryers, receivers and electrical and instrument and control system.

Flow diagram for Compressed Air is included as Drawing No. 1638-002 Sh 08

04.05.3. HVAC System

The temperature and RH to be maintained in various areas of the plant is as follows:

Table 35: Design Temperature & RH for premises.

Area	DBT °C	RH
Control room and other rooms with electronic equipments	23 ± 1	50 ± 5
UPS &battery charger	24 ± 1	50 ± 5
Operational staff/ administrative rooms	24 ± 1	30 -70
Variable Frequency Drive (VFD) panel room	26 ± 1	30 -70
Switchgear room	25 ± 1	

The main plant control room housing the controls for the boiler and the turbo-generators shall be air conditioned with packaged air conditioners (using chilled water). The condenser plant and other buildings shall be provided with suitable exhaust fans of heavy duty, to ensure heat dissipation and effective ventilation for maintaining a dust free atmosphere. The offices, local control rooms in material sorting facility area and CEMS area will be facilitated with split air conditioner of suitable size. The WTP area will be covered using ceiling fans. The design basis for HVAC system is as shown Table 37:

Table 36: Design basis for HVAC system

Duty type	Type of Construction	Equipments / Systems	Area (m^2)	Recommended HVAC system	Approximate Quantity & Size
Ventilation with heat load	Closed RCC Hall	STG Hall	400	Venturi extractor	12 Nos x 500 m^3/h
Sub cooling with electronics heat load	Closed RCC Hall	Control Room, VFD Drive Room, DCS & PLC room	390	Vapour-compression and absorption chillers	1 x 90 TR (screw compressor)
Ventilation with lower heat load	Closed RCC Hall	Electrical panel, PCC & MCC area	200	Exhaust fans	07 No. x 1000 m^3/h
Ventilation with dust collection	Open Area	Ash Handling, Boiler House	-	Not required	-
Sub cooling	Closed RCC	Offices	40	Split air conditioner	4 No. x2 TR
Ventilation without heat load	Closed RCC	MSW Pit area	-	To be covered by the PA suction	-
Ventilation with lower heat load	Shed	Local Crane panel Room (2 No.)	15 (each)	Ceiling fans	2
Sub cooling with electronics heat load	Closed RCC	Local Grab Control Room for MSW pit (2 No.)	15 (each)	Split air conditioner	2 No. x 1.5 TR
Sub cooling with electronics heat load	Closed RCC	CEMS	6	Split air conditioner	1 No. x 1.5 TR
Ventilation with lower heat load	Shed Area	WTP Control Room	40	Ceiling fans	8

04.05.4. Fire-Fighting System

The fire extinguishing system would consist of the following sub systems:

- Hydrant System
- Spray Water System
    - High Velocity water spray system
    - Medium velocity water spray system
- Hand Appliances System
- Sprinkler System

The hydrant system contains a header pipeline that covers the overall plant and also the hydrants categorized as Fire escape hydrants, single hydrants and water monitors.

The spray system would be deployed for the electrical equipments, specifically the high velocity water spray system for transformer and medium velocity water spray system for all the conveyors.

Number of hand operated portable devices would be housed all around the plant as per requirement of TAC.

Sprinkler System shall include the following:

1. Galvanized iron class C(heavy class) main sprinkler distribution piping complete with welded, forged steel fittings, supports, hangers all required accessories.
2. Installation control valves drain valve, test valve and all connecting pipes and fittings
3. Sprinkler head, nozzles and spare sprinklers.
4. Connection to riser, pumps and appliances.
5. Sprinklers, pump, motors, Control panels, Air vessels, cabling, instruments and accessories etc.

Operation of fire extinguishing system shall be semi-automatic. A common pressurized fire water header would be installed for the Hydrant system, Spray System and sprinkler system. The constant pressure is maintained in fire water header through Jockey pumps.

As per TAC rule no. 7.2.3, grass, hay, fodder, chaff, biomass fuel is coming in the category of High Hazard Occupancy Sub category “A”. We have assumed MSW similar to above mentioned fuels therefore MSW area can be considered in High Hazard Occupancy Sub category “A”. According to TAC 7.2.1 rest of the plant area can be considered in Light Hazard Occupancy. Accordingly, the broad capacity of the fire fighting system has been worked out as follows.

Table 37: Fire Fighting System

Description	Unit	Values
Main fire pump electrical driven		
No of Pumps	No.	1.0
Size	m^3/h	273.0
Diesel engine driven fire pump		
No of Pumps	No.	1.0
Size	m^3/h	273.0
Jockey pump		
No of Pumps	No.	1.0
Size	m^3/h	16.8

Pump House configuration is shown in Drawing No. 1638-002 Sh.09

04.05.5. Effluent Treatment

Effluent is generated from three main sources:

1. Drain from cooling tower
2. Reject & back wash from water treatment section
3. Leachate from the pit

As the TDS of raw water is quite high thus it is recommend installing the air cooled condenser. There will be small cooling tower for auxiliaries.

Reject from the back wash of the equipment's in water treatment section & continuous reject from RO is collected in the tank, Blow down of the cooling tower is also collected in the same tank (Central monitoring basin).

There is net generation of the approximately ~151 t/d of effluent from cooling tower & WTP section, with TDS level varying from 500 to as high as 8,400 ppm. Same is mixed in tank where the TDS is diluted to around 4045 ppm.

As TDS is quite high thus same cannot be discharged into water body, effluent can be used in the plant for the various applications like ash quenching, washing, service water, horticulture, etc, this will consume the effluent on the other hand will reduce the fresh water consumption, thus same is having dual advantage. Water balance sheet attached in the drawing:

Proposed Water Balance Flow Chart 1638 – 002 Sh. 07

Leachate is produced in the MSW storage area and same is computed to vary in range of 5- 10% on the mass of the fuel (MSW). Same is function of the climate also. Leachate collected will be treated to recover water and reject part will be utilized for ash quenching. Thus this will be zero emission as we are completely utilizing the effluent & reducing the raw water.

04.05.6. Environment Monitoring System

The flue gas measurement and monitoring is required for meeting the pollution control board's requirement and also for operation / control of the plant. Central Pollution Control Board has formulated guidelines for flue gas emissions in various kinds of industries. The flue gas measurement and monitoring should meet the CPCB's guidelines and standards. As per CPCB guidelines, below table gives the frequency of monitoring for various parameters for Common Hazardous Waste Inclinator plant:-

Table 38: Flue gas monitoring parameters

Parameters	Location	Frequency
Temperature	Stack emission	Continuous
Carbon Monoxide	Stack emission	Continuous
Excess Oxygen	Economizer outlet, Stack emission	Continuous
Total Particulate Matter	Stack emission	Continuous
HCl emission	Stack emission	Continuous
SO_2	Stack emission	Continuous
NO_x	Stack emission	Continuous
HF emission	Stack emission	Quarterly
Mercury	Stack emission	Quarterly
Heavy metals	Stack emission	Quarterly
Dioxins and Furans	Stack emission	Quarterly

Note: - The above requirement is as per the CPCB's Guidelines for Common Hazardous Waste Incineration, Doc. No. HAZWAMS/---/2010-2011 (May 24, 2010).

The stack is equipped with a Continuous Emission Monitoring System (CEMS). The CEMS will be installed at a sufficiently high level in the stack to assure an even flue gas flow at the monitoring point.

Equipment for measuring gaseous components is installed in an analyser room near to the measurement platform (extractive measurements). Equipment for measuring the flow, dust, pressure, temperature, HCL, H_2O and NH_3 will be installed in situ in/on the flue.

Sampling platform shall be provided as per CPCB norms to collect stack samples from the chimney for monitoring the air pollutants, as and when required. Access shall be provided, online, to see the continuous monitoring data by the local regulatory Board/ Committee and annual environmental report giving complete details of operation & compliance with regulatory requirements need to be published and made available to the public.

There is a laboratory service inside the plant boundary which follows ISO 9000 and other similar standards. The lab shall be well-equipped for monitoring and analysis of environmental parameters for air quality, meteorology, water, wastewater, noise, groundwater, MSW characterization study, GCV testing of MSW, sieve analysis of waste, ash etc. The dedicated weigh bridge which measures the MSW input to the plant and rejects coming out There will be online display inside the plant boundary which shows all above key parameters.

04.06. Electrical System

Plant Electrical System comprises:

- Power Generation
- Power Evacuation
- Power Distribution for Complete WtE facility

04.06.1. Design Criteria

The broad design parameters of electrical power evacuation, generation and distribution system are as follows:

Table 39: Design Parameters for Electrical System

		Power Evacuation System	**Power Generation system**	**Distribution System**
Nominal System Voltage	:	33 kV	11 kV	415 V
Highest System Voltage	:	36 kV	12 kV	433 V
Frequency	:	50 Hz		
Voltage variation	:	±10%		
Frequency variation	:	±5%		
Combined variation	:	±10%		
Impulse Voltage withstand level.	:	170 kV $_{Peak}$	75 kV $_{Peak}$	
One min. Power Frequency withstand voltage	:	70 kV $_{rms}$	28 kV $_{rms}$	
Rated Short time Thermal current	:	31.5 kA	40 kA	65 kA / 50 kA
System Grounding	:	Solidly Grounded	Through NGR	Solidly Grounded

Proposed Power Distribution Scheme is as shown in Drg No. 1638-403 Sh.01.

Necessary control and protection system for parallel operation with grid and also protection of the Generator and the auxiliaries would be provided. It is proposed to provide electronic system for both the AVR and synchronization system. All protection system would be designed for the prevailing fault level at the Grid Sub-station

04.06.2. Power Generation

Power will be generated at 11 kV. The generator will be rated for 15 MW, 11 kV, 50 Hz, and 0.8 PF. The generator will be of air-cooled design and will be provided with brushless type excitation system.

04.06.3. Power Evacuation

Power generated from the Power Plant will be connected to 11 kV Switch Board through segregated phase bus. One of the Circuit Breaker (Synchronized) of this board is connected to LV side of 33/11 kV, 20 MVA Transformer, for power evacuation to the Grid by laying 33 kV transmission line from nearest grid substation of APEPDCL Anandpuram. The grid substation has also adequate land available for installation of the 33kV bay link for the project.

Table 40: Brief Specification Switchyard

Service Type	:	Outdoor
No. of Pole	:	Three (3)
Nominal System Voltage	:	33 kV
Highest System Voltage	:	36 kV
Rated Short time Breaking current	:	31.5 kA
Rated operating sequence (for Auto reclosing)	:	O-0.30 sec -CO-3 min-CO
SF_6/VCB	:	1250A
CT Ratio	:	
PT Ratio	:	
Gapless Lightening Arrestor	:	6 nos.
Isolator with earth switch	:	2 sets
Insulator and Conductor	:	ACSR Conductor (Panther/Zebra)

Metering Section:

Metering facility shall be installed at grid interconnection point. As per the PPA, three meters shall be installed i.e. main meter, check meter and standby meter. Specification of these meters shall be as per the DISCOM metering code. The bill amount generated shall be based upon the main meter.

Proposed Power Distribution Scheme is as shown in Drg No. 1638-403 SH01

Table 41: Brief Specification of Power Transformer

Service Type	:	Outdoor, Oil filled
Numbers	:	1
Rating	:	20 MVA
Rated Voltage	:	33/11 kV ±10%
Frequency	:	50 Hz ±5%
Design Ambient temp.	:	50^0C
Vector group	:	Ynd1
% Impedance	:	6%
Insulation Class	:	A
Temp. rise top oil	:	40^0C
Temp. rise winding	:	45^0C
Tapping range on HV side	:	OLTC & RTCC, 16 steps -10 to +10 @ 0.8%
Overload	:	As per IEC/IS
Separate source power frequency voltage withstand		
HV Winding (kV rms)	:	70 kV
LV Winding (kV rms)	:	28 kV
Full wave lightning impulse withstand voltage		
HV Winding (kV_p)		170 kV
LV Winding (kV_p)		75 kV

Tariff Metering

Export/Import energy meters of 0.2 accuracy class as stipulated by APEPDCL will be provided at the 33kV evacuation sub-station. As per PPA, three meters shall be installed i.e. Main meter, Check meter and Standby meter. Specification of these meters shall be as per DISCOM metering code. The bill amount generated shall be based upon the main meter.

04.06.4. Black Start of The Power Plant

It is the process of restoring an electric power station or a part of an electric grid to operation without relying on the external transmission network.

Normally, the electric power used within the plant is provided from the station's own generators. If all of the plant's main generators are shut down, station service power is provided by drawing power from the grid through the plant's transmission line.

To provide a black start, Power plants shall have diesel generators.

The power required for Black start can be taken from the DG set of required rating.

Table 42: Brief Specification of Power Transformer

Duty	:	Continuous
Quantity	:	One (1)
Continuous rating	:	1500 kVA
Diesel engine	:	4 stroke, water cooled
No. of Phase	:	Three (3)
Voltage	:	415 V ±10%

Frequency	:	50 Hz ±5%
Design Ambient Temp	:	50^0C
Power Factor	:	0.8 (lag)
RPM	:	As per Manufacturer's standard
Class of Insulation	:	H
Starting	:	Auto/Remote
Type of Alternator	:	Self-starting (Electrical)
Cooling System	:	Radiator cooled

04.06.5. Power Distribution

Required number of distribution Transformers is provided to cater the Aux. load requirement of the power plant. These Transformers are fed from the 11 kV switchboards. PCC (Power Control Centre) are considered with the Transformers for further distribution of the loads.

415V PCC also have Incomers and Bus coupler configuration and required number of outgoing feeders.

The 415V Power Control Centre (PCC) will feed the 415V Motor Control Centres (MCCs) for group control of motors as well as Lighting Distribution Board (LDB) and Power Distribution Board (PDB).

Voltage Levels

The generation voltage will be 11 kV, 50 Hz while the power evacuation voltage to grid will be at 33 kV. Power Plant auxiliaries and plant loads will be fed from 415V.

For single phase consumers, 240 V will be used. Control power supply will be 230 V AC derived through dual control transformers for control of motors.

415V Substation for Auxiliary Power Distribution

LVSS of power plant comprises of Unit Auxiliary transformer (UAT), LT Power Control Center (PCC), Motor Control Center (MCC), LT Cables, Motors, earthing, lighting etc.

One (1) no. LVSS viz. for Boiler & TG auxiliaries, miscellaneous loads, for Water Cooled Condenser, Water system and Pneumatic Ash Conveying system will be considered. Actual number of MCCs required will be reviewed during engineering. Necessary provision for feeding emergency DG set power to TG MCC will be made through an incomer of adequate rating.

Table 43: Brief Specification of Distribution Transformer

Service Type	:	Outdoor, oil filled
Numbers	:	3
Rating	:	2.0 MVA
Rated Voltage	:	11/0.433 kV ±10%
Frequency	:	50 Hz ±5%
Design Ambient temp.	:	50^0C
Vector group	:	Dyn11
% Impedance	:	6%
Insulation Class	:	A
Temp. rise top oil	:	40^0C
Temp. rise winding	:	45^0C
Tapping range on HV side	:	Off load, +5% to -5% @ 2.5%
Overload	:	As per IEC/IS
Separate source power frequency voltage withstand		
HV Winding (kV rms)	:	28 kV

LV Winding (kV rms)	:	5 kV
Full wave lightning impulse withstand voltage		
HV Winding (kV_p)	:	75
LV Winding (kV_p)	:	NA

Table 44: Brief Specification of LV PCC

Service Type	:	Indoor
Numbers	:	3
Voltage	:	415 V ±10%
Frequency	:	50 Hz ±5%
Distribution	:	TPN
Busbar Rating	:	3200A Continuous
Busbar Material	:	AL
Current Density of Busbar	:	1A/1.5 Sq mm
Incomer Type	:	ACB, 4P
Configuration	:	Dual Incomer with Buscoupler
Short circuit rating	:	65 kA for 1 sec
Control Supply	:	230 VAC
Space Heater & LED	:	230 VAC
Ingress Protection	:	IP 42

Motors and Controls

All AC motors will be squirrel cage induction type energy efficient machines. The rating and speed of various motors will be suitably based on duty requirements of driven equipment. Motor control centres will have two (2) nos. incomers and one (1)

no. bus coupler. DC motor for emergency oil pump and Jack oil pump of Turbo-Generator will be connected to 110 VDC supply from battery.

Table 45: Brief Specification of Motors

Type	:	Induction motor
Duty	:	Continuous
Cooling	:	TEFC
Winding	:	Copper
RPM	:	As per Process requirement
No. of Poles	:	As per Process requirement
Insulation class	:	F
Temp rise restricted Class	:	B
Rated Voltage	:	415 V ±10%
Rated Frequency	:	50 Hz ±5%

Power and Control Cables

11 kV cables (UE) will be of cross linked polyethylene insulated (XLPE), PVC sheathed, armoured type with aluminum conductor. Cable for 415 V system will be 1100 V grade, heavy duty, XLPE insulated, PVC sheathed armoured, aluminum conductors. 1100V grade multi core PVC insulated PVC sheathed cables with stranded copper conductors will be used for control application. Special cables will be used for signal / data transmissions as required.

04.06.6. Earthing and Lightning Protection

11 kV Generator will be earthed through NGR to limit the earth fault current. 415 V transformer neutrals will be solidly earthed. All non current carrying metallic parts of

various electrical equipment will be properly earthed in accordance with Indian Standards, IE rules and other statutory requirements.

04.06.7. Plant Lighting System

Lighting for the plant will be designed as per current industrial standards. Power for lighting in the power plants and adjoining areas will be fed from emergency power through Lighting Distribution Board (LBD) and Miniature Circuit Breaker Distribution Boards (MCBDBs). Additionally portable chargeable battery type emergency lamps may be considered wherever required.

High efficiency sodium vapour lamps will be used for illuminating high /medium bay areas, pump houses and other plant buildings and outdoor areas / roads. LED lamps will be used for control room, HT & LT panel room, administration and miscellaneous buildings.

04.06.8. 110 VDC Power supply system

110 V DC supply system comprising Battery , Battery chargers, DCDB will be provided for the complete requirement for control protection and interlocks, emergency DC drives of Turbo generator etc., for the Power Plant. The Battery Sizing will be done such that it would be possible to feed the Emergency lube oil pump.

04.07. Instrumentation & Controls

A well designed control and instrumentation system is very vital for sustainable performance of a WtE plant. It also helps in better management of the environmental and social concerns of the public at large through a transparent and open display of real time performance of the plant. A well designed C&I system helps in achieving the set performance goals in a project in respect of:

- Operational efficiency and resource conservation
- Productivity of men & machines
- Safety
- Environmental Integrity

The instrumentation and control system for WtE Plant shall be of Microprocessor based programmable instrumentation with hydraulic/ pneumatic final control Elements. The system shall be of latest state-of-the-art hardware and software based digital Control and information system based automation system. The system shall have capabilities to Supervise, control, operate & collect data from various field instruments located in Power Plant and auxiliaries through-out the network running inside the plant and control room.

The Distributed Control System (DCS) configuration is shown in the drawing No. **1638-412 SH01**. The system configuration shall be functionally/ geographically distributed. In general the configuration shall be as per the enclosed configuration drawing.

The overall I&C system for the project has been designed to have a judicial mix of local and remote control with adequate redundancy briefly summarised as follows.

Simple Segregation System (SSS) area is provided with local control panels at many levels. These panels would communicate with the DCS primarily for the purpose of monitoring and historical trend analysis.

Critical controls of STG set are controlled through their dedicated panels. STG Panel shall house Electronic Governor and Vibration Monitoring Panel. These operations are independent of the DCS operations. However, indications are available in the DCS for monitoring. All other operations are through the DCS such as remote controls for all auxiliary motors of turbine (AOP, EOP and barring gear), condenser hot well level controls, and alarm annunciator for turbine faults, turbine, gearbox and generator bearing oil temperature monitoring, turbine safety interlocks and trip logic. Necessary direct reading field instruments like pressure gauge, temperature gauges, pressure transmitters and level gauges will be provided as per manufacturer's standard practice.

On-line Emission Monitoring System

Continuous emission monitoring systems are used as a tool to monitor air emission standards. Typical monitored emissions include: sulphur 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.

Details of Stack Monitoring are covered in Para 4.6 above.

Figure- 13: Typical Stack Monitoring Station

04.08. Sanitary Landfill (Scientific Landfill)

There will be a dedicated engineered scientific landfill site which will handle the disposed waste from the MSW processing facility. Drainage system, leachate collection system and HDPE Liners have to be established. The facilities will also include weigh bridge, operator cabin, approach road etc.

Leachate Collection System:

The leachate collection system will be designed to maintain a leachate depth or head of 30 cm or less above the liner. The design leachate head is very important as flow of leachate through imperfections in the liner system increases with an increase in leachate head above the liner. Maintaining a low leachate level above the liner helps to improve the performance of the composite liner system. The main components of leachate collection system are leachate collection tank, feeder mains and header main.

Liner System Design:

The liner system for landfill site shall be designed for non-permeable lining system at the base and wall of waste disposal site area. For landfill receiving residues of waste processing facilities or mixed waste having contamination of hazardous material (such as

aerosol, bleaches, polishes, batteries, waste oils, paint products and pesticides) minimum liner specification shall be a composite barrier having 1.5 mm High density Polyethylene (HDPE) geo-membrane or equivalent overlying 90cm of soil(clay/amended soil).

Final Cover System:

The final cover system consists of the following components,

1. Vegetative layer of 450 mm thick with good vegetation supporting soil
2. Drainage layer of 150 mm thick granular material
3. Barrier layer of 600 mm thick clay/amended soil
4. Gas venting layer of 200 mm thick granular material

05. PLANT LOCATION AND LAYOUT

05.01. Plant Location

Visakhapatnam Waste to Energy Plant is proposed to be located in KapuluppadaVillage, BheemiliMandal in Visakhapatnam district. Salient features of the plant site are as follows:

Latitude	:	23^0 39' N
Longitude	:	85^0 33' E
Nearest Railway Station	:	Visakhapatnam
Nearest Airport	:	Visakhapatnam
Nearest Access Road	:	NH-16
Nearest Highway	:	NH-16 Chennai – Kolkata National Highway (Previously NH-5)
Source of Water	:	Bore Well / Treated Waste Water

TotalLand Area of Existing Plot : 17.08 Acres Identified by GVMC out of 20 acres.

Location Map is shown in **Fig.- 15**

Land is to be allocated by Greater Visakhapatnam Municipal Corporation (GVMC) as per the terms of Concession Agreement. Site is connected to NH-16 by approach road. Plan of the site allocated for the project is shown in Fig-16

Figure- 14: Location Map

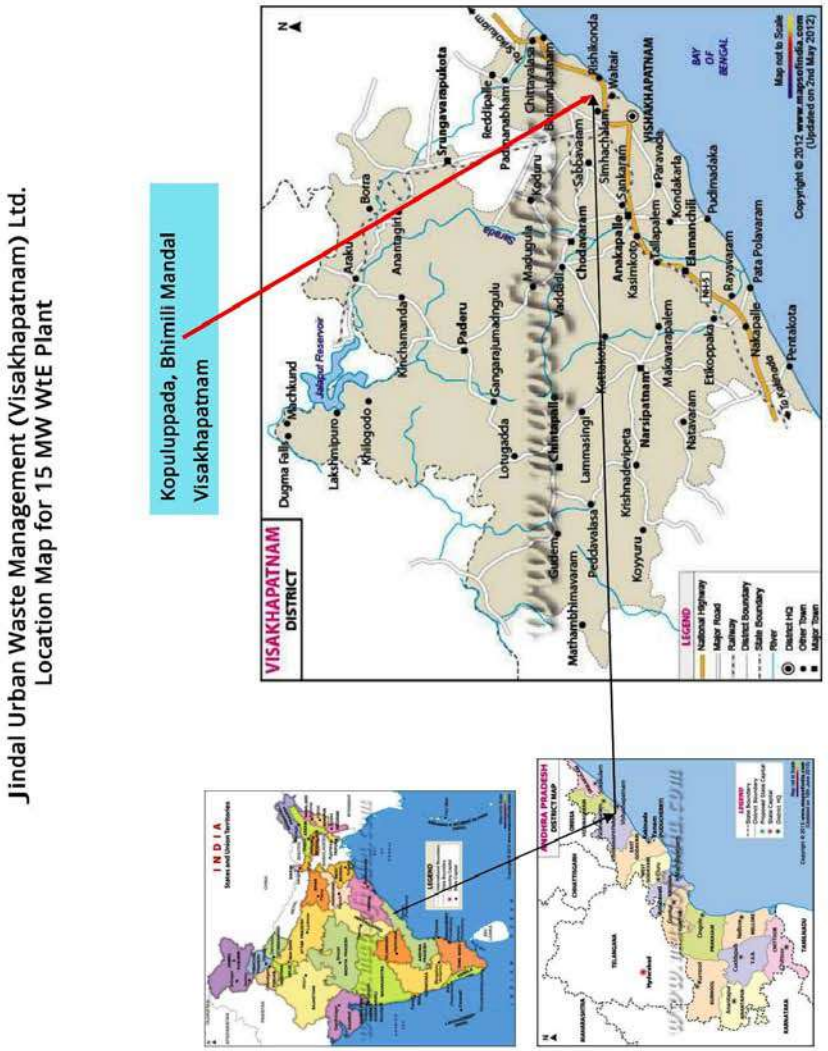


Figure- 15: Plot Location for WtE Project

SITE FOR WtE PLANT AT VISAKHAPATNAM

05.02. Land Use – WtE Pant

The total project area required is about 20 acres. The area will be used for construction and development of Integrated MSW processing facility comprising SSS and Power Plant with auxiliaries, Water treatment plant, Administrative and Amenities Blocks and Common facilities etc. Apart from the above, internal roads and green belt will be development as per the norms. About 6 Acres will be developed as greenbelt. This greenbelt will serve as a buffer between the peripheries and the industry, there by controlling the air emissions and noise levels.

05.03. Proposed General Plant Layout

Layout of proposed MSW Processing Facility with Power Plant is shown in Drg No. **1638-001 Sh01**. Following aspects have been considered in the layout shown in the drawing:

i) The proposed Integrated MSW SSS as well as auxiliary units are located in a **compact configuration.**

ii) MSW Tipping and processing area is located with convenient approach for vehicles from main material gate. Weigh bridges are located near the entry point. Parking area for trucks is also envisaged near the entry gate.

iii) Common MSW pit is provided for receipt of MSW, area for storage/ drying heaps and segregated fuel for boiler feed.

iv) Manual and mechanical segregation facilities are connected by belt conveyors,

v) Boiler island with MSW storage, flue gas treatment and chimney are arranged

in compact layout.

vi) Turbine-Generator building is located close to Boiler to minimize steam piping. Air Cooled condenser is adjacent to TG building

vii) Electrical & Control Room building is attached to the TG building shed. Switch yard will be outdoors close to plant boundary for power evacuation through overhead conductors.

viii) Space is provided for Water treatment plant with storage. Location will ensure that it does not come in path of predominant wind direction from flue gas treatment area.

ix) Environmental aspects, pollution control and safety measures are accorded due importance.

x) Utmost economy but at the same time maximum flexibility have been kept in view in locating various units for ease in material movement within the plant as well as in and out of the plant.

Figure- 16: Plant Layout - Visakhapatnam

05.04. Site Analysis

Project is located within the Area earmarked by GVMC for disposal and processing of Municipal Solid Waste

Vacant land will be handed over by GVMC, therefore, there will be no requirement for Rehabilitation and Resettlement.

The site is well connected with municipal area of Visakhapatnam and easily approachable from NH-16.

For disposal of non-combustible inert, sanitary land fill site is also located nearby.

06. REQUIREMENT OF LAND, SHEDS, BUILDINGS AND OTHER CIVIL WORKS

06.01. Requirement of Land & Land Development

GVMC have identified 17.08 acres of land for accommodating various facilities envisaged for the project. Part of the allocated land falls at the foot of hill with sloping terrain. Land development will require leveling of the site as per layout. Allocated area is adequate for accommodating plant facilities.

For developing landfill site additional area of about 65 Acres will be required. This will be made available by GVMC in their own land.

Survey has been conducted for the plot and contour plan and soil investigation report for the area is also available.

The dedicated land for power plant is developed as per the results of topographic survey, excavation or back filling may require for land development. Dressing of surfaces including strutting, shoring & dewatering if required and filling and back filling in layers.

Landscaping will be done to enhance the visible features of an area of land which includes flora or fauna, gardening, art and craft of growing plants to create beautiful environment, nature elements such as landforms, terrain shape and elevation or bodies of water.

Approach road shall be designed to accommodate vehicles having a minimum 40 ton gross weight. The access road shall be at a minimum of 15m wide to handle two-way transfer trailer traffic from the scale house to the face of the landfill.

Interconnecting roads inside the plants will be developed keeping waste input and rejects outflow into consideration. The interconnection of different equipment placement is properly addressed in layout and approach road thereof. The width of road is maintained as per standards.

General layout and construction details such as fencing/boundary wall, building sectional view, etc., plantation and greenbelt area with species details. The green cover requirements within the processing facility shall be minimum of 3 m wide along the site boundary. Garden/lawns shall be created wherever possible to improve the aesthetics. Part of green belt area required as per norms is proposed to be developed in additional area proposed to be allocated by GVMC.

06.02. Sheds & Buildings

Following sheds and buildings are envisaged to be constructed to accommodate various facilities of the project:

Simple Segregation System:

- Operator shed for Weigh Bridges
- Common Shed for tipping floor and Bio-drying Section having two bays with EOT Grab Cranes
- Shed for Simple Segregation System

BoilerIsland:

- Protection canopies for boiler.

TG Building:

- TG Building with RCC Columns & operating floors, masonry walls, side sheeting, EOT Crane and structural roof.
- Electrical and control room building having two floors plus cable basement.

Balance of Plant:

- Building for water treatment plant
- Pump rooms for Fire fighting and circulating pumps
- Compressor House & DG Station

Auxiliary Buildings:

- Administrative & Office Block
- Canteen & amenities building
- Laboratory
- Store
- Gate complexes with security rooms, etc.
- Toilets & Rest Rooms at various locations.
- Covered Parking & open parking

06.03. Foundations & Civil Works

Civil foundation work for equipment shall be executed as per the soil investigation report of that area. The structure & foundation work has to be done for following equipment & buildings:

- Ramp for MSW unloading
- MSW pit

- Shed column foundations
- Foundation for equipment of Simple Segregation System
- Boiler foundation & Chimney
- STG deck & its columns
- STG building
- Air cooled condenser deck & its columns
- Water treatment plant
- Auxiliary Cooling tower
- Raw water reservoir & fire fighting tank
- Miscellaneous tanks
- Foundations for other miscellaneous equipment like compressors, pumps, fans, DG, Skid mounted assemblies, etc.
- Pipe trestles, conveyor gallery & cable gantry supports
- Switchyard and Transformers.

07. ENVIROMENT, HEALTH, SAFTEY & SOCIAL MANAGEMENT

07.01. Health & Safety

The site shall be managed by the Principal Contractor who shall be responsible and accountable for all activities on site.

He shall delegate authority for the day-to-day running as deemed appropriate, but liaise with those with delegated authority on a daily basis to discuss and sort out Health and Safety issues that have been identified.

Staff is responsible for their own safety, for their actions that may affect the safety of those they are working with or persons who may be working nearby. In this respect they have the obligation to report unsafe actions and situations to the client/ Site Manager. It's everyone's duty to prevent unsafe situations and actions.

The health and safety of all those who work at the Plant shall be ensured, as far as is reasonably practicable by:

- Assessing the risk of all work activities, recording the significant findings and developing method statements as appropriate.
- Providing and maintaining safe plant and systems of work, together with appropriate personal protective equipment.
- Minimising risks associated with hazardous substances including waste to be processed, materials used and the by-products of waste treatment processes.
- Minimising risks associated with other occupational health risks including noise, vibration and manual handling.

- Maintaining the Plant in safe condition including as regards workplace transport and fire risks.
- Providing appropriate information, instruction, training and supervision to those working at the Plant or visiting the Plant, including information and training with regard to the emergency procedures.
- Implementing effective systems for active and reactive monitoring of compliance, including by inspections, audits and incident/ near miss investigation.

Staff has to follow plant's in-house rules and regulations as described further in this HSE plan..

In addition the following rules & regulations if any, are also imposed to each staff:

- The client's worksite safety rules and regulations.
- The general safety rules imposed by Indian / State Government legislation.

If a hazard arises or suspected to be present, they shall be reported immediately and, if necessary, all work stopped and persons withdrawn from the area.

07.01.1. Risk assessments and Work Procedures

Risk assessments are an important step in protecting the health and safety of people working in construction sites. The key aim is to identify hazards early on, so they can be eliminated or reduced before the work will be carried out. Therefore before any work can commence which is not part of a person's daily routine a Risk Assessment must be carried out of the activity being undertaken. As a result work procedures are made to

give specific instructions on how to safely perform a work related task or operate a piece of plant or equipment.

In most cases, the assessment results in permits to work and/ or Lockout/ Tagout (LOTO) procedures.

Activities listed below are some examples of work that will need a risk assessment and work procedures:

- Working at height
- Hot work
- Using lifting equipment
- Working with hazardous substances
- Entry into confined spaces
- Excavation work
- Use of cranes or hoists
- Erection of scaffolding or access towers
- Electrical testing

The above list of activities is not exhaustive and other activities may require a recorded method statement/ risk assessment.

For this project, risk assessments and method statements are made by the supplier of the specific equipment to be erected and/ or installed. Reviewing by the principal contractor.

07.01.2. Training

Site personnel will attend a site induction that will include a briefing on the site rules and regulations, including how to notify site management of any deficiencies. It will also include information on how to address training where training deficiencies have been identified. Site inductions shall be carried out by the Principal contractor for all personnel intending to work on site for any period of time.

Personnel who are to carry out work (inclusive advisory or supervision work) on the construction site shall hold a current SCC certificate – Safety for Operational Supervisors. Personnel can only undertake tasks or work on equipment where they have been authorised and trained for that task or equipment. Safety training will be undertaken as required by competency role profiles and risk assessment. Training will be provided based upon identified needs and will focus on job specific requirements and wider awareness. (e.g. confined space, Electrical testing, etc).Anyone who may be employed on a construction site must have taken a first aid course.

07.01.3. Drugs and Alcohol Policy

Alcohol and drug misuse affects performance, behaviour and relationships at work and at home. There is overwhelming evidence of links between alcohol misuse and social and psychological disturbances, medical problems, accidents and violence.

Alcohol consumption is prohibited to all employees and contractors within the site boundary including car parks.

- Furthermore, all personnel are forbidden to:
- Use prohibited drugs at any time
- Abuse prescribed or “over the counter” drugs at any time
- Attend for work under the influence of alcohol
- Have in their possession drugs of abuse during working hours including breaks
- Attend for work under the influence of prescribed medications or over the counter medications that will or may adversely affect their ability to perform their duties.

All project managers/ supervisors are required to bring this policy to the attention of contractors and report to their line manager if they see anyone consuming alcohol or misusing drugs, or who appear to be under the influence of either.

Any contravention of the drug or alcohol policy will be viewed as a serious disciplinary matter, any transgressor will be removed from site.

07.01.4. Working in site / plant area

Prior to working in an area not previously discussed or approved during a pre-work review or where process-related hazards may be present, consult the Principal Contractor for the following information:

- Special instructions
- Restrictions
- Permits required
- Location of lockout
- Potential changes in work environment, including unexpected liquids or vapours
- Special training
- Location of emergency alarms, emergency equipment, evacuation routes and assembly points
- Type of emergency escape equipment available and how to use it.

All personnel attending site, shall be equipped with Long Sleeves work clothes, Safety Helmet, Safety Boots, Hi-Vis vest or jacket and Safety Glasses which shall be worn at all times whilst working in the construction area unless there is a specific requirement in the Method Statement or Risk Assessment agreed by the principal contractor/ Client that specifically removes this requirement. Open fronts, short sleeves and shorts are not allowed.

Other task specific Personnel Protective Equipment may be required during the project. The risk assessment shall identify the specific type/ grade of protective equipment to guard against the specific hazards identified in these risk assessments.

For certain operations other specialist equipment may be required, including fall arrest system, buoyancy equipment, gas detection, oxygen deficiency monitoring equipment and breathing apparatus. Details of the precise utilisation of such items shall be addressed in the specific method statement and risk assessment. Personnel provided with this special PPE shall have received appropriate training prior to use.

All PPE should be maintained on good condition. Holes in boots or overalls etc will not be tolerated and replacements shall be issued as soon as possible. Work clothes should be washed regularly as to prevent skin infections, irritations and other forms of skin diseases. Replace safety helmets immediately if it is cracked or distorted.

Hearing protectors shall be worn in areas where noise levels exceed 85 dB, and where areas with hearing protection warning sign is posted such as pump room, boiler house, turbo generator hall, air cool condenser, fans areas, etc.

When handling chemicals, please refer to the Material Safety Data Sheet (MSDS) for the appropriate glove to be used

Respirators shall be worn in contaminated atmospheres. When working in refuse bunker, fly ash handling areas or any dusty environment, suitable masks or respirators must be worn.

Employees with pre-existing conditions of heart disease, asthma, hypertension or breathing difficulties are not encouraged to wear respirators unless physically certified by a doctor.

07.01.5. Equipment safety rules

All necessary tools and equipment, including personal protective equipment, shall be properly maintained. Defective tools and equipment shall be repaired or replaced immediately.

- All equipment shall be used only be employees who have been properly trained and are otherwise competent to use the tools and equipment safely

- Only authorised personnel shall operate heavy-duty equipment/ equipment/ machinery in the Plant. Equipment can only be started when the following two conditions are fulfilled:

- Comply with the applicable Permit-To-Work System
- Local check has been carried out to confirm that the equipment is in working condition and that no one is near the equipment. For equipment with local on/ off switch, it should always be started locally. Unauthorised possession of equipment switching keys by any person is prohibited. No bypassing is allowed unless approval given by the authorised person

Safety guards and other safety features provided for all tools and equipment must not be removed for convenience.

The allowable safety load limit of a machine, a working tool, or piece of equipment may not be exceeded. Tools, equipment, and machinery shall not be altered in any manner that would reduce their original safety limit. Any and all changes to machines, equipment and/or materials must be approved by an official inspection unit.

Machines for manual use and all such similar apparatus must be adapted to the prevailing conditions. For example, for work to be carried out above shoulder height, the apparatus selected should be as light as possible, and easily manageable.

Equipment and machines are designed for a specific purpose. Do not abuse or misuse them.

Never wear loose sleeves, dangling neckties or finger rings while working around machinery.

Permits/ authorization

Permits will be issued at the work site when required for the works. Prior to start the operations, it's necessary to become informed about the work permits that are applicable for the site.

When permits to work are in force, they are always required before commencement of work, in written and properly authorized.

Plant's personnel shall carefully read, understand, sign and explicitly comply with all conditions required by the permit.

The permit holder must be on the work spot for the duration of the works being carried out under the permit, if he is to leave the work spot whilst work is on-going, he must transfer the permit through the correct permit transfer system.

In commissioning or testing of equipment, the person responsible for the equipment must be present so that all necessary checks are made prior to the commencement of work.

Table 46: List of permits commonly required for work on site/ plant

Type of Permit	When Required
Work permit	A general permit for all activities
T&C Permit	For testing and commissioning
Hot Work	For works involving naked flame, sources of ignition or sparks
Confined Space	For work carrying out inside a confined space such as underground manholes, tanks, inlet channel, area where possible of asphyxiated from lack of oxygen, the risk of fire/ explosion and the presence of dangerous airborne substances

Work at height	For work activities carried out at a workplace exceeding the height of 2m
Excavation	For any excavating (including drilling) in earth, roads, parking lots, slabs, and slab floors
Lifting & Hoisting	For any lifting and hoisting activities involving lifting machines or lifting appliances
Radiation permit	For radiation works

Working on height

Not all work at height can be reasonably removed by the design process. Therefore, the hierarchy of managing and selecting work equipment for work at height shall be followed as set out by the Work at Height Regulations.

Working at height will be covered as part of the risk assessment for all work where there is a risk a person could be injured by falling.

Hot work

Some systems or equipment have a hot surface and consequently a thermal hazard.Where reasonably practicable insulation of the system or equipment is provided in design.Other thermal hazards occur in e.g. the SNCR system, bag filter, ID fan, boiler feed water pumps, steam circuit, fire fighting pump station. General arrangements for controlling are in most cases implementation of the Lockout/ isolation procedure combined with providing personal protection means.

- No hot works are allowed to be carried out in the following areas:
- Fully closed storage tanks, vessels or drum of any nature (pressure vessel)
- Pipes and vessels under internal pressures whether of steam, feed water, air or gases

- Pipes, tanks and spaces which have contained fuel and other flammable substances

Naked flames, hot works or element that produces sparks (including electric devices) must not be near vicinity of fuel storage areas, oil paint and bottled gas stores and locations where activities such as painting works are in progress.

Chemical hazards

All chemicals must be accompanied by a Material Safety Data Sheet (MSDS) to enable the user to prepare for the arrival, storage and use of the specific substance and to ensure that all safety and environmental implications can be taken into account before the work is started.

Plant's personnel should carefully read the MSDS and shall handle all chemicals in accordance with the instructions as stated. It should not be mistaken by appearance of chemicals (e.g. some chemicals look like water). Legal requirements and instructions for labelling, handling and care of waste must be followed. The removal of used products, which are contaminated after a spill, shall be carried out in line with the site waste procedure.

Noise

Exposure to excessive noise should be avoided.Excessive noise is avoided by providing noise enclosure where reasonably practicable (e.g. turbine/ generator and auxiliaries). Where the specific risk assessment for noise still shows that action is required, the principal contractor must ensure that the appropriate controls are introduced. For reference the action levels are as follows:

- Lower exposure Action Levels: Daily or weekly noise exposure of 80 dB(A) or a maximum noise (peak sound pressure) of 135dB(A) where appropriate hearing protection should be worn.

- Upper Exposure Action Levels: Daily or weekly noise exposure of 85 dB(A) or a maximum noise (peak sound pressure- of 137 dB(A) where appropriate hearing protection shall be worn.

- Exposure limits: Daily or weekly exposure of 87 dB(A) or peak sound pressure of 140 dB(A).

- Notwithstanding the above, common sense shall apply and ear protection shall be worn if the short term working noise level is found to be uncomfortable for the exposed person at levels below 80 dB(A). At levels higher than 80 dB(A) ear protection is obliged.

Moving/ rotating parts of machines

Hazards caused by moving or rotating parts of machines are covered with providing an electrical/ pneumatic lockout procedure.

Pressurised Equipment/ Compressed air

The term 'pressurised equipment' refers to equipment and units for which the maximum permitted pressure specified by the manufacturer is greater than 0.5 bar.Flanges, nozzles, coupling, bearing elements, lifting eyes and similar elements, which are connected to pressuring-bearing parts, are counted as part of the pressure-bearing device.

In the event of any work on pressurised equipment a lockout procedure and restricted access has to be implemented. Personnel has to be trained for this specific purpose.

Turbine and steam circuit are examples of pressurised equipment.

When using compressed air for cleaning purposes, it should be ensured that it does not exceed 30 psi. Compressed air should not be used to clean dust or debris off the body.Compressed air can cause injuries and great pain when it comes into contact with body. Thus, all compressed air must handle with care.

X-Ray Measurements

All necessary licenses/ permits for the materials or equipment should be obtained before use.Hazard warning signs should be used to identify restricted areas and equipment.

Electrical

Only authorised persons is allowed to carry out work to the site/ plant's electrical installation. Unauthorized personnel should not be permitted to enter any switch room.

- No equipment or extension cord should be used if the grounding prong has been removed. No two-wire extension cords are permitted.
- All electrically powered hand tools shall be inspected before use.

After work or in the case of power failure, all portable electrical tools should be switched off. Any equipment that is locked or tagged out into the switch receptacle should not be activated.

Conductor should not be handled with bare hands, but with rubber gloves or insulated appliances designed for the voltage applied. Rubber boots shouldalso be provided against the risk of electrical shocks, if necessary. All electrical appliances and conductors have to be clearly marked to indicate their purpose and voltage.

The nominal voltage of the extra low voltage supply is 24V AC 50 Hz single phase. This voltage is safe in conditions where simultaneously accessible parts (such as exposed electric cable) may be touched by a person whose skin is dry or moist, but not wet. It shall not be used in locations where a person is immersed in water or working in the rain or working in a confined conductive location such as inside tanks or boiler furnace etc.

07.02. Environmental Protection

Chemicals and wastes must be stored in appropriate locations and containers so as not to cause pollution to the environment.Staffshould conserve energy by switching off office equipment, lights, etc. when not in use.No one should discharge chemical substances through open drains.

The purpose of the Environment Management Plant (EMP) is to mitigate potential emissions from various activities associated with the integrated facility. This includes understanding and incorporating mitigation measures to ensure that the emissions at site boundary are within the required pollution limits.

07.02.1. Air Pollution Management Plan

In addition to the robust and state of the art air pollution control system for the boiler flue gas, following mitigation measures are proposed to reduce the dust levels in the ambient air environment:

- Maintaining and/or re-establishment of a grass cover on area where there is no on-going activity
- Frequent watering of unsealed roads and stockpile area- cover material
- Blacktop of the roads as and when they are settled and ready for the same
- Repair, relaying of blacktop roads from the landfill area to the main road
- Using dust control sprays during loading and unloading of wastes
- Ceasing dust generating activities during high wind times
- Minimizing working distances for internal transport of wastes
- Periodical monitoring of ambient air quality for all relevant parameters as indicated in the monitoring plan
- Odour control by rapid stabilization and disposal of wastes at the earliest along with daily cover placement

The above mentioned measures will help in minimizing the fugitive emissions and dust.

07.02.2. Noise Pollution Management Plan

The sources of noise generation in the landfill will be from the generators, heavy earth machinery in addition to the vehicular movement. While all noise levels are well within the acceptable limits, the following strategies would be adopted to further minimize the noise levels:

- Maintaining the site machinery in good operating condition
- Regular maintenance of systems and installation of noise control equipment wherever required
- Development of green belt all around the site
- Periodical monitoring of noise levels

07.02.3. Water Pollution Management Plan

During the construction phase, a septic tank shall be provided to treat the domestic wastewater generated due to labour settlements.

Reject water from blow downs, and treatment plant rejects will be collected in effluent pond and recycled for use for ash cooling, brick making, fire water make up and other non critical used. Reject from leachate treatment facility will be used for boiler bottom ash quenching. There will be no discharge of effluent from the plant.

07.02.4. Development of Green Belt

With the development of the proposed plant, green belt would be developed and other aesthetic changes would be made to the plant site, thereby creating overall positive impact on the aesthetics of the site. A properly landscaped entrance area with a green belt of 10 m containing tree plantation for good visual impact will be maintained in line with the norms stipulated in Environment Clearance. The domestic wastewater

generated along with washings/leachate from MSW pits will be treated and used in windrows along with green belt development.

A green belt is provided to mitigate various emissions. Green belts are wide strip of trees and shrubs planted in rows to reduce air velocity there by facilitating settling of the particles on the leaf surfaces and allowing absorption of the pollutant gases. It also serves to cool the atmosphere by transpiration from the leaf surface and also provide habitat for birds, reptiles and insects. The advantages of a green belt are given below:

- Greenbelts are important habitats for birds and animals, which add to the aesthetic value of the environment. Generally, birds prefer to make their habitat, nest, on trees. Further trees provide shade and hiding places to wild life
- It helps to restore the ecological balance
- It helps in prevention of soil erosion
- It helps to improve the aesthetics in the area
- It also diminishes noise pollution by absorbing high degree of noise due to their spongy foliar crown

Selection criteria of Plant species for Green belt development

The selection of plant species for the development depends on various factors such as climate, elevation and soil. The list of plant species that can be suitably planted and having significant importance are provided below. The plants should exhibit the following desirable characteristic in order to be selected for plantation. The species should be fast growing and providing optimum penetrability. The species should be wind-firm and deep-rooted.

The species would form a dense canopy. As far as possible, the species should be indigenous and locally available Species tolerance to air pollutants like SPM, SO_x and NO_x should be preferred.

- The species should be permeable to help create air turbulence and mixing within the belt.
- There should be no large gaps for the air to spill through.
- Trees with high foliage density, leaves with larger leaf area and hairy on both the surfaces.
- Ability to withstand conditions like inundation and drought.
- Soil improving plants (Nitrogen fixing, rapidly decomposable leaf litter).
- Attractive appearance with good flowering and fruit bearing.
- Bird and insect attracting tree species.
- Sustainable green cover with minimal maintenance

07.02.5. Specific Measures for EMP

MSW Handling & Processing

The unloading as well as processing of the waste would not generate dust and odour. Since these activities are carried out under covered areas.

Leachate

The municipal waste arriving at the site will be unloaded on a tipping floor, which is covered. The concrete platform shall be constructed to prevent ground water contamination due to leachate. Leachate generated shall be stored in an underground leachate tank and used for ash quenching after treatment.

Simple Segregation System

Solid rejects

The solid rejects (maximum of 20% of the total waste) from the processing would consist of stone, sand, earth, ceramic etc. that will be segregated and managed appropriately.

Noise Pollution

There sources of noise pollution includes truck traffic, blowers, shredders. Where necessary, enclosures would be provided to ensure that noise levels do not exceed the prescribed standards

MSW Storage

The proposed facility will have seven days storage for MSW. To mitigate potential fire problems, adequate measures such as water hydrants with adequate pressure or dry powder type will be provided.

Rotating & Moving Equipment

There are a large number of rotating & moving equipment in the Simple Segregation System area and accidental occurrences can take place in few of the equipment, as mentioned below:

- Rotary Screens: All rotary screens are covered to ward off the dangerous occurrences.

- Conveyors: Although conveyors operate at low speed but can cause some accidents due to negligence of the operating personnel. For this suitable training will be imparted to all concerned.

Other Measures

All the workers in SSS area will be provided with safety gears such as safety boots, gloves safety glasses and dust masks enc. The storage area is enclosed and barricaded to prevent entry of stray animals and unauthorized persons.

- Maintaining buffer zone and plantation around the facility
- Vehicles carrying solid waste shall be covered.
- Collection system should be properly supervised so that quick and regular removal of waste from the dustbin is practiced.
- The proper cleaning of tipping floor will be done periodically.

07.03. Community Engagement

Community engagement plays a very important role for sustainable operation of waste management system in general and WtE projects in particular. This is proposed to be achieved by undertaking various activities broadly in line with the following objectives:

(i) Training & capacity building activities for improving employability of the local population

(ii) Creating awareness about benefits of WtE projects for the local community through various promotional activities

(iii) Keeping the community informed about environmental performance of the project on an ongoing basis

07.03.1. Training and capacity building

Training centers would be constructed for providing skill development for employability as well as social development through general education and promotion of health and hygiene. Training courses would be developed in collaboration with the Government/Private technical institutes in the vicinity of the project site and NGOs active in the area of social development. Assistance would be sought from the ULBs and other Government departments to facilitate implementation of the training and extension program.

07.03.2. Awareness development-WtE projects

It is proposed to develop audio-visual education materials, which would be periodically shown to the public along with educational films on ecology and environmental sustainability in general and WtE projects in particular. It is also proposed to participate in community development activities for promoting better waste management practices at least around the project area.

07.03.3. InformationManagement

It is proposed to develop an electronic information management system, which can be linked to the mobile telephones for sharing information on project performance, accept public grievances and communicate redressed measures in a transparent manner.

08. ORGANISATION & MANPOWER REQUIREMENT

08.01. Project Implementation Stage

For implementation of the Project, efficient organisation is to be created with specified key result areas and substantial delegation at execution and operation level. The organization structure during project stage has been developed with clearly defined responsibility for execution and cost management and smooth transition from construction to operation. Recruitment for the project stage shall also be carried out in a phased manner coinciding with the construction schedule. Project stage structure and the tentative schedule for filling up the structure are shown in the following figure.

The Chief Executive Officer (CEO) for the business overall and the Chief Financial Officer (CFO) are part of the corporate management team and are managing the development of new and operation of the existing businesses and projects. The following table shows the roles and responsibilities at the individual positions to be filled up for the project, the qualification requirements and the schedule for filling up the positions.

Organisation structure for Project implementation is shown in Fig 18.

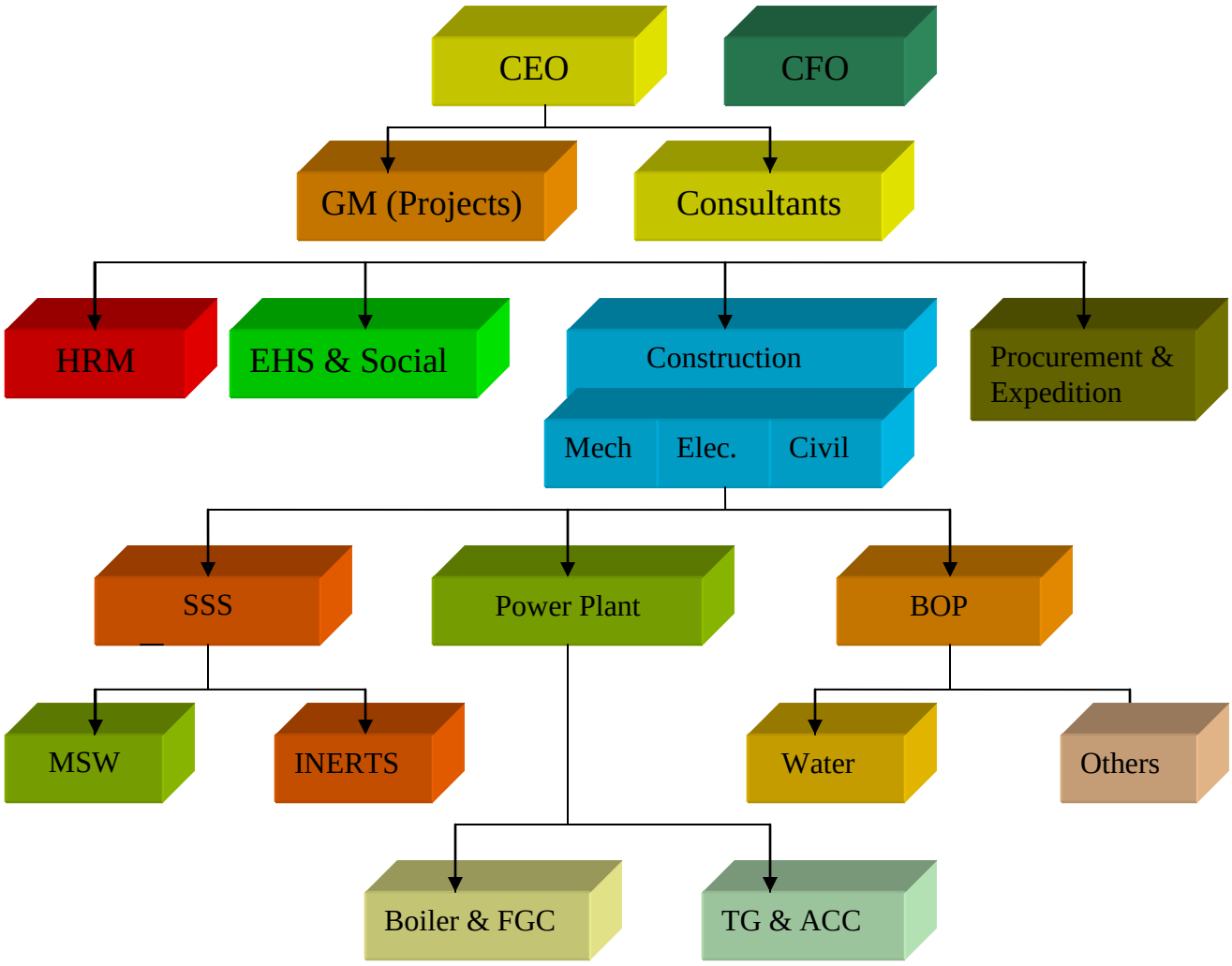


Figure- 17: Organization for Project Implementation

Table 47: Project Manpower

Position	Roles & responsibilities	Qualification requirement	Schedule for appointment
General Manager	Overall responsibility for project development and operation thereafter including technical, commercial, HRM, social and environment and compliances	Mechanical/Electrical Engineer with minimum 15 years experience in development and operation of WtE/Power/Captive power/Infrastructure projects	Immediate
Manager (HRM)	Planning and development of the organization structure, system and human resource development processes at the project and operation stages Training & capacity building activities	Post Graduate in HR/Social development with minimum 10 years experience in operating plants preferably in the semi urban areas Experience of working with NGOs involved in environment related activities preferred	Immediate
Manager (Material recovery facility)	Procurement & construction of the weigh bridges, MRF facility as per cost & time budget Operation of the facility meeting the fuel requirement for WtE plant and compost production as per plan Compliance with the relevant provisions of the concession agreement for the MRF area Environment management for the MRF area	Mechanical/Chemical/Civil Engineer with minimum 10 years experience in solid waste management system Persons with experience in development of SWM technologies would be preferred	Immediate
Manager (Power)	Procurement & construction of the boiler, APC system, fuel & ash handling system, STG set, Condensing	Mechanical/Electrical Engineer with minimum 10 years experience in development and operation of	Immediate

Position	Roles & responsibilities	Qualification requirement	Schedule for appointment
	plant as per cost & time budget Operation of the WtE plant post construction Environment management for the WtE plant	WtE/Power/Captive power projects Persons having experience of MSW fired boilers would be preferred	
Manager (EHS) & Social	Development of the overall environment, health, safety plan for the entire facility, provide technical inputs to Manager (MRF) & (Power) for implementation of the EHS plan and monitoring of the EHS system during construction and operation phase Operation of the EMP system including training and capacity building activities	Environmental engineer preferably with additional qualification on HR/Social development Prior experience of working with NGOs in the relevant areas and extension work in industrial projects in rural areas would be desirable	On financial closure
Manager (Balance of plant-Mechanical)	Procurement & construction of the balance of plant including water, compressed air, Effluent treatment, fire fighting& HVAC systems as per cost & time budget Operation & maintenance of the raw water, cooling water, treated water &effluent treatment plant post construction	Mechanical/Chemical engineer with minimum 10 years experience in water treatment related projects	On financial closure
Manager (Electrical)	Procurement & construction of the entire electrical and instrumentation and control systems as per cost & time budget	Electrical engineer with minimum 10 years of experience in IPP/export oriented Captive power plants. Experience in development/operation	Immediate

Position	Roles & responsibilities	Qualification requirement	Schedule for appointment
	Liaison with the Distribution Utility during construction and operation of the plant Electrical maintenance of the entire system post construction	of the integrated control system such DCS would be preferred	
Manager (Civil)	Construction of all infrastructure, structures & foundations as per cost & time budget	Graduate civil engineer with minimum experience of 5 years as Lead for execution of infrastructure/housing projects	Immediate
Engineer	Operation and maintenance of the MSW facility including fuel quality &feeding system for the boilers	Chemical engineer/Environmental engineer/Post Graduate in Chemistry with minimum 5 years experience in operation of SWM/Composting plants	Six months prior to commissioning
Others Mechanical engineers-2 Electrical engineer-1 I&C engineer-1	Supporting project construction activities and in operation and maintenance work post commissioning	Graduate/Diploma engineer with 2 to 5 years experience infrastructure projects	Two months prior to start of the construction work
Consultants	Detailed engineering Procurement & construction documents Project management	-	Already engaged

08.02. Plant Operation & Maintenance

The management structure during the operational phase would change as shown for performing day to day jobs of operations and maintenance activities.

The Operation & Maintenance manpower has been estimated for the Material Recovery Facility & Power plant sections as shown in the following tables. The manpower has been determined on the basis that the Plant shall be operated for all the seven (7) days in a week round the clock on three shift per day basis.

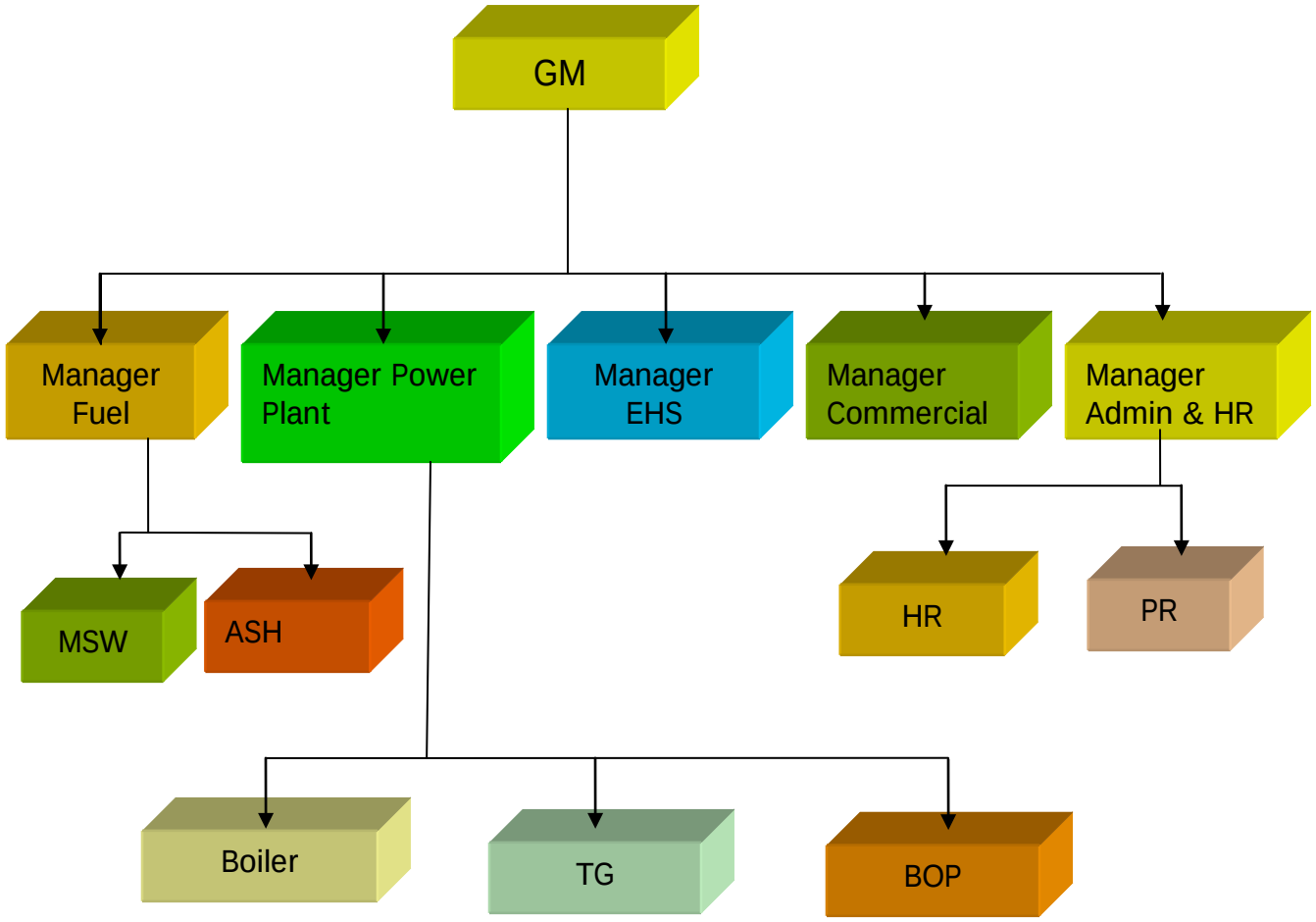


Figure- 18:Organization Operation & Maintenance

Table 48: Manpower Deployment

Sl. No.	Designation	Task	Shifts				Total
			A	B	C	G+R*	
Material Recovery Facility							
	Supervisor	Inspection & Weighing of MSW	1	1			2
	Supervisor	Supervision & Control of Trucks	1	1			3
	Grab Operator	Grab operation	1	1	1	2	5
	Helper	To look/poke hoppers	1	1	1	2	5
	Supervisor	Manual Sorting Activities	1	1	1	2	5
	Helper/Pickers	Manual Sorting at lines	12	12	12	16	52
	Line Operator	Operation of conveyors/Trommel	1	1	1	2	5
	Shift In charge	Overall responsible for Shift	1	1			2
	Power Pack Operator	Power Pack Operation	1	1	1	2	5
	Helper/ House Keeping	Cleaning at floor	1	1	1	2	5
	Supervisor	Trolley Positioning & removal	1	1		1	3
	Shredder Operator	Operation of shredder	1	1	1	2	5
	Power Pack Operator	Operation of Power pack	1	1		1	3
	Helper/Pickers	Manual sorting & house keeping	2	2	2	3	9
	Mechanical engineer (shift)	Repair/ Maintenance R&M	1	1			2
	Fitter cum Welder	R&M	1	1		1	3
	Helper	R&M	2	2		1	5
	Hydraulic Mechanic	R&M	2	2		1	3

Sl. No.	Designation	Task	Shifts				Total
			A	B	C	G+R*	
	Electrician	R&M	2	2		1	3
	Electrical Engineer (Shift)	R&M	1	1			2
	Turner	Lathe Operation				1	1
	Welder	Welding Work				2	2
	Helper	Helper in Workshop				2	2
	LTP Operator	LTP Operation				2	2
	Chemist for Lab	Testing				2	1
	TOTAL		**34**	**34**	**20**	**46**	**134**

Sl. No.	Designation	Task	Shifts				Total
			A	B	C	G+R*	
Power Plant							
	Shift In charge	Power plant Operation & Maintenance	1	1	1	1	4
	Boiler Attendant	Boiler & FGCS Operation	1	1	1	1	4
	Asst. Boiler Attendant	Boiler & FGCS Operation	1	1	1	1	4
	Fireman / Helper	Boiler & FGCS Operation	3	3	3	5	14
	Supervisor	Primary Water Treatment Plant	1	1	1		3
	Operator	Primary Water Treatment Plant	1	1	1	1	4
	Operator	RO Plant & Cooling Tower Operation	1	1	1	1	4
	Helper	RO Plant & Cooling Tower Operation	1	1	1	1	4
	Chemist	Sample collection & checking	1	1	1	1	4
	Fitter	Maintenance of Power Plant	1	1	1	2	5

Sl. No.	Designation	Task	Shifts				Total
			A	B	C	G+R*	
	Asst Fitter	Maintenance of Power Plant	1	1	1	2	5
	Welder	Maintenance of Power Plant	1	1	1	1	4
	Helper	Maintenance of Power Plant	1	1	1	1	4
	Operator	Operation of Turbine & ACC	1	1	1	1	4
	Helper	Operation of Turbine & ACC	2	2	2	1	7
	Shift In-charge	Electrical Operation & Maintenance	1	1	1	1	4
	Electrician	Responsible for Electrical Operation & Maintenance	1	1	1	1	4
	Helper	Electrical Operation & Maintenance	1	1	1	1	4
	Shift In-charge	Instrumentation & Automation	1	1	1	1	4
	Technician	Instrumentation & Automation	1	1	1	1	4
	TOTAL		**23**	**23**	**23**	**25**	**94**

** G + R represents General Shift and relievers.*

09. PROJECT IMPLEMENTATION SCHEDULE

09.01. Implementation Schedule

The Project Implementation Schedule shown in the form of a Bar Chart in **Annexure-9.1** has been developed on the basis of the estimated duration of activities from date of LOA to commissioning. Construction phase is based on quantum of Civil and Structural Works to be executed at site, expected delivery schedule of the various equipment proposed to be installed and expected time period for the erection, testing and commissioning of equipment.

Activities up to preparation of DPR, which have completed are also shown in the chart.

Detailed engineering and procurement process for major equipment has also started concurrently and ordering can be done soon after financial closure.

It is estimated that the procurement of equipment, engineering, construction of sheds, buildings and equipment foundations, erection of equipment, piping and cabling work shall be completed in a period of 14-15 months from order placement of major equipment. Another 2 months will be required for conducting the commissioning and Trial run of all systems and integrated facility. There after the commercial production shall commence. Commercial operation is expected to start by Dec 2018.

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09.02. Project Implementation Strategy

There are some unique features of these WtE projects that would require an innovative implementation strategy for conformance with the bid conditions as articulated in the concession agreement as well as project performance objectives.

Key provisions in the concession agreement from the perspective of implementation include:

- AP Government's vision of developing these projects as model projects for the country.
- Engagement of independent engineer (IE) entrusted with the role of carrying out review engineering at the design and construction stage as well performance monitoring at the operating stage.
- Penal provisions of encashment of security at different stages (Bid, construction and operation) of the project for non-performance.
- Video monitoring and reporting of project progress.

The project implementation strategy has been developed with a view to ensure that the cost of the project is managed within the budget and the cost as well as the implementation schedule does not get adversely impacted as a result of IE intervention.

09.02.1. Contracting Methodology

It is often believed that the best way to manage the project cost is by award of EPC contract to reputed contractors as opposed to EPCM strategy adopted by developers of smaller projects.

In a traditional EPC contract the owner contracts a company (EPC Contractor) to provide engineering, procurement and construction services for the entire project. The project is therefore largely managed by the contractor who also bears the associated risks. The EPC Contractor has direct contracts with several sub-contractors. The features of these contracts include:

- Better control on project cost and no adverse impact due to cost overrun.
- Lesser man-power requirement for project organization (to owner)
- Lesser transaction cost (to owner)
- High degree of risk for contractor
- Higher cost of the project due to owner (10-20%)

In EPCM (Engineering, Procurement and Construction Management) mode a company is contracted by the owner to provide engineering, procurement and construction management services. Other companies are contracted by the Owner directly to provide construction services and they are usually managed by the EPCM contractor on the Owner's behalf. This mode of implementation scores over the EPC on the following:

- Lesser overall project cost
- Better control on specifications and quality
- Flexibility in technology decision making
- Easy to implement changes, if required
- Better control on project cash flow

However, it becomes critically important to develop a robust project implementation organization for managing the project in the package route.

The following table shows the differences in the type of contracts and how each would differ under the same situations. The list below is not a complete list of differences between EPC and EPCM modes but it does address many of the major contractual differences.

Table 49: Differences between EPC and EPCM

Task / Issue	EPC	EPCM
Scope of the Contractor	Has to be defined prior to bid process where the contractor is selected. Limited flexibility to change scope after selection of the contractor (or can be done at extra cost)	EPCM Contractor is essentially a **consultant** engaged by the owner. The owner with advice from the EPCM Contractor can modify the specifications without restrictions applicable in EPC.
Construction and Equipment Supply	Is negotiated and signed by the EPC Contractor with selected supplier/ vendor	Is negotiated and signed between the owner and the supplier/ vendor with advise from the EPCM
Warranties (Supply and Performance)	Are negotiated by the suppliers/vendor and the EPC Contractor and issued to the EPC contractor. The owner has a separate warranty from the EPC contractor	Owner negotiates the warranties with each supplier/ contractor with EPCM Consultants advice.
Safety during Construction	Is the responsibility of the EPC Contractor and its sub-contractors	Responsibility lies with owner and is also delegated to individual contractors
Permits for Construction	Would be obtained by EPC Contractor, except where it has to be issued in the name of the	Would be obtained by the owner and individual contractors.

	owner.	
Cost Over- Run and Savings	Cost risks are borne by the EPC Contractor. Overruns in any are borne by the EPC Contractor and Savings if any retained by them	Cost risks are borne by Owner. Overruns in any are borne by the individual Contractors and Savings if any retained by them
Financing of the project	Owner is required to have financing in place at the onset of the project so that a letter of credit and required down payments can be made to the EPC contractor	Allows owner to have partial financing in place at the onset of the project with the remaining amount being raised based on project out-flow requirements.
Legal costs	Low for the owner as only one detailed contract is negotiated	Higher for the owner as multiple contracts are negotiated
Administration	Owner's administration costs are lower	Higher with substantially higher staff required to manage multiple contracts

In this particular case, EPC option may not produce the desired result due to the following reasons:

- Very few WtE projects have so far been implemented in India and as already stated their track record is quite unsatisfactory.
- EPC contractors in the power sector are not very familiar with the technology for MSW handling and processing as well as cost of such projects.
- It would be necessary to carry out cost optimization exercise at every stage of the project development for ensuring financial viability of such projects. It would be very difficult to enforce such a review system on EPC contractors.

- During the stage of detailed engineering, it may become necessary to change specifications of some of the equipments/systems as a result of feedback from IE. EPC contractor may not either agree for such changes or ask for disproportionate cost escalation.

On the other hand, JUIL has already successfully implemented both SSS and WtE projects on EPCM mode and developed the required engineering insights for cost optimisation. It is therefore, proposed to carry out the execution of the project under EPCM mode.

Based on assessment of relative merits and demerits of both the options, the owner's have opted for a variant of the second model viz. EPCM. The owner will have on board an owner's engineer, while the project management will be handled by the owner's team. The roles and responsibilities of various key players under such a contracting model are described below:

Role of owners

- Arranging all permits and clearances
- Developing organization for pre-construction, construction and O&M
- Managing cash flow

09.02.2. Role of EPCM Consultant

EPCM Consultant would be appointed by the Owner's for performing the following tasks on behalf of the Owner.

- **Pre-bid services**
  - Setting up overall performance parameters for the plant and preparing a management plan on action in individual areas for achievement of the overall performance
  - Basic engineering and preparation of bid documents
- **Post-bid services**
  - Review of bids and preparation of technical evaluation, comparative statement and recommendation report on bid selection
  - Preparation of draft contract documents for individual equipment
  - Assistance in finalization of equipment suppliers/vendors
- **Project implementation phase**
  - Managing all interfaces between various vendors and contractors.
  - Review of design of equipment and drawings prepared by equipment suppliers and providing comments for modifications or improvement.
  - Prepare execution drawings for civil, structural and other engineering as required for the project.
  - Integration of all sub-units of the plant and prepare execution drawings for interconnecting services.
  - Close monitoring of the implementation of the management plan and providing timely feed back to the Owner on intervention need
  - Preparing a master plan for the project implementation and assist in organization development work for implementation of the same.
  - Providing operation and maintenance related inputs to the Owner and review the design to ensure performance

- Preparing the organization chart and process chart and assistance in recruitment & training of personnel
- Monitoring quality assurance system followed by equipment suppliers and other contractors
- Operating a project management system to ensure timely execution
- Witnessing the pre-commissioning testing & commissioning of plant
- Analysis of post commissioning troubles, if any and providing engineering inputs for solving the same
- Witnessing the final performance test

09.02.3. Role of independent engineers

- Review of Project drawings and milestones submitted by the Concessionaire in conformance with Schedule.
- Review, inspection and monitoring of construction works as set out in Schedule.
- Conducting tests on completion of construction and issuing Completion/Provisional Certificate as set forth in Schedule.
- Review, inspection and monitoring of operations and maintenance as set out in Schedule.
- Determining as required under the Agreement the cost of any works or services or their reasonableness.
- Determining as required under the Agreement, the period or any extension thereof, for performing any duty or obligations.
- Assisting the parties in case of any dispute.

- Undertaking all other duties and functions in accordance with the Agreement.

- The Independent Engineer shall discharge its duties in a fair, impartial and efficient manner, consistent with the highest standards of professional integrity and Good Industry Practice.
- During the Development Period, the Independent Engineer shall undertake a detailed review of the Drawings to be furnished by the Concessionaire along with supporting data. The Independent Engineer shall complete such review and send its comments/observations to the Participating ULBs and the Concessionaire within 15 (fifteen) days of receipt of such Drawings. In particular, such comments shall specify the conformity or otherwise of such Drawings with the Scope of the Project and Specifications and Standards.

- The Independent Engineer shall review any modified Drawings or supporting Documents sent to it by the Concessionaire and furnish its comments within 7 (seven) days of receiving such Drawings or Documents.

- The Independent Engineer shall undertake a detailed review of the Construction Milestones defined and submitted by the Concessionaire and send its comments/ observations to the Participating ULBs and the Concessionaire within 15 days of receipt.

- Upon reference by the Participating ULBs, the Independent Engineer shall review and comment on the contracts entered into by the Concessionaire for the purpose of execution of this Agreement.

- The Independent Engineer shall review the monthly progress report furnished by the Concessionaire and send its comments thereon to the Participating ULBs and the Concessionaire within 7 days of receipt.

- The Independent Engineer shall inspect Project Facilities twice in a month, preferably after receipt of the monthly progress report from the Concessionaire, and make out a report of such inspection (the "Inspection Report") setting forth an overview of the status, progress, quality and safety of construction, including the work methodology adopted, the materials used and their sources, and conformity of construction works with the Scope of the Project and the Specifications and Standards.

- The Independent Engineer may inspect the Project Facilities more than 2 times in a month if any lapses, defects or deficiencies require such inspections.

  For determining that the construction conforms to construction requirements, the Independent Engineer shall require the Concessionaire to carry out, or cause to be carried out, tests on a sample basis, to be specified by the Independent Engineer in accordance with Good Industry Practice for quality assurance.

- In the event that the Concessionaire fails to achieve any of the Project Milestones, the Independent Engineer shall undertake a review of the progress of construction and identify potential delays, if any. If the Independent Engineer shall determine that completion of the project facilities is not feasible within the time specified in the Agreement, it shall require the Concessionaire to indicate within 10 (ten) days the steps proposed to be taken to expedite progress, and the period within which the Project construction would be completed. Upon receipt of a report from the Concessionaire, the Independent Engineer shall review the same and send its comments to the participating ULBs and the Concessionaire forthwith.

- The Monitoring Agency during operation period shall review the monthly report furnished by the Concessionaire, and shall submit its comments on the same to the Participating ULBs and to the Concessionaire within 7 days of the receipt of the report.

09.02.4. Role of vendors

- **Engineering Services**
  - Detailed Engineering - for complete plant within the defined boundary limits of individual packages.
  - Training – As and where required.
  - Facilitating project execution as per agreed technical standards
  - Submission of Drawing and documents for review/ approval and take action taken on comments from Owner's engineers as per agreed plan.
  - Quality Assurance Plan & Inspection and testing procedure for all equipments shall be provided action taken on comments from Owner's engineers as per agreed plan.
  - Assistance for Statutory Clearances and approvals viz IBR for Boiler, Electoral Inspectorate, Transmission utility for grid interface equipments etc.
- **Supply of Equipment**
  - Supply of all equipments and systems within the boundary limits under the scope of equipment supplier
- **Erection, Testing & Commissioning Services**
  - Civil construction of power plant building, all equipment foundations, auxiliary plant buildings, foundations and all other civil work associated with plant within power plant boundary.

- Erection of all Equipment as indicated under supply of equipment including all Erection Materials.
- Testing, Commissioning of all the Equipment and Systems

09.02.5. Role of IE/Monitoring agency

- The Monitoring Agency during operation period shall inspect the Project Facilities and processes at least twice in a month and carry out tests as might be deemed necessary and furnish the observations of the inspection to the Concessionaire and to the Participating ULBs within 7 days of such Inspection
- The Monitoring Agency during operation period is authorized to conduct surprise checks on the Project Facilities and processes to ensure that they comply with the Project specifications
- The Monitoring Agency during operation period shall report the results of surprise checks to the Participating ULBs within 7 days of such checks
- The Monitoring Agency during operation period is authorized to require the Concessionaire to carry out such tests/ arrange to carry out such tests as it deems necessary and present the result and inferences of the same to the Participating ULBs.
- In case any deficiency or maintenance requirement is observed by the Monitoring Agency during operation period during the inspection or tests, it shall report the same to the Participating ULBs along with the possible impact on the Project Facilities and the cost of rectification of the same.
- The Monitoring Agency during operation period shall inspect the Project Facilities once the Concessionaire rectifies the defect and report the results of such inspection to the Participating ULBs.

- The Monitoring Agency during operation period shall audit and certify the weighbridges located at the Processing Facility at least once a month and submit the results of such review to the Participating ULBs and the Concessionaire

- The Monitoring Agency during operation period shall audit the MSW quantity supply data recorded at Processing Facility and Landfill site to ensure that the data reported by the Concessionaire is accurate and that the provisions of this agreement are conformed with. The Monitoring Agency during operation period is authorized to conduct surprise checks and tests for this purpose

09.03. Cost control

A two step methodology has been developed within the framework of overall management of the project consisting of:

1. At the design stage-The entire project would consist of over 15 individual procurement & construction packages. Micro detailing would be carried during design and detailed engineering with a view to identify cost reduction opportunities in each package, particularly the high cost packages such as Material Recovery Facility, Boilers and Air Pollution Control System and STG Island. Brainstorming exercise would be carried out with the participation from the project as well as current operation and maintenance team for identification and execution of cost reduction measures. Cost budget would be prepared and approval obtained from the higher management.

2. Procurement & construction stage-One member each would be made responsible for budget and cost control for individual package. A control system would be developed and followed for capturing all cost at the

initiation stage (procurement & construction) so that total cost remains within the approved budget.

09.04. Quality Assurance

A quality assurance plan (QAP) would be prepared consisting of:

- A detailed protocol including codes and standards that would be followed for design, drawings, construction, testing and commissioning
- Schedule of documents and drawings and 'Hold points' for IE clearances
- Transaction processes-electronic and physical for approval and release of drawings, documents for follow on action
- Monthly report on QAP and periodic review meetings, if required, for resolution of issues

09.05. Managing Project Schedule

The critical procurement and construction activities have been identified based on the prior experience of JUIL in execution of 16 MW Okhla and 400 t/d material recovery facilities at Bathinda. The detailed schedule has been prepared for the entire project. Linkages of various activities to the critical path have been established. JUIL has been following a very robust project management system for implementation of its various infrastructure projects including SWM projects.

Project management protocol has been prepared taking into account:

- Identified critical path for the MRF and WtE project
- JUIL system of management of infrastructure project
- Requirement of interface with Independent Engineer (IE)
- Requirement of interface with lead ULB

010. PROJECT COST ESTIMATES AND MEANS OF FINANCE

010.01. General

The Project Cost Estimates for the project are presented under different expenditure heads and are based on the offers received for the equipment and facilities envisaged to be installed for the plant as described in the preceding chapters.

010.02. Project Cost Details Of Plant

The Project Cost of the Plant is estimated at **Rs22077 Lakhs**as Summarized in Annexure-10.2. It includes the cost of;

a) Land, Site Development&Buildings

b) Plant Machinery& Equipment including Misc. Fixed Assets, Spares, Foundation & Installation for Waste to Energy(WtE) Plant

c) Engineering Consulting - Design and Supervision

d) Independent Engineer's cost during construction

e) Scientific Land Filling (SLF) Plant

f) Preliminary and pre-operative expenses

g) Contingencies

h) Margin Money for Working Capital

i) Interest during Construction (IDC)

1. Land, Site Development&Buildings - Rs 3220 Lakhs

The cost of Site Development covers the expenses towards cost of Leveling, Construction of boundary wall, internal roads, drainage etc. Land cost is not considered as the land is on lease and is considered in tariff calculations.

The cost of Buildings covers Civil & Structural Works relating to sheds, buildings, Equipment Foundations, overhead water tank, water reservoirs, shop offices, stores, flooring & Services etc.

The estimated cost of Land, Site Development and Buildings as per details given in Annexure-10.3.

2. Plant Machinery &Equipment, - Rs 14204 Lakhs IncludingInstallationForWte Plant

The cost of various items of Plant and Machinery envisaged for the unit are along with various duties as listed in Annexure-10.3, the figure also includes freight, Erection charges, service Tax etc.

The site cost of has been worked out on the present rate of packing & forwarding @ 2.5% of ex work cost which isAssessable value (AV), Excise Duty (ED) @ 0.0% on AV & Central Sales Tax @ 2% on ED & AV, inland freight & transit insurance @ 2.5% of AV.Insurance charges have considered as 0.03% of AV cost.

3. Mandatory Spares For 3 Years - Rs 269 Lakhs

This is taken at 2% of Equipment Cost including freight, CST & Insurance.

4. Engineering Consulting – Design And Supervision **Rs98 Lakhs**

This includes the fee to be paid to the Consultants who shall be carrying out the detailed engineering of the project comprising the following tasks:

- Developing Plant & Shop Layouts.
- Design & supply of construction drawings for factory buildings, roads, drains and other Civil & Structural Works.
- Design and supply of construction drawings for equipment foundation of Plant & Machinery, Utility & Auxiliary Services etc.
- Preparing tender specifications for procurement of equipment, analysis of bids and assistance in finalizing the orders.
- Preparing tender specifications for installation of equipment, piping & cabling.
- Preparation of engineering drawings for electricals& utility services, including piping, cabling, earthing& lighting.
- Assistance in designer's supervision of work at site for Civil & Structure, installation and commissioning of equipment.

5. Independent Engineer's Cost During Construction - Rs 77 Lakhs

It covers the cost for an independent engineer on the behalf of GVMC (Greater Visakhapatnam Municipal Corporation) to monitor the Project activates & progress.

6. Scientific Land Filling - Rs 250 Lakhs

This plant shall be outside the main plant and shall be used to dumping of residual inerts from Municipal Solid Waste plant.

7. Preliminary & Pre-Operative Expenses - Rs 530 Lakhs

Establishment expenses which include Salary & Wages of staff during construction period, administrative & travel expenses including those for foreign technicians and consultant's staff, expenses for hot & cold trials have been estimated under this head. It is taken as 3% of Land, Site Development & Buildings and Plant & Machinery.

8. Contingencies - Rs 888 Lakhs

Provision of Contingencies has been kept @5.0% for Land, Site Development, Foundations, Plant & Machinery, Independent Engineer's Cost During Construction, Scientific Land Filling.

9. Margin Money For Working Capital - Rs 151 Lakhs

Margin money for working capital has been estimated at Rs164Lakhsas detailed in Annexure 12.4.

10. Financial Services Charges - Rs 149 Lakhs

It is calculated as 1% on the Debt being availed from the Financial Institutions.

11. Interest During Construction - Rs1448 Lakhs

It is worked out in Annexure 10.4.

12. Equity and Debt funded DSRA – Rs793

13. Means Of Finance

The total cost of the project is proposed to be financed as under:

Institutional Loan @ 70%	:	Rs15454 Lakhs
Equity @ 30%	:	Rs6623 Lakhs

011. REVENUE GENERATION & WORKING RESULTS

011.01. Revenue Generation

The revenue for the project has been estimated based on following:

- Sale of power
- Sale of recyclables

Out of these products for the base case only the sale of power & compost has been considered. However, the Project ratios have been calculated when all thee four products shall be sold. Product Mix & Heat & Mass Balance of the Plant for 25 years has been shown in **Annexure 10.1**.

1. Sale of Power

The revenue for power sales has been computed based on the following formula provided in PPA (Clause 2).

Payable tariff = A + B + min (C, C'); where

A = Tariff in Rs./kWh considering land lease rental at a nominal value of Rs. 1 / acre per annum and scope of work excluding scientific land filling of project

B = tariff in Rs./kWh required for scientific land filling activities

C = tariff in Rs./kWh required for land lease rental computed as per following

C = 0.001522* Land requirement (acres)* Basic value of land (in Rs. Lakhs/acre) / quoted capacity in MW

C'= 0.001522* Normative Land requirement (acres)* Basic value of land (in Rs. Lakhs/acre) / Normative capacity in MW

As defined in PPA the escalation of payable tariff shall be as follows.

60% of the payable tariff for the first financial year shall reduce at a rate of 2% every financial year for the term of PPA

40% of the payable tariff for the first financial year escalated as follows:

Financial year	Payable indexed fixed tariff (TFi) in Rs./kWh	Payable indexed variable tariff (TVi) in Rs./kWh	Payable tariff (TFi + TVi) in Rs./kWh
1	$T_{F1} = T_1 * 0.6$	$T_{V1} = T_1 * 0.4$	$T_{F1} + T_{V1}$
2	$T_{F2} = T_{F1} * (1-2\%*D/365)$	$T_{V2} = T_{V1} * [1+(WPI_1-WPI_0)/(WPI_0)*D/365]$	$T_{F2} + T_{V2}$
i=3 to 25	$T_{Fi} = T_{Fi-1} * (1-2\%)$	$T_{Vi} = T_{Vi-1} * [1+(WPI_{i-1}-WPI_{i-2})/(WPI_{i-2})]$	$T_{Fi} + T_{Vi}$

Where;

D is the number of days in the period beginning on the Commercial operation date and ending at 12.00 midnight on following 31st March.

WPIi is wholesale price index for all commodities for the financial year i.

Payable tariff definitions

Payable Tariff $_{FY1}$ (T_1)	Scenario
A + B + Minimum of (C, C')	ScientificLand filling included in the Developer's scope of work & land leased out at a value calculated according to G.O.571
A + B	ScientificLand filling included in the Developer's scope of work & land leased out at a nominal rate of Re. 1/acre per annum
A + Minimum of (C, C')	ScientificLand filling excluded from the Developer's scope of work & land leased out at a value calculated according to G.O.571
A	ScientificLand filling excluded from the Developer's scope of work & land leased out at a nominal rate of Re. 1/acre per annum

The quoted values indicated in the PPA are as follows:

A = Rs.5.976/kWh, B= Rs. 0.220/kWh and C=Rs. 0.0304/kWh

The computed tariff as considered for the financial analysis is indicated in **Annexure 11.1.**

2. Sale of Recyclables

Materials like metal Scrap, glass, paper, plastic etc shall be sold to the scrap dealers.

011.02. Cost Of Inputs

The costs of various inputs and their basis have been indicated in **Annexure 10.0**.

011.03. Process Costs

The Costs for the processinclude the followings:

- Fuel Cost
- Lease Rentals
- Operating Costs
- Insurance Premiums
- Independent engineer cost

011.04. Sale Price Consideration

Sale prices for various items like Recyclables have been indicated in **Annexure 10.0** along with expected annual increase. Power tariff for 25 years has been presented in **Annexure 11.1**.

011.05. Income Statement

Annual costs & revenue generated from the process for 25 years have been presented in **Annexure 11.2**.

012. FINANCIAL PROJECTIONS AND PROJECT APPRAISAL

012.01. Computation of Financial Projection

Computation of Interest on the debt and its repayment schedule is attached as **Annexure 12.1.**

Depreciation schedule using SLM method considering 3.80% depreciation for Site Development, Sheds & buildings and Plant & Equipment is attached in **Annexure 12.2.** The WDV considering 10% yearly depreciation on site development, 10% yearly on Sheds and buildings and 15% yearly on Plant Equipment is also detailed therein.

Calculations of the requirement for the working capital and Margin Money have been worked out and are attached as **Annexure 12.3.**

Income Tax calculations for 25 years have been done and attached at **Annexure 12.4.**

Projected Balance Sheet for 25 years has been worked and attached at **Annexure 12.5** and Projected Cash Flow Statement for 25 years has been worked and attached at **Annexure 12.6.**

012.02. Finiancial Appraisal

Financial Appraisal is carried out on the basis of the generally acceptable following criteria's;

1 Debt Service Coverage Ratio (DSCR)
2 Internal Rate of Return (IRR)
3 Pay Back Period
4 Sensitivity Analysis

1. Debt Service Coverage Ratio (DSCR) (Annexure 12.7)

The debt service coverage ratio for the project has been calculated for the period of Sixteen Years and average DSCR for is **1.87**. Minimum DSCR over these years is **1.05**.

2. Internal Rate of Return (IRR) (Annexure 12.8)

Internal rate of return is used to evaluate the desirability of investments on projects. The higher a project's internal rate of return, the more desirable it is to undertake the project. As calculated and detailed in **Annexure 12.8** an Project IRR (Pre Tax) over 25 years of **16.44%,** IRR(Post Tax)is**14.84%** and Equity IRR of **19.24%**shows that the project is quite justifiable.

3. Pay Back Period (Annexure 12.10)

The payback period has been calculated on total inflow for a period of 25 years is **11 years&6 months**.

012.03. Sensitivity Analysis (Annexure 12.11)

The Sensitivity Analysis for the Project is as follows:

S.No.	Case Basis	IRR (Post Tax) 25 Years	Avg. DSCR	Min DSCR
1	**Base Case**	**14.84%**	**1.87**	**1.05**
2	Interest Rate increased to 12.5%	15.07%	1.80	1.47
3	Increase in Hard Cost by 5%	14.16%	1.81	1.51
4	Power sale is only source of revenue	12.55%	1.58	1.38
5	Decrease in waste quantity by 25%	10.72%	1.36	1.10
6	Increase in O&M cost by 15%.	14.07%	1.80	1.51
7	No increase in waste quality (i.e. GCV)	14.33%	1.83	1.52
8	Decrease in base waste quality (i.e. GCV) by 10%	13.88%	1.80	1.42

012.04. Conclusion

As the Project critical ratios are quite favorable hence project is viable.

ABBREVIATIONS

~	Approximate value
<	Less then
>	Greater then
5-R	Reduce, Reuse, Recover, Recycle and Remanufacture
A+M	Automatic + Manual
AC	Alternating Current
ACC	Air Cooled Condenser
ACSR	Aluminium Conductor Steel Reinforced
ADS	Air density separator
AGMA	American Gear Manufacturers Association
Al	Aluminum
AOP	Auxiliary Oil Pump
AP	Andhra Pradesh
APC	Air Pollution Control
APDISCOM	Andhra Pradesh Distribution Company
APEPDCL	Andhra Pradesh Eastern Power Distribution Company Ltd
APERC	Andhra Pradesh Electricity Regulatory Commission
API	American Petroleum Institute
APPCB	Andhra Pradesh Pollution Control Board
Approx	Approximate
APSDMS	AndhraPradeshState Disaster Mitigation Society
APTDPC	Andhra Pradesh Technology Development & Promotion Centre
APUFIDC	Andhra Pradesh Urban Finance & Infrastructure Development Corporation
As	Arsenic
ATC	Air Traffic Control
AVR	Automatic Voltage Regulator
B	Boron
BA	Boiler Association
BOD	Bio-Chemical Oxygen Demand
BOP	Balance of Plant
C	Carbon
C&I	Control and Instrumentation
C&T	Collection and Transportation
C/N	Carbon to Nitrogen Ratio
Ca	Calcium

CA	Concession Agreement
$CaCO_3$	Calcium Carbonate
CACW	Closed Air Circuit Water Cooled
CAGR	Compounded Annual Growth Rate
Cd	Cadmium
CDM	Clean development mechanism
CEMS	Continuous Emission Monitoring System
CEO	Chief Executive Officer
CER	Renewable certificates
CERC	Central Electricity Regulatory Commission
CFO	Chief Financial Officer
CH_4	Methane
Cl	Chlorine
Co	Cobalt
CO	Carbon Mono Oxide
CO_2	Carbon Di Oxide
cod	Chemical Oxygen Demand
COD	Commercial Operation Date
CPCB	Central Pollution Control Board
CPHEEO	Central Public Health and Environmental Engineering Organization
CPP	Captive Power Plant
CSR	Corporate Social Responsibility
CST	Central Sales Tax
Cu	Copper
DBFOT	Design, Build, Finance, Operate and Transfer
DC	Direct Current
DCS	Distributed Control System
DER	Debt Equity Ratio
DG	Diesel Generator
DI	Ductile Iron
Dia	Diameter
DISCOM	Distribution Company
DM	De-Mineralized
DoI	Directorate of Industries
DPR	Detailed Project Report
DSCR	Debt Service Coverage Ratio
DST	Department of Science &Technology

Dyn	Delta Star Neutral
EBITDA	Earnings Before Interest, Tax, Depreciation And Amortization
EHS	Environmental Health & Safety
EIA	Environmental Impact Assessment
EMP	Environment Management Plant
EOP	Extraction Oil Pump
EOT	Electric Overhead Travel
EPA	Energy Purchase Agreement
EPC	Engineering Procurement and Construction
EPCM	Engineering Procurement and Construction Management
F	Fluorides
Fe	Iron
FGCS	Flue Gas Cleaning System
FGT	Flue Gas Treatment
FY	Financial Year
GCV	Gross Calorific Value
GHG	Green House Gases
GI	Galvanized Iron
GM	General Manager
GVMC	Greater Visakhapatnam Municipal Corporation
GoI	Government of India
H	Hydrogen
HBD	Heat Balance Diagram
HCl	Hydrogen Chloride
HDPE	High Density Polyethylene
HF	Hydrogen Fluoride
Hg	Mercury
HOC	Halogenated Organic Compound
HP	High Pressure
HPSV	High Pressure Sodium Vapour Lamps
HR	Human Resource
HRM	Human Resource Management
HSAW	Helical Submerged arc Welding
HT	High Tension
HVAC	Heat Ventilation and Air Conditioning
I&C	Instrumentation & Control
I/O	Input/output

IBR	Indian Boiler Regulation
ICICI	Industrial Credit And Investment Corporation of India
ID Fan	Induced Draft Fan
IDC	Interest During Construction
IE	Independent Engineer
IEC	International Electro-technical Commission
IED	Industrial Emissions Directive
IEEE	Institute of Electrical &Electronics Engineers
IFCI	Industrial Finance Corporation of India
ILFS	Infrastructure Leasing & Financial Services Limited
IP	Ingress Protection
IPP	Independent Power Producer
IRR	Internal Rate of Return
IS	Indian Standards
ISHRAE	Indian Society of Heating Refrigerating and Air Conditioning Engineers
ISO	International Organization for Standardization
JIL	JITF Infralogistics Limited
JITF	Jindal Infrastructure Transport Fabrication
JRIL	Jindal Rail Infrastructures Limited
JSL	Jindal Saw Limited
JUIL	JITF Urban Infrastructure Limited
JUISL	JITF Urban Infrastructure Services Limited
JUWMVL	Jindal Urban Waste Management (Visakhapatnam) Ltd.
JV	Joint Venture
JWIL	JITF Water Infrastructure Limited
JWL	Jindal Waterways Limited
LASC&PT	Lightning Arrestor Surge Capacitor & Potential Transformer
LED	Light Emitting Diode
LHV	Low Heating Value
LoI	Letter of Intent
LOTO	Lockout/Tagout
LP	Low Pressure
LPBS	Local Push Button Station
LSAW	Longitudinal Submerged Arc Welded
LTP	Leachate Treatment Plant
LV	Low Voltage
MBF	Moving Bed Feeders

MCC	MotorControlCenter
MCR	Maximum Continuous Rating
Mg	Magnesium
Mn	Manganese
MNRE	Ministry of New and Renewable Energy
MOC	Material of Construction
MOEF	Ministry of Environment & Forest
MoLE	Ministry of Labour& Employment
MRF	Material Recovery Facility
MS	Mild Steel
MSDS	Material Safety Data Sheet
MSL	Mean Sea Level
MSW	Municipal Solid Waste
N	Nitrite
NA	Not available
NEERI	National Environmental Engineering Research Institute
NFB	Non Fund Based
NGO	Non-Governmental Organization
NGR	Neutral Grounding Resistor
NH	National Highway
NH_3	Ammonia
Ni	Nickel
NO	Nitrogen Oxide
NO_2	Nitrous Oxide
NOC	No Objection Certificate
No.	Numbers
NO_x	Nitrogen Oxides
NPV	Net Present Value
NREDCAP	New And Renewable Energy Development Corporation of Andhra Pradesh Limited
O or O_2	Oxygen
O&M	Operation and Maintenance
O_3	Ozone
ONAF	Oil Natural Air Forced
PA	Primary Air Fan
PAH	Polycyclic Aromatic Hydrocarbons
PAT	Profit After Tax
PCC	Power Control Centre

PFD	Process Flow Diagram
PLC	Programmable Logic Controller
PLF	Plant Load Factor
PNB	Punjab National Bank
PPA	Power Purchase Agreement
PPP	Public Private Partnership
PVC	Polyvinyl Chloride
QAP	Quality Assurance Plan
R&M	Repair and Maintenance
RCC	Reinforced Cement Concrete
RDF	Refuse Derived Fuel
RFP	Request for Proposal
RH	Relative Humidity
RO	Reverse Osmosis
RTO	Regional Transport Office
SA	Secondary Air
SAC	Swachh Andhra Corporation
SBM	Swachh Bharat Mission
SCAPH	Steam Coil Air Pre Heater
SCR	Selective Catalytic Reduction
SLF	Scientific Land Filling
SMF	Sealed Maintenance Free
SNCR	Selective Non-Catalytic Reduction
SO_2	Sulphur Di Oxide
SO_3	Sulphur Tri Oxide
SO_x	Sulphur Oxides
SPM	Solid Particulate Matter
SPV	Special Purpose Vehicle
SS	Stainless steel
STG	Steam Turbine Generator
STP	Sewage Treatment Plant
SWG	Standard wire gauge
SWM	Solid Waste Management
T&C	Testing & Commissioning
TAC	Tariff advisory committee
TDS	Total Dissolved Solids
TEFC	Totally Enclosed Fan Cooled

Th	Thorium
TIFAC	Technology Information, Forecasting & Assessment Council
TNW	Total Net worth
TOC	Total Organic Carbon
TOL	Total Outside Liability
TOWMCL	TimarpurOkhla Waste Management Company Pvt. Ltd
TPN	Three Pole Neutral
TRANSCO	Transmission Company
TSS	Total Suspended Solids
UCC	User Collection Charges
UK	United Kingdom
ULB	Urban Local Bodies
UNFCCC	United Nations Framework Convention on Climate Change
UPS	Uninterrupted Power Supply
UPSIDC	Uttar Pradesh State Industrial Development Corporation
USA	United State of America
V	Volt
VFD	Variable Frequency Drive
VGF	Viability Gap Funding
W+S	Working + Standby
WACC	Weighted Average Cost of Capital
WCC	Water Cooled Condenser
WPI	Wholesale Price Index
WtE	Waste to Energy
WTP	Water Treatment Plant
XLPE	Cross Linked Polyethylene
Ynd1	Star Neutral Delta
YoY	Year on year

UNITS AND MEASURES

+	Plus
-	Minus
±	Plus or Minus
~	Approximate
%	Percentage
µS	Micro Siemens
O	Degree
^{0}C	Degree Celsius
(a)	Absolute
A	Ampere
CFM	Cubic Feet per Minute
cm	Centimeters
cm^2	Centimeter Square
cum	Cubic Meter
D	Day
dB	Decibel
DBT	Dry Bulb Temperature
G	Grams
GWh	Giga Watt Hour
GWh/y	Giga Watt Hour Per Year
H	Hours
Hz	Hertz
kA	Kilo Ampere
kcal	Kilo Calorie
kcal/kg	Kilo Calorie Per Kilogram
kg	Kilogram
kg/d	Kilogram Per Day
kgf/cm^2	Kilogram force per square centimeter
kV	Kilo Volt
kV-rms	Kilo Volt Root Mean Square
kW	Kilo Watt
kWh	Kilo Watt Hour
L	Liter
M	Meter
m^2	Square Meter
m^3	Meter Cube

m^3/h	Meter cube per Hour
Mcal	Mega Calorie
Mcal/h	Mega Calorie per Hour
mg	Milligram
mg/l	Milligram per litre
mg/Nm^3	Milligram per Normal Meter Cube
min	Minutes
mm	Millimeter
MT	Metric Tons
MT/y	Metric Tons per Year
MVA	Mega Volt Ampere
MW	Mega Watt
MWh	Mega Watt Hour
MWh/d	Mega Watt Hour per Day
m/min	Meter per minute
$ngTEQ/Nm^3$	Nano gram Toxicity Equivalent per Normal Meter Cube
Nm^3	Normal Meter Cube
Nm^3/h	Normal Meter Cube per hour
p.a.	per Annum
ppm	Part per Million
psi	Pounds per Square Inch
rpm	Revolution per Minutes
Rs/acre	Rupees per acre
Rs/kWh	Rupees per Kilo Watt Hour
Rs/MT	Rupees Per Metric Ton
T	Tons
t/d	Tons per Day
t/h	Tons per Hour
TR	Tons of Refrigeration
V AC	Voltage Alternating Current
V DC	Voltage Direct Current
y	Year

CURRENCIES

USD	United States Dollar $
Rupees	Rs.