ELECTRICITY GENERATION FROM THE MUNICIPAL SOLID WASTE (MSW)

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Abstract- In India, Municipal Solid waste is a major challenge in most cities and especially in developing countries where budgetary constraints exist. This is exacerbated by the ever increasing urbanization which puts even more pressure in the existing infrastructure. With India having the highest rate of urbanization at 3.5% annually and the least developed waste management infrastructure, an urgent solution is required in order to save the environment and the health of people living near the open dumps which is the most common final waste disposal system. The study sought to find the entrepreneurial opportunity in the final waste disposal in the city of Pane. The study sought to estimate the potential of electricity in the current waste generated in Pane city by using the different waste to energy technologies i.e. Landfill gas to electricity and incineration. Literature was reviewed on landfill gas to electricity, incineration, factors affecting successful set up of a waste to electricity facility and the benefits of converting waste to electricity. The study also sought to understand the factors that have the most impact for setting up a successful waste to energy facility and a survey was administered to players in the municipal waste segment. Factor analysis was done to identify the factors that have the most impact in successful set up of a waste to electricity facility. Data collected from the survey was analyzed and the factors with the greatest impact successful set up of a waste to electricity facility were identified. The factors identified were: Stakeholder involvement for political support, regulatory framework and municipal waste chain management. The other factor was location in order to understand the available waste quantities and the environmental impact. The last factor was economical with incentives to attract investors being a key component to this. The benefits of setting up a waste to electricity facility were articulated as employment creation, carbon credits and carbon tax, financing and tax incentives, revenue from sale of electricity and heat and environmental benefits.
Keywords: MSW, Waste to Energy, Landfill gas, Solid Waste management, Factors

1. INTRODUCTION

1.1 Background

Urbanization is on the rise in India and this trend is expected to continue in the future. Of concern is that the infrastructure and land use planning including for waste management is not coping with the growth of urban areas (around 3.5% annually, highest in the world). This is particularly urgent in the slum areas which constitute a big part of many of the cities and towns in India.
Solid Waste Management (SWM) is a major public health and environmental concern in the urban areas and many developing countries. The situation in India, particularly in the large urban towns is severe. The public sectors in many countries are unable to deliver services effectively, regulation of the private sectors is limited and illegal dumping of domestic and industrial waste is a common practice. Local authorities charged with the responsibility of providing municipal services have found it increasingly challenging to play this role. Pune’s solid waste situation, which could be taken to generally represent India’s status, is largely characterized by low coverage of solid waste collection, pollution from uncontrolled dumping of waste, inefficient public services, unregulated and uncoordinated private sector and lack of key solid waste management infrastructure. Municipal solid waste is defined to include refuse from households, non-hazardous solid waste from industrial, commercial and institutional establishments (including hospitals), market waste, yard waste and street sweepings.Proper management of solid waste provides benefits to the environment, quality of life of people living in the urban areas and generates employment and income. The principles of sustainable waste management strategies are thus to: minimize waste generation, maximize waste recycling and reuse, and ensure the safe and environmentally sound disposal of waste.

Figure No-1.1 Dumping site

1.2 Statement of the research problem

Waste generation is expected to increase significantly as a result of industrialization, urbanization and modernization of agriculture in India. This will further aggravate the currently- existing capacity constraints in waste management. The changing lifestyles and consumption patterns of in particular the growing urban middle class is increasing the complexity and composition of waste streams in India. Adoption of technology is generating high amounts of e waste. Municipalities are struggling with budgetary constraints. Waste has a huge energy potential that can be tapped and converted into economic use.

Using waste to generate electricity not only creates an additional revenue stream for the city but also reduces the burden of waste management. For a long time, solid waste collection and disposal in Pane has been characterized by general inefficient, unfavorable and inadequate organizational set-up. The current dumpsite in Pane is overflowing with waste and an urgent solution needs to be found. The new landfill project at Hadapsar Pane has not proceeded with the required urgency because of conflicting interests.

The studies done on waste management has focused on situational analysis and the current status of waste in Pune City. Some studies have focused on entrepreneurial opportunities for small and medium enterprises mainly on recycling and composting.

Little is known about the electricity potential that the municipal solid waste in Pane has and the factors that should be considered when setting up a waste to electricity facility. Converting the waste to energy could be a long term solution to the municipal solid waste management challenge in Pane City. It is critical to estimate the electricity potential from the municipal solid waste before studying the factors needed to set up a waste to electricity facility. This study therefore seeks to explore the estimated potential of electricity, and the determinant factors for successful set up of a waste to electricity facility .The study will also seek to explore the economic model that is likely to be successful in setting up a waste to electricity facility and seek to articulate the benefits of converting waste to energy.

1.3 Research objectives

1. To estimate the electricity potential of the municipal solid waste in Pane city based on different conversion technologies.
2. To determine the factors that has the greatest impact in successful set up of a waste to electricity project.
3. To articulate the benefits of converting waste to electricity.

1.4 Research questions

1. What is the estimated electricity potential of municipal solid waste in Pane city based on different conversion technologies
2. What factors have the greatest impact for successful set up of a waste to electricity project
3. What are the benefits of converting waste to Electricity?

1.5 Justification of the study

Findings will inform the city county and private investors of the options available to convert municipal solid waste to electricity and the policy and stakeholder management that is needed for a successful waste to electricity project.

1.6. Policy significance

The aim of this study is to inform the city county on the value of waste. The electricity potential will help the city to direct resources to the waste management process as there will be a clear business case for the same. Additional revenue from electricity sales to the grid will be generated, which can then be reinvested back into the city waste management system. It is expected that the results of the study will inform investors willing to partner with Pane city in the municipal solid waste management process. The city could also consider options of outsourcing the entire waste management process including final disposal to private companies as there will be a business case to do

2. LITERATURE SURVEY

1. Sudhir Kuma[1]says that, the Municipal Corporation being the responsible authority for MSW in addition to wide range of responsibilities related to health and sanitation has not been very effective as far as MSW services are concerned. Collection, transportation and disposal of all the three components of waste lack in terms of infrastructure, maintenance and up gradation. However, the weakest link in the chain of waste management in Indian situations is the collection of waste. This analysis unambiguously shows that recycling impact is of importance in the prediction of solid waste generation. Waste to Energy (WTE) is a proven, environmentally sound process that provides reliable electricity generation and is extensively used in Europe and other developed nations in Asia. MSW depending upon the moisture and energy content of waste material is a good fuel source. The thermal treatment of MSW results in the generation of 500-600 Kwht of electricity per ton of MSW combusted. This study provides a scope for the planning of Energy projects in India by mixing urban waste with other wastes of renewable nature like rice husk or biogases as back-up fuel which is eligible as per the national programme on energy recovery from urban waste of the Ministry of New and Renewable Energy, Govt. of India. The degree of accuracy of this analysis is determined by the reliability of the published information, which has been provided by Municipal Corporation of Eluru.

2. Saad Mohammed Khan[2] says that, the use of non-renewable source of energy for energy production might not be feasible due to its harmful impact on the environment and its issues with its long term sustainability. The mentioned reason calls for the use of renewable sources of energy. Energy derived from solid municipal waste could be used to meet the demand of energy for the general population of Bangladesh. Bangladesh, a land scarce country, does not have physical space to accommodate the disposal of the ever increasing wastages. But by using the waste to produce electricity, the waste amount that is to be disposed could be significantly reduced and thus reducing the area of land required for waste disposal. The further scope of the project would include field testing, proper site selection and developing an analytical or simulative model. Keeping all the above points in mind the government should start intense research on improving the ways and technologies to use municipal waste as source of energy.

3. Surajit Bag[3] says that, the most of the State/ULBs have yet to understand the benefits of integrated waste management which facilitates efficient utilization of different components of waste management and select suitable developers or agencies for collection, transportation, processing & disposal of waste. Awareness amongst the States/ULBs about the benefits of integration of various technologies for MSW processing is lacking. This is necessary as different technological options are required for treating the different components of waste, such as Composting/Biomethanation process for Organic component, incineration/ gasification/ Refused derived fuel (RDF) process for combustibles portion of waste, inert management facility for Construction and Demolition (C&D) waste, etc. SPCBs and PCCs do not have adequate infrastructure including personnel to maintain regular interaction with ULBs. Fear amongst sanitary workers/private sweepers/ rag-pickers of losing their job/ livelihood if private developer a takes over waste management. Municipal authorities fail to appreciate the concept of PPP. They treat the partner as any other contractor. Non supply of the quantity / quality of waste committed to and presence of inert such as street sweeping, silt and construction and demolition wastes in a high proportion in the wastes delivered at the processing plant. Municipal authorities making their partner responsible for collection of user fees from the beneficiaries and linking their payment with the fees collected without extending any regulatory support. The municipal authorities fail to extend support to the concessionaire by invoking penal provisions for collection of user charges from the defaulters leading to poor recovery making the PPP project unsustainable. Tariff structure that does not adequately cover the risk of increase in the fuel price and wage structure resulting in non viability of the project. Absence of ESCROW account mechanism resulting in inordinate delay in release of payment to the concessionaire and serious financial crunch. Absence of supervision by a professional. Multiple agencies supervising the concessionaire lead to complications in assessment of performance. Selection of appropriate site and all necessary clearances (such as EIA, Consent to Establish etc)should be ensured by the Municipal Authority before the bidding process. Dispute resolution mechanism must be a part of the contract Agreement clearly binding both the parties for resolution of dispute through a mutually agreed arbitrator. Evaluation of different W to E technologies based on the patterns of energy consumption, production, and different levels of material recovery and on the cost– benefit analysis is necessary to arrive at a suitable technology that will be economically viable and energetically efficient.

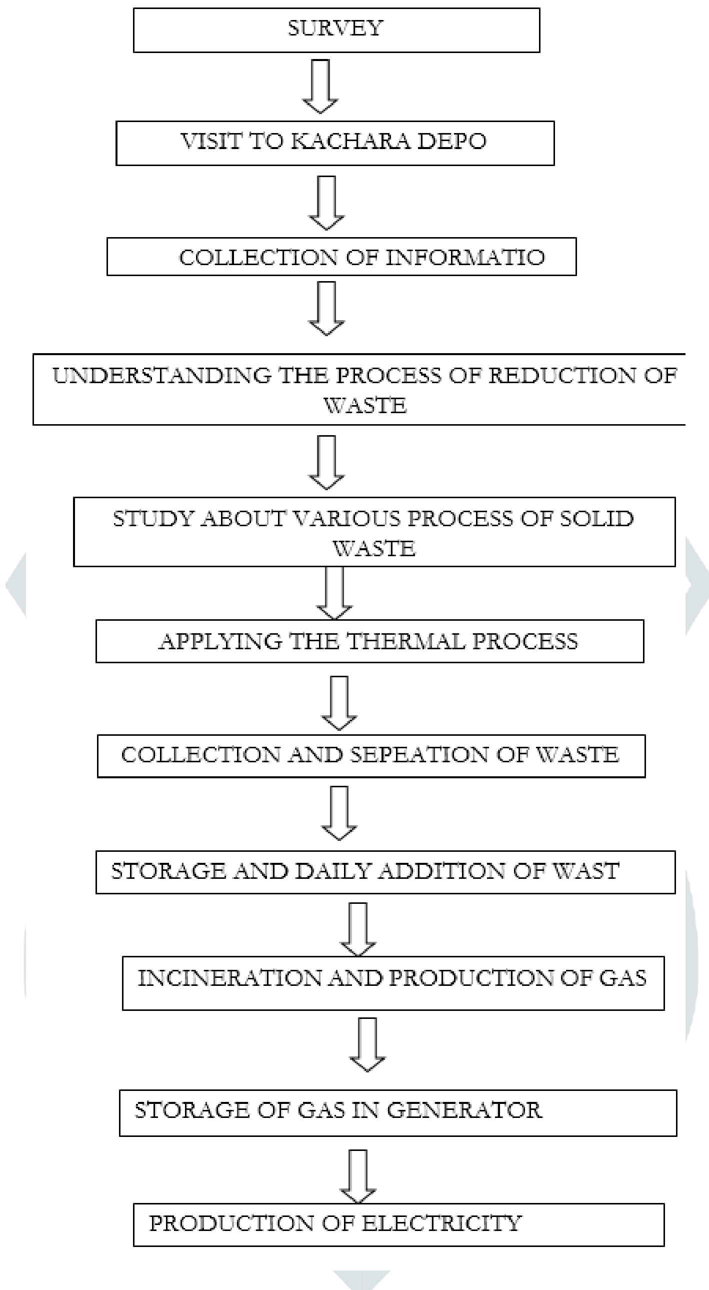
4. Arifur Rahman[4] says that, the Worldwide, about 130 million tons of municipal solid wastes are combusted annually in WTE facilities that produce electricity and steam for district heating and also recover metals for recycling . In Bangladesh 58% of waste are dumped on the roadside and in open spaces that producing adverse impact on environment. By proper management we can produce electricity and if this electricity is gathered in national grid then energy crisis can be minimized. Approximately, 4.482MWh/day electrical energy has been found from the solid waste of RCC depends on the physical and chemical characteristics of solid waste. In conclusion, a 5- 10 MW power plant can be installed based on the present generation of solid wastes in RCC to produce electricity as well as to reduce adverse impact of solid waste on environment.

5. Santiago Alzate[5] says that, the techno-economic evaluation of WTE projects presented in this article highlights the positive impact of government support in the promotion of those technologies. In Colombia, the tax incentives proposed in Law 1715 of 2014 enabled improvements in the rate of return on investment. However, the evaluation also showed that the certified emission reductions (CERs) do not have a significant economic impact due to their low value. On the other hand, in addition to tax incentives, special energy sale prices should be considered for this type of renewable source of energy in order to ensure that they can be competitive in the electric power market. Waste separation is a condition for the operation of WTE facilities. Therefore, classifying the waste at the source should be promoted among the population. To change people's behaviour, campaigns should motivate citizens to demonstrate their moral commitment to the planet. Such campaigns should seek to raise environmental awareness. The commercialization of reusable waste should also be promoted to further motivate the separation, recycling and reuse of waste. Colombia must embrace the practices of developed countries to implement WTE technologies. Government intervention is essential in the form of specialized regulatory agencies to promote and supervise the construction and operation of WTE facilities.

6. Kalyan Chakravarthi[6]says that, based on the questionnaire carried over the four villages in Amaravati region, it is concluded that majority of the people are using bins and trashcans for the collection of all types of waste such as organic waste (vegetable waste, leaves), inorganic waste, E-waste form the households. The deposal of this waste is carried out manually and mechanically. Four methods of solid waste deposal systems such as RFID, Pneumatic system, M2M and IOT are considered to find out which system is best suitable for the selected region. By analyzing the questionnaire survey conducted among the various stakeholders it is found that pneumatic system is best suitable for the increasing population in the Amaravati capital city.

3. PROPOSED METHODOLOGY

3.1 Methods



3.1. Survey- Generation Of waste

The waste generated by a population is primarily a function of the people's consumption patterns and, thus, of their socio-economic characteristics. At the same time, waste generation is conditioned to an important degree by people's attitudes towards waste: their patterns of material use and waste handling, their interest in waste reduction and minimization, the degree to which they separate wastes and the extent to which they refrain from indiscriminate dumping and littering.

Waste prevention often called source reduction means reducing waste by not producing it. Examples of waste prevention would include purchasing durable, long-lasting goods and seeking products and packaging that are as free of toxic substances as possible. It can be as simple as switching from disposable to reusable products, or as complex as redesigning a product to use fewer raw materials or to last longer. Because waste prevention actually avoids waste generation, it is the preferred waste management activity. Overall, waste prevention conserves resources, protects the environment, and prevents the formation of greenhouse gases.

The types of Municipal Solid Waste (MSW) produced change according to the standard of living in the city. Wastes generated in low- and middle- income cities have a large proportion of organic waste, whereas the wastes in high-income cities are more diversified with relatively larger shares of plastics and paper. The changing composition of waste in turn influences the choice of technology and waste management infrastructure, and underscores the importance of waste separation.

3.2. Data Collection

Many cities in developing countries have low collection and the quality of collection services is poor. Waste collection services are generally non-existent in poorer neighborhoods such as slums. While there are some successful examples where the private sector and communities are involved in waste management services, in many cities of developing countries, involvement of these segments of society is still very limited. The wastes collected typically end up in open dumps, where they may be burnt and in some cases are deposited in illegal dumping sites. The collection efficiency is the quantity of MSW collected and transported from streets to disposal sites divided by the total quantity of MSW generated during the same period. The collection efficiency is a factor of manpower availability and transport.

The collection rate of MSW in Pane City is as low as 33% which leaves about 2,690 tons uncollected .The total solid waste reuse and recycling in the city is about 100-150tons/day which is approximately equivalent to 3.7% of total waste generated. With the assumption that collection of recyclables/reusable happens before final collection, uncollected waste reduces to 2,540 tons per day. This could be assumed to be largely disposed-off in inappropriate ways such as burning and illegal/indiscriminate dumping either by collectors or due to non-collection.

3.2.1 Storage, Collection and Transportation of MSW

Storage of waste at source is the first essential step of solid waste management. Every household, shop and establishment generates solid waste on day to day. The waste should normally be stored at the source of waste generation till for its disposal. In India, such a habit has not been formed and in the absence of system of storage of waste at source, the waste is thrown on the streets, streets as store of waste. If citizens show such indifference and keep on throwing waste on streets and expect that municipal sweepers should clean the city, the cities will never remain clean. Even if l0ocal bodies make arrangements to remove all the waste disposed off by the citizen on the street on day to day basis the city will remain clean only for two to three hours and not beyond till the habit of throwing waste on the streets is not changed.

Collection of waste is the second essential step of solid waste management activity. Collection system is necessary to ensure that waste stored at source is collected regularly and it is not disposed off on the streets, drains, water bodies etc. however, step has to co-ordinate well with the first step i.e. storage of waste at source

Transportation- All the waste collected through collection system, from the households, shopes and establishment has to be taken to the processing or disposal site either directly necessitating a large feet of vehicle and manpower cost effective systems which are designed to ensure that all the waste collected from the sources of waste generation is temporarily stored at a common place called waste storage depots and then transported in bulk to the processing sites. Such as temporary arrangement for storage of waste is popularly known as dust bin, dhalavas etc. The facility has to be designed that the system matches with the system of collection as well as transportation of waste.

Figure No 3.1 Collection and Transportation of waste

3.2.2 Waste Technologies- Organic waste-to-energy technologies can be broadly classified as either biochemical, chemical or thermal processes, and will be individually discussed below.

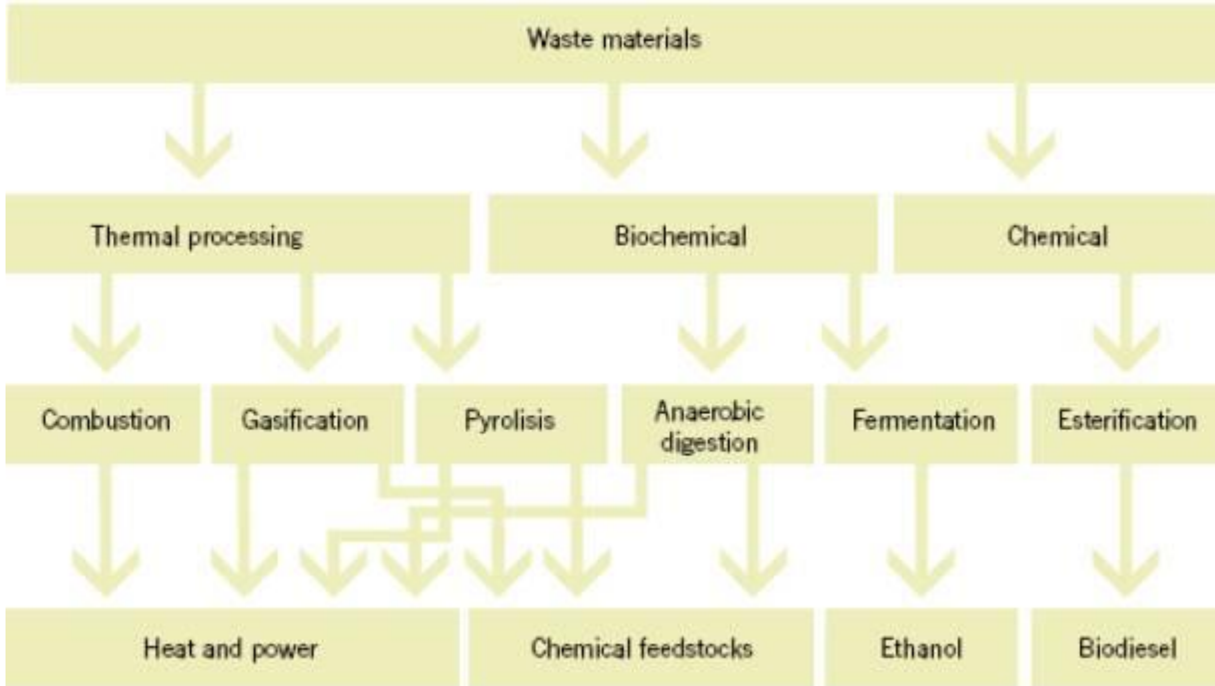


Figure No. 3.2 Pathways which waste can be converted to energy or energy related products (courtesy of the Australian Business Council for Sustainable Energy.)

3.2.3 Bio-chemical Conversion

Digestion is a bio-chemical process by which organic waste is broken down by the action of bacteria into simple molecules, either aerobically (with oxygen) or anaerobically (without oxygen). Aerobic digestion takes place where the waste is aerated, such as in the early stages of decomposition of municipal solid waste (MSW) and during composting. Anaerobic digestion takes place where the waste has restricted aeration, such as in the later stages of the decomposition of MSW or in the digestion of sludge's or wastewater in enclosed digestion vessels. Aerobic digestion produces carbon dioxide and water, whereas anaerobic digestion produces methane and water, and also some carbon dioxide and hydrogen sulphide. The gas produced by anaerobic digestion can therefore be combusted and used, either to produce electricity or heat, thereby converting the methane gas to carbon dioxide (with a lower global warming potential).

Worldwide, the dominant methods of MSW disposal are to place it into landfills or on open rubbish tips. Although these disposal methods have low initial costs, they may contribute to serious local air and water pollution; they produce obnoxious odours; they look unsightly; and they release methane, which is an explosive gas with a high global warming potential. The traditional alternative, incineration, is frequently opposed as a generic approach due to environmental impacts, such as toxic emissions, and the poor or zero energy recovery from the wasted resource. Suitable sites for landfilling are becoming scarce. The traditional alternative of combustion in the open air also gives environmental problems, and even incineration under controlled conditions is frequently opposed as a generic solution, due to perceived environmental impacts such as toxic emissions and the poor or zero energy recovery from the wasted resource. Waste-energy projects can alleviate such disposal problems and utilize an otherwise neglected resource to partly offset the costs of disposal.

3.2.4 Anaerobic Digestion

Anaerobic digestion is the decomposition of wet and green biomass through bacterial action in the absence of oxygen to produce a mixed gas output of methane and carbon dioxide known as 'biogas', which can then be used as a substitute for fossil fuels. Both liquid and solid wastes and green crops can be digested to produce biogas, a mixture of methane and carbon dioxide, which are both greenhouse gases. The natural decomposition of organic wastes in the absence of oxygen (anaerobic decomposition) by bacteria, occurs on the bottom of lakes and wetlands indicated by gas bubbles rising. It is a major source of methane, one of the major greenhouse gases resulting from hydropower installations when the surrounding land area is first flooded and the vegetation decomposes over fairly long periods of time.

Figure No. 3.3 A component of the biogas installation at Berry bank farm

Digesters range in size from around 1m^3 for a small household unit to as large as 2000m^3 for a large commercial installation. In Western Australia, the Water Corporation operates wastewater digesters at its Woodman Point operation, which separates sludge from the water.

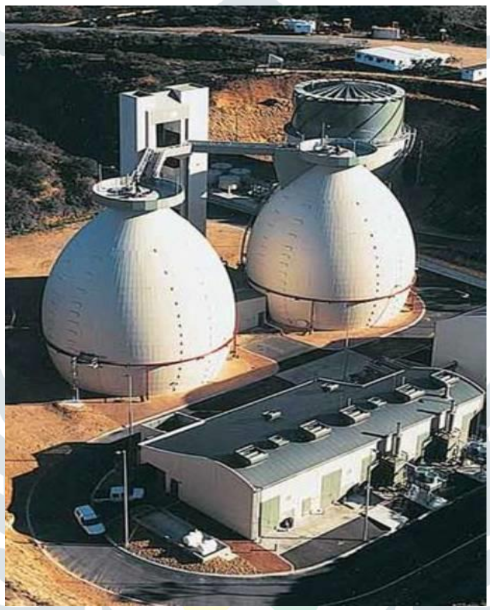


Figure No .3.4 Egg-shaped anaerobic digesters at Woodman Point rated at 1.8 MW

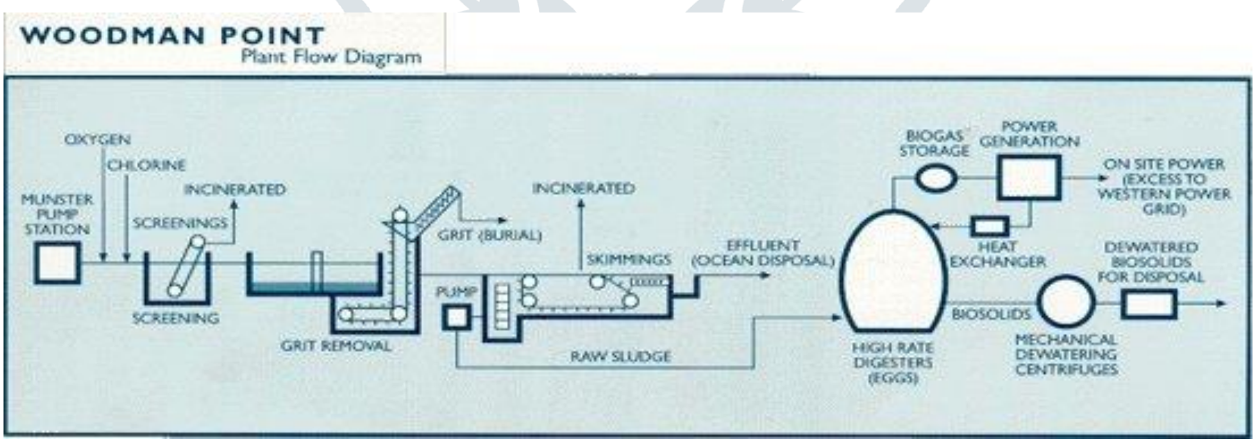


Figure No3.5 Plant flow diagram for Woodman Point facility

At Woodman Point the sludge is digested in one of two 38-metre tall anaerobic digesters. Biogas produced by the digester is used on site to provide electricity, and excess power is sold to the electricity retailer, Western Power Corporation. What is left after the digestion is complete and the gas is extracted is a sludge. This bio solid is dried then sold as a soil conditioner and fertilizer to the agricultural and landscaping industries.

Figure No.3.6 A Spreader dispersing bio solid fertilizer

Another of the Water Corporation waste-water treatment sites, in Subiaco Western Australia, uses the world's first "Oil from Sludge" process. This process, known as Enersludge converts the organic component of the waste sludge into a pyrolytic oil with properties similar to crude oil.

3.2.5 Landfill Gas

Landfill gas is an adventitious fuel that is a by-product of current landfilling practices and hence occurs only after MSW has been disposed of in a totally non-sustainable way. The anaerobic digestion of the buried solid organic waste produces the landfill gas naturally, as the bacterial decomposition of the organic matter continues over time. It is an extremely low efficiency way of recovering energy from MSW. In the long run, as the use of landfills necessarily dwindle, landfill gas will disappear as a resource. It is thus of an inherently transient nature, but will be covered here as many examples of landfill gas plants exist.

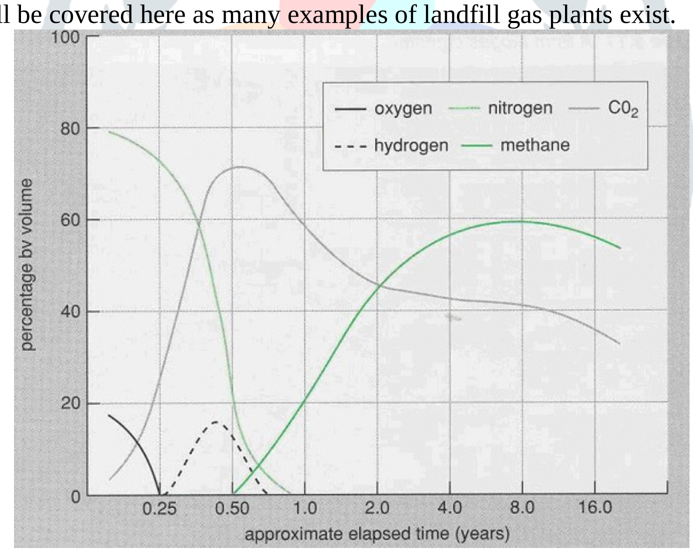


Figure No.3.7 Gases produced by a typical landfill site.

The methane produced in landfill sites normally escapes into the atmosphere, unless the landfill gas is captured and extracted by inserting perforated pipes into the landfill.

Figure No.3.8 Landfill gas extraction and generation - 2.9 MW plant in Glasgow.

In this process, the gas will travel through the pipes under natural pressure or a slight vacuum to be collected and used as an energy source, rather than simply escaping into the atmosphere to contribute to greenhouse gas emissions. The burning of the methane to produce carbon dioxide and water also reduces the greenhouse impact of landfill, as carbon dioxide is a less potent greenhouse gas than methane.

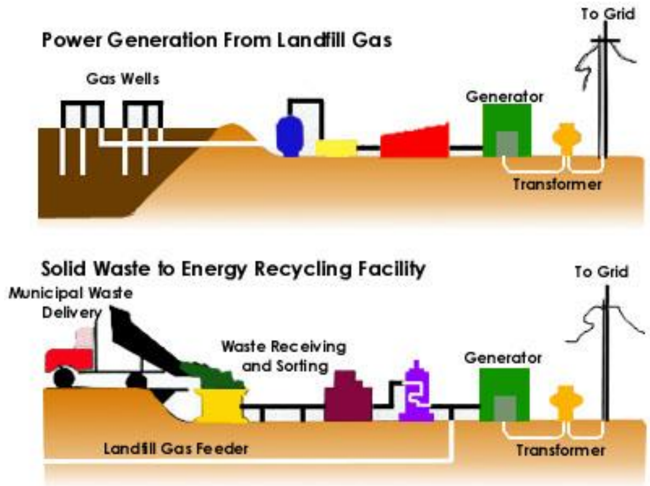


Figure No.3. 9 Power generation from landfill gas and solid waste to energy recycling
(Image adapted from Australian Energy News).

Concerns over the disposal of waste in landfill sites have led to the development of hybrid technologies, such as Solid Waste to Energy Recycling processes, which produce energy rich-gas at a higher efficiency. This energy-rich gas can then be combined with the landfill gas prior to the generation of electricity.

In theory, up to 300m^3 of biogas per tonne of waste can be extracted from a landfill gas site over a ten-year lifetime. This represents an energy content of about 5 GJ (gigajoules). In reality, because of the nature of landfill designs and construction, and the high component of non-putrescibles in the MSW, landfill gas projects produce only between twenty-five and fifty percent of their theoretical gas potential.

Improved designs and management of landfill facilities have largely overcome the litter, odour and leachate problems by lining and covering the tip, and by controlling access to trucks or rail wagons delivering wastes from local land transfer stations where recycling is encouraged. This, however has been at a cost that is passed on to the users of the facility in terms of a $x/t to deposit the waste material. Minimizing the volumes of materials going into landfills is the goal of many communities by encouraging the use of garden refuse for mulch and compost, recycling glass and metals, and utilizing any combustibles for "waste-to-energy" projects . However, the majority of wastes currently end up in a landfill. The aim then should be to avoid methane emissions for both environmental and safety reasons, since the gas is flammable and has caused explosions in nearby buildings after seeping through the ground and accumulating.

As well as electricity production, landfill gas can be used in thermal applications, where the gas is burnt to provide heating for buildings and industrial processes. Whilst this application can be less economic than electricity production due to transmission costs associated with taking the gas to the desired location, the use of gas on site (such as the construction of facilities on reclaimed landfill sites) increases the viability.

3.2.6 Thermo-chemical Conversion

Thermal processing of organic waste materials can produce heat or a number of liquid or gaseous fuels. There are three main options for recovering energy from solid refuse:

- By mass burn (combustion or direct incineration) of MSW without pre-treatment,
- By production of more or less refined fuels out of the main waste stream either partially processed or more highly processed refuse derived fuels (RDF) as pellets for later combustion in incinerators (such as rotary kilns) or via new pyrolysis or gasification techniques, and
- By the development of new approaches involving the recovery of chemicals such as plastic monomers combined with gasification, pyrolysis, hydrogenation and/or reforming of the gases and oils produced.

3.2.7 Direct Combustion and Incineration

Also described as mass burn or direct incineration, direct combustion is the burning of waste to produce heat for cooking, space heating, industrial processes or for electricity generation. Ash from the incineration process can also be sold to the construction and road building industry to further reduce the amount of material to be ultimately disposed. Dry wastes are required for direct combustion, and dried sludge from wastewater can also be used as a feedstock.

Small-scale applications (such as domestic cooking and space heating) can be very inefficient, with heat transfer losses of 30 - 90% of the original energy contained in the waste. This problem can be addressed through the use of more efficient stove technology and the use of dry, compact biomass fuels, such as wood.
On a larger scale, solid waste (including agricultural and forestry residues), can be combusted in furnaces to produce process heat to feed steam turbine generators. Power plant size is often constrained by the availability of local feedstock and is generally less than 25 - 40 MWe. However, by using dedicated feedstock supplies, such as the co-location of incinerators at waste disposal sites, the size can be increased to 50 -75 MWe, gaining significant economies of scale.

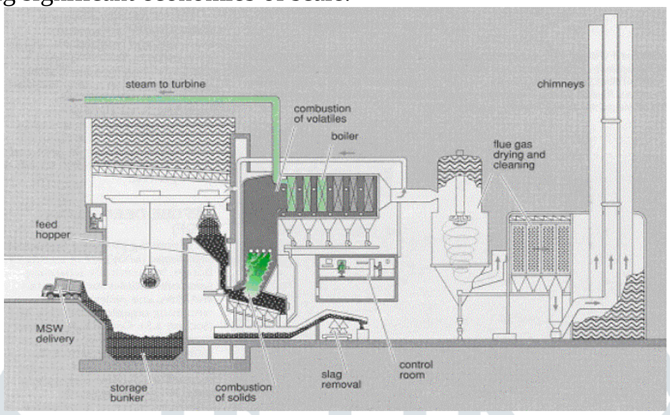


Figure No. 3.10 A typical large MSW combustion plant

Mass burn technology involves the combustion of unprocessed or minimally processed refuse. The major components of a mass burn facility include:

- refuse receiving, handling and storage systems
- the combustion and steam generation system (a boiler)
- a flue gas cleaning system
- the power generation equipment (steam turbine and generator)
- a condenser cooling water system; and
- a residue hauling and storage system.

Early incinerators were associated with a very negative environmental image and very poor performance. Concerns over direct combustion, particularly gas and smoke emissions as well as the disposal of ash, means that direct combustion technologies are now governed by more stringent government scrutiny and approvals, thereby increasing the establishment cost of these projects. Incinerators are often seen as a solution to the scarcity of urban landfill sites, rather than as a means for efficient energy recovery from waste streams.

3.3 "**Incineration"** is a generic term that encompasses a wide range of options that differ markedly in technology, economics and environmental impact. In countries such as USA, New Zealand, and Australia where there is land available, a number of incineration schemes have been considered over the last decade but few so far have found economic acceptance relative to landfills. Present trends indicate a move away from single solutions (such as mass burn or landfill) towards the integration of more advanced incineration technologies within overall waste management strategies, based on setting priorities for waste treatment methods. These include waste minimization, recycling, materials recovery, composting, biogas production, energy recovery through RDFs, and residual landfills. This approach favors the integration of incineration within a range of complementary approaches. In the process, mass burn incineration tends to be replaced by more specific and efficient techniques such as RDF incineration, gasification or pyrolysis.

The incinerators required by different waste-energy combustion routes (mass burn, RDF, incineration, gasification, pyrolysis) are markedly different, and so are their costs and environmental impacts. Mass burn is typically a low efficiency approach. While it eliminates large amounts of refuse, little energy is recovered. Typically, MSW has an average heat value of 8 to 12 MJ/kg, as compared with 19 MJ/kg for dry wood, 15 MJ/kg for lignite or 22 MJ/kg for steaming coal. Mixed plastics have an average heat value of 33 MJ/kg. Wet compostable material is in the range of 4 to 6 MJ/kg, while for comparison, natural gas has a value of about 39 MJ/Nm^3 (56 MJ/kg). In its modern versions, the mass burn process is costly as substantial "end of pipe" technology must be applied for environmental control of emissions. New technology, however, is being developed that improves performance and reduces costs.

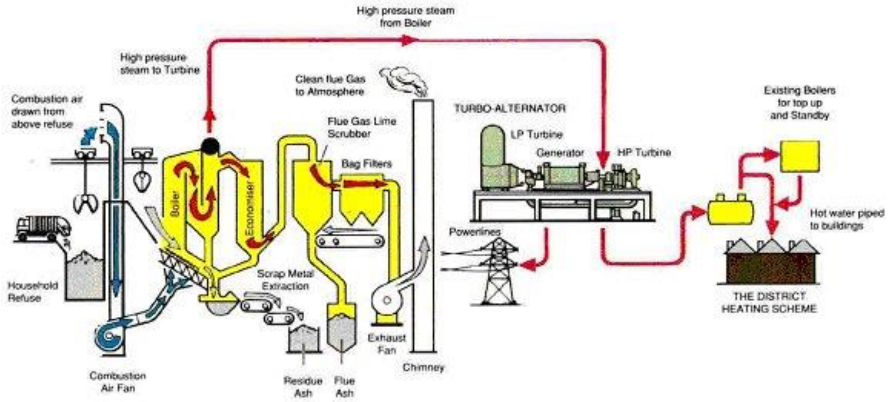


Figure No. 3.11 A typical modern waste-to-energy combustion plant generating electricity and using the waste heat, in this case for district heating.

The mass-burn or RDF combustion and boiler system provides the steam for the electricity generation equipment (steam turbine and alternator). Gas cleaning equipment, a flue stack, and ash storage and loading area are the other key components of the plant. Because of high corrosion in the boilers, the steam temperature in these plants is less than 400ºC. As a result, their total system efficiency is usually only between 12-24%.

Most dry wastes can be used as fuels and burned successfully to produce heat for direct use as process heat in industry or space heating in buildings. However, municipal and industrial wastes tend to be:

3.4 Gasification

This process of partial incineration with restricted air supply to create an air-deficient environment, can be used to convert biomass and plastic wastes into synthesis gas with a heating value 10-15% that of natural gas. When integrated with electricity production it can prove economically and environmentally attractive, though it appears better suited for clean biomass, such as wood wastes. The synthesis gas (CO + H) in turn can be converted to methanol, synthetic gasoline, or used directly as a natural gas substitute and even blended with it in a gas supply line. Even at a larger scale (say >50MW), such processes are not usually cost effective compared with using natural gas.

In principle, gasification is the thermal decomposition of organic matter in an oxygen deficient atmosphere producing a gas composition containing combustible gases, liquids and tars, charcoal, and air, or inert fluidizing gases. Typically, the term "gasification" refers to the production of gaseous components, whereas pyrolysis, or pyrolisation, is used to describe the production of liquid residues and charcoal. The latter normally occurs in the total absence of oxygen, while most gasification reaction take place in an oxygen-starved environment.

In a gasifier, the biomass or waste particle is exposed to high temperatures primarily generated from the partial oxidation of the carbon. As the particle is heated, the moisture is driven off. This could range from below 10 percent to over 50 percent of the incoming fuel weight. Further heating of the particle begins to drive off the volatile gases. For wood, this volatile content could be as much as 75 to 80 percent of the total dry weight. Discharge of these volatiles will generate a wide spectrum of hydrocarbons ranging from CO and methane to long-chain hydrocarbons comprising tars, creosotes and heavy oils. After reaching about 900ºF, the particle is reduced to ash and char. In most of the early gasification processes, this was the desired by-product. In gas generation, however, the char provides the necessary energy to effect the heating and drying previously cited. Typically, the char is contacted with air or oxygen and steam to generate CO and CO_2 and heat.

There have been some interesting and innovative ideas put forward for using small scale gasifiers to dispose of special wastes such as clinical waste by mixing it with other biomass sources such as cotton waste using an entrained flow, down draft gasifier.

The Texaco Gasification Process is an example of a proven large scale gasification technology being actively marketed for a wide range of applications, including MSW processing. The core of the process is a pressurisedgasifier operating at 20 to 80 bar, 1,200 to 1,500 °C, and using an oxygen supply. The product is synthesis gas for which the potential use could be power generation, say in a combined cycle power plant, large scale cogeneration, or chemical synthesis of a new polymer.

In Germany, Veba-Oel uses a similar gasification approach to produce an oil substitute (40,000 t/yr) followed by hydrogenation at 300 bar in its oil refinery. Texaco consider that a 100t/day plant (that is about 30,000 t/yr. of pre-sorted waste) would cost about $40 million (without the ancillaries and downstream processing plant) and would be economical in the USA.

3.5 Fermentation

Organic wastes can be converted to ethanol, the alcohol found in beverages, through bacterial fermentation, which converts carbohydrates in the feedstock to ethanol. Feedstock's to date have included agricultural wastes, such as molasses or waste starch, with more recent developments focusing on municipal organics, including food and sewage sludge. The production of ethanol from cellulose components, such as corn cobs and rice straw is under development (Australian Business Council for Sustainable Energy, 2005). When certain species of yeast metabolize sugar in the absence of oxygen, they produce ethanol and carbon dioxide. The overall chemical reaction conducted by the yeast is represented by the chemical equation: $C_6H_{12}O_6 \rightarrow 2\ CH_3CH_2OH + 2\ CO_2$. The vast majority of ethanol is produced by fermentation and is used as fuel.

The process of culturing yeast under conditions to produce alcohol is referred to as brewing. Brewing can produce only relatively dilute concentrations of ethanol in water, as concentrated ethanol solutions are toxic to yeast. The most ethanol-tolerant strains of yeast can survive in up to about 20% ethanol by volume. In order to produce ethanol from starchy materials, such as cereal grains, the starch must first be broken down into sugars. For fuel ethanol, this hydrolysis of starch into glucose is accomplished more rapidly by treatment with dilute sulfuric acid, fungal amylase enzymes, or a combination of the two. At lower petroleum prices, ethylene hydration is a significantly more economical process than fermentation for producing purified ethanol. Fluctuations in petroleum prices, coupled with the uncertainty in agricultural prices, make forecasting the relative production costs of fermented compared to petrochemical derived ethanol difficult. In general, the production of fuel alcohols from petroleum is cheaper than fermentation and extraction from biomass, but this is expected to change as fermentation and extraction processes become more efficient while petroleum becomes more expensive.

3.6 Pyrolysis

Pyrolysis is defined as incineration under anaerobic conditions and is another option for waste-to-energy that is being investigated. Pilot projects using pyrolysis for plastic wastes, and for mixed municipal solid waste potentially have very high-energy efficiencies. Combined pyrolysis and gasification systems and combined pyrolysis and combustion have also been developed and implemented.

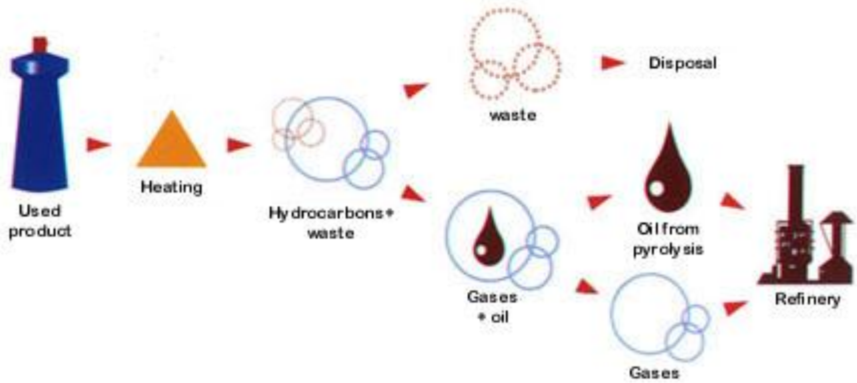


Figure No.3.12 Pyrolysis Outline

A number of approaches treat organic waste less through various pyrolytic or cracking processes. The Texaco approach produces, what are effectively oil substitutes. Examples of such processes include the Conrad and Toshiba processes.

In the USA, the Conrad process has been used to process urban waste to recover material from chemical polymers. A small-scale unit processing 5000 t/y through a rotary kiln and a liming stage was used to produce an oil-like product. The process has been banned, however, because the oil substitute was considered by the authorities to be an energy product and, as such, the overall process was not considered to achieve the required level of material recovery.

The Toshiba pilot process has a capacity of 250 kg/h over an 11 hour work day. It processes mixed plastics from Toshiba's factories in Japan to produce a range of oil substitutes. The process is essentially a series of cracking units. A high density alkaline solution is used to neutralize the chlorine (e.g. from PVC) and some of the additives that resist heat cracking. A second high-pressure cracking unit boosts reclamation further. No economic data is yet available, but other Japanese companies are now embanking on similar projects.

Net GHG emissions from waste-to-energy facilities are usually low and comparable to those from biomass energy systems, because the energy generated is largely from originally photo synthetically produced materials such as paper, MSW and organic wastes, rather than from fossil fuels. Only the combustion of fossil fuel-based waste, such as plastics and synthetic fabrics, contribute to net GHG releases. Increased recycling of these materials will generally produce even lower emissions.

3.7 Enersludge

An alternative to incineration or anaerobic digestion of sewage sludge (or dumping it out at sea, which is still often used as the disposal method, is the innovative Enersludge process, which coverts the sludge into useful bio-oil. The concept was first promulgated by Prof Bayer in Germany in the early 1980s but it is only recently that environmental pressures and the economics of other treatment options have made it competitive. The process was commercialized by Environmental Solutions Ltd. and the first plant installed was the Water Corporation's Subic water treatment plant in WA. In essence, this plant uses standard technology, which is fairly common in Europe, to produce dry pellets from the raw sludge. The pellets have a fertilizer and soil conditioning value and are free of pathogens, etc. The innovative part of the Enersludge process is the addition of a pyrolysis unit, which produces gas, char and oil. The gas and char are used to heat the plant, leaving the bio-oil for revenue earning activities - either for direct sale or for use on site in an internal combustion engine to produce electricity and offset purchase.

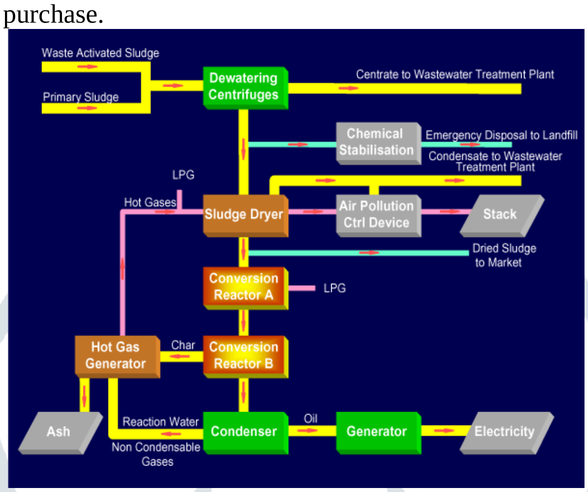


Figure No.3.13 Enersludge process flow diagram

After being macerated, the raw primary sludge is mixed with active sludge that is in excess when being circulated through the treatment plant so is taken off and thickened by air diffusion. The blend then leaves the mixer tanks and enters the dewatering centrifuges. Polymers are added to help settle out the solids and results in a "sticky cake" material. The dilute centrate fraction is separated off and returned to the treatment plant and then eventually discharged out to sea. The alternative option is for the cake to enter the rotary dryer, which is around 2m in diameter and 6m long. An LPG burner is installed as a back-up system for the dryer. The pellets are graded by size using a shaker table - returning the too large and too fine portions for reprocessing through the dryer. The bulk density of the pellets is the quality control measurement and only after several modifications, including a means of removing hair from the system, was it proved successful.

The Enersludge process converts these pellets into fuel, some of which is used for drying heat. Normally the pellets are conveyed from the dryer direct to the pyrolysis conversion reactor, although when this is being maintained up to 50% can be used for fuel in the hot gas generator and the remaining fraction is then sold or dumped. The Pyrolysis process is two stage, with volatiles being driven off at the first stage and the char passing from stage 1 to stage 2. The heavy metals present in the sludge act as catalysts. An LPG burner is installed to maintain the temperature at 400ºC. From 1 tonne of pellets, around 300 liters of bio-oil is produced. In the longer term, it is hoped to produce this bio-oil to a sufficient standard in order to run the plant diesel engine/genset and provide a portion of the site's power demand.

The hot gas generator is a fluidized bed incinerator manufactured by Energy Equipment in Queensland and designed originally for burning coal dust, but scaled down. Ash from the fluidized bed incinerator includes the heavy metals that are now immobilized. This can either be landfilled or used in a concrete mix to make terracotta paving bricks.

The cost of the LPG is around $400,000/yr., double that expected, due to the hot gas generator problems and natural gas may be a future option (though it will cost $0.25M to connect). The bio-oil is stored in tanks ready for collection and the ash in a hopper. The process itself has proved to be successful. Like many demonstration plants, finding the best equipment and adapting it to suit has proved the most difficult challenge. The ESI company is hopeful that replications will be made and is investigating a German tannery, as well as markets in South America and Europe. The advantage is that the Enersludge plant can be retrofitted on the back end of a standard sludge pelleting system.

3.8 Combustors

Technology for coal combustion has been adapted for combustion of biofuels and waste products. Combustion of biomass is more complex than coal combustion, due to the non-homogeneity, variation in moisture content and composition of the feedstock. Chain-grate boilers and fluidized beds are commonly used to improve the efficiency of combustion and heat transfer, whilst meeting environmental standards.

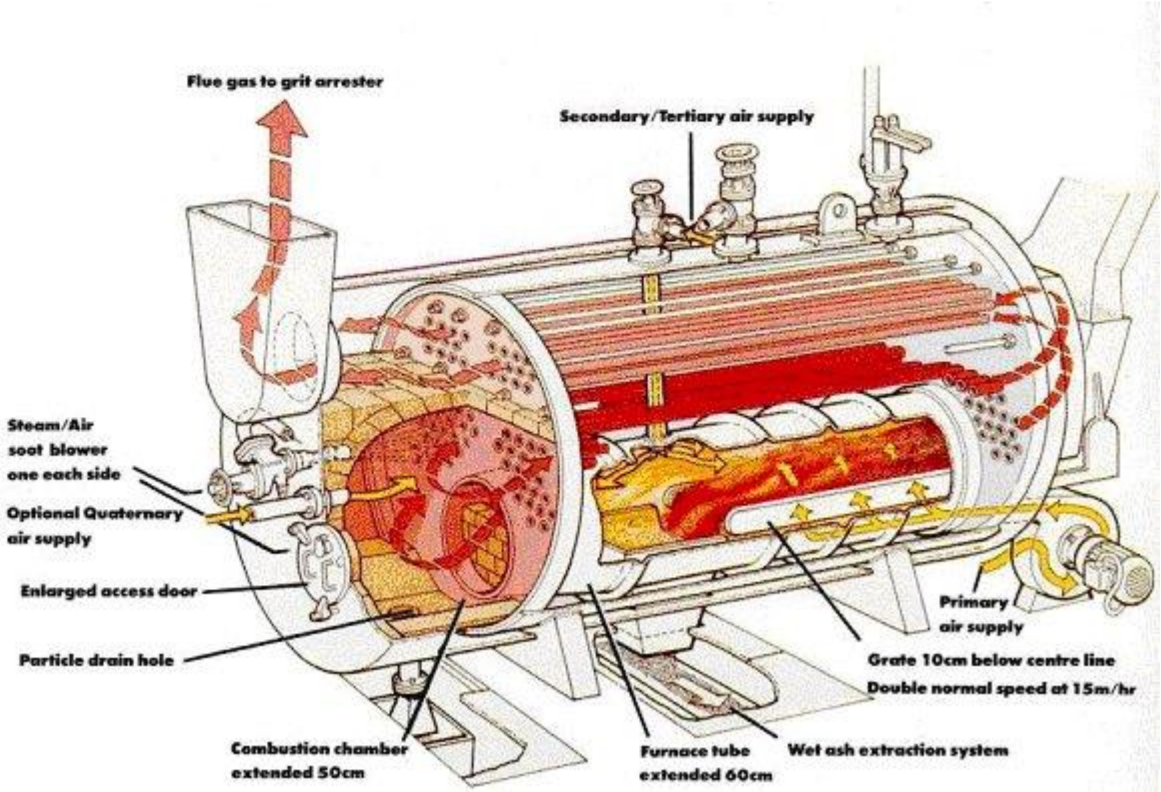


Figure No. 3.14 A 5.5MW chain grate stoker, shell boiler modified to be able to burn RDF

Fluidized bed combustion systems use a heated bed of sand-like material suspended (fluidized) within a rising column of air to burn many types and classes of fuel. This allows oxygen to reach the combustible material more readily and increases the rate and efficiency of the combustion process. The technique results in a vast improvement in combustion efficiency of high moisture content fuels, and is adaptable to a variety of waste type fuels.

The bottom of the bed is supported by water-cooled membrane walls with specially designed air nozzles that uniformly distribute the air. The fuel and limestone (for sulphur capture) are fed into the lower bed. In the presence of fluidizing air, the fuel and limestone quickly and uniformly mix under the turbulent environment and behave like a fluid. Carbon particles in the fuel are exposed to the combustion air. The balance of combustion air is introduced at the top of the lower, dense bed. This staged combustion limits the formation of nitrogen oxides(NOx).

The bed fluidizing air velocity is greater than the terminal velocity of most of the particles in the bed and thus fluidizing air elutriates the particles through the combustion chamber to the U-beam separators at the furnace exit. The captured solids, including any unburned carbon and partially oxidized carbon, are re-injected directly back into the combustion chamber without passing through an external recirculation. This internal solids circulation process provides longer residence time for fuel and limestone, resulting in good combustion and improved sulphur capture.

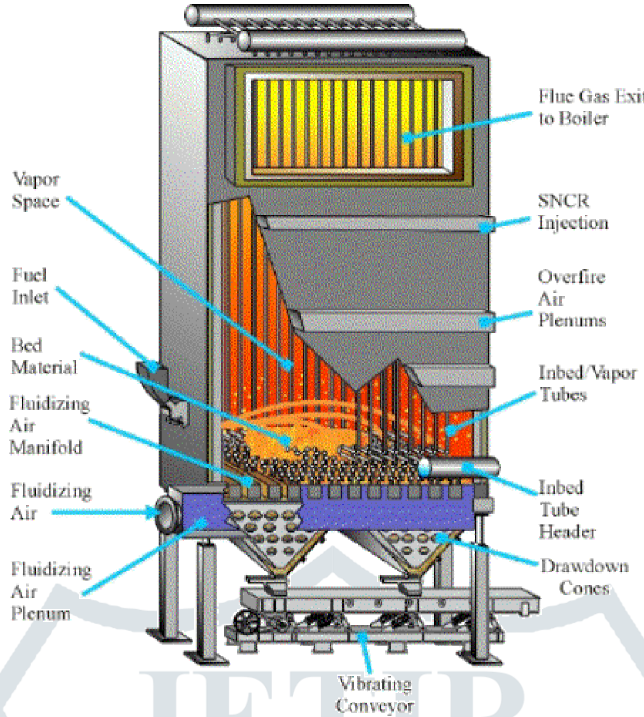


Figure No. 3.15 A fluidized bed boiler system

New combustion technologies with higher efficiencies of energy production and lower emissions are also currently under development. Fluidized bed combustion is a very efficient and flexible system that can be used for intermittent operation and can operate with solid, liquid, or gaseous fuels. Despite high operating costs, this low pollution combustion technology is increasingly used in Japan and has also been used in Scandinavia and the USA.

3.9 Recent Processes

Technology is moving fast in the waste to energy area with a number of new approaches or renewed technologies. The EnerTechSlurryCarb process currently under demonstration in the US for example, is based on a pre-treatment of MSW in water slurry form to facilitate the removal of recyclables. The slurry is then subjected to high pressure and temperature conditions and partial dewatering to turn it into a higher calorific value RDF amenable to gasification for combustion in a high-pressure steam boiler or to power a gas turbine. If successfully demonstrated this process, albeit expensive, will have very low pollution levels and significantly higher thermal efficiency than mass burns.

The WABIO process developed by EcoenergyOy, Espoo, Finland, is bio-thermal waste treatment. Waste is pre-treated and divided into organic and combustion fractions. The organic fraction is degraded into biogas and compost matter. The RDF is burned in a specially designed fluidized bed boiler unit. The temperature is kept below 900^0 c to avoid the formation of thermal NOx and of dangerous slagging compounds that could reduce the life of the boiler.

The VALORGA process, developed in France and recently adopted by Babcock-Borsig Power, uses a similar approach. MSW is shredded and sorted mechanically (with manual polishing) to recover glass, metals, plastics, inerts such as sand and gravel, and remove sources of toxic compounds such as batteries. The remaining fractions (including hospital waste) are separated into a dry RDF that is directed to a rocking kiln for steam raising and base load power generation, while the fermentescibles are sent to a proprietary, high solids (above 45% solids), computer-controlled, high yield methane digester. The methane is used to produce peak load power. The organic residues are composted to produce a sterile high quality soil conditioner. A plant processing 120,000 t/yr. of fermentescibles could generate 31 GWh of power from the methane produced and 57,000 t of soil conditioner. The trend in favour of such new energy technology integrated within an overall waste management strategy focusing on materials and energy recovery is illustrated further by the recently announced French government's plan to phase out landfills and to develop up to 150 new MSW conversion facilities.

Conclusions:-

The first research objective was to estimate the potential of electricity from municipal solid waste in Pane city using the different waste conversion technologies. This was estimated to be in the range of 80-90MW using incineration technology based on literature review. The estimated electricity potential based on landfill gas to energy is in the range of 8-15MW. Based on responses from the interviewees on the question asked on what they thought was the electricity potential, a mean of 51-60MW was estimated. The incineration technology yields the highest electricity potential and also has the least land requirement.

Table no:- 1

Sr. No.	Plant Name	Organic waste collection/day	Generation of electricity/day
1.	NMC	800MT	11.5MW
2.	Sweden	2200MT	1200MW
3.	MKD	700MT	10.08MW (Approximately)

- Table no.1 shows the quantity of waste generated and electricity generation per day. From above table we say that at Nagpur Municipal Corporation Plant 800MT Organic waste is generated per day. By doing various operations electricity generated from that waste is 11.5 MW.
- One another reference case is taken for study from Sweden country and observe that 2200MT/ day waste produced 1200 MW electricity.
- Our plant i.e Moshi Kachara Depo can be produced electricity approximately 10.08 MW from 700 MT organic waste.
- All these values may vary according to the quality of waste and the quantity of the waste.

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