MUNCIPAL SOLID WASTE MANAGEMENT

WASTE TO ENERGY

By

(G J P KUMAR REDDY , SAP ID : 500026893)

Guided By

(V Kiran Kumar, Site Engineer, Sri SaiLeela Electrical Projects)

A DISSERTATION REPORT SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR

MBA POWER MANAGEMENT

OF

UNIVERSITY OF PETROLEUM & ENERGY STUDIES, INDIA

CENTRE FOR CONTINUING EDUCATION

UNIVERSITY OF PETROLEUM & ENERGY STUDIES, DEHRADUN

Acknowledgement

This is to acknowledge with thanks the help, guidance and support that I have received duringthe Dissertation.

I have no words to express a deep sense of gratitude to the management of **Sri SaiLeela Electrical Projects** for giving me an opportunity to pursue my Dissertation, and in particular**Mr.V Kiran Kumar** for his able guidance and support.

I must also thank **Mr. M. Kannapa, Municipal Executive Engineer** for his their valuable support. Also, I like to thank the municipal authorities, who have willingly shared their precious time during interview.

Signature: Gjphaneendra

Name of the Student: G.J.P.KUMAR REDDY

Residential Address: HNo:28-807D, NGOS Colony, Nandyal, Kurnool(D),
Andhrapradesh-518502

Mobile: 8801129004
e-mail: phanigj@gmail.com

Date: 22-04-2016

Place: Bangalore.

Declaration by the Guide

This is to certify that the Mr. **G J P Kumar Reddy**, a student of EMBA (PM) Roll No. 500026893 of UPES has successfully completed this dissertation report on "**MUNICIPAL SOLID WASTE MANAGEMENT-WASTE TO ENERGY**" under my supervision.

Further, I certify that the work is based on the investigation made, data collected and analyzed by him and it has not been submitted in any other University or Institution for award of any degree. In my opinion it is fully adequate, in scope and utility, as a dissertation towards partial fulfillment for the award of degree of MBA.

Signature

Name & Designation: KIRAN KUMAR, SITE ENGINEER

Address: KPHB, HYDERABAD

Telephone:

Mobile: 8121299909

e-mail:kirankumar@srisaileelaelectrical.com

Date:16.04.2016
Place:Hyderabad

Table of Contents

List of figures

List of tables

ABBREVIATIONS

Abbreviation	Full Form
C & D	Construction & Demolition
CPCB	Central Pollution Control Board
DST	Department of Science and Technology
FB	Fluidized Bed
IMSWM	Integrated Municipal Solid Waste Management
kW	Kilo Watt
LPI	Leachate Pollution Index
NEP	National Environment Policy
NUSP	National Urban Sanitation Policy
MoEF	Ministry of Environment and Forests
MoUD	Ministry of Urban and Development
MSW	Municipal Solid Waste
MSWM	Municipal Solid Waste Management
MT	Metric Tonn
MW	Mega Watt
IPCC	Intergovernmental Panel on Climate Change
PPP	Public Private Partnership
RDF	Refused Derived Fuel
SPCB	Sate Pollution Control Board
TIFAC	Technology Information Forecasting and Assessment Council

TPD	Tonnes Per Day
W to E	Waste to Energy
WHO	World Health Organization

Executive Summary

The population in cities going on increasing due to rapid urbanization and industrialization, which leads to generate more waste. Municipal Solid Waste (MSW) management use many methods and technologies for waste disposal enable keeping our cities clean, pollution free and protect the environment. It is observed by World Health Organization (WHO) that 22 types of diseases can be prevented or controlled by proper Municipal Solid Waste Management (MSWM).

This report provides an overview of Municipal Solid Waste (MSW) disposal through waste to energy technologies and issues in the operation of waste to energy plants.

As per data given by CPCB (Central Pollution Control Board) in 2014, 62 million tones of waste generated annually by 377 million people who are living in urban areas. More than 80% of this waste is going in into dump yard without proper treatment which cause environmental and health problems. The untapped MSW has a potential to generate power, heat, biogas and electricity, which reduces the using of conventional sources like coal, wood etc. for generation. The current waste to energy technologies, programs and policies of Municipal Solid Waste (MSW) management are not treating the Municipal Solid Waste (MSW) properly which cause the increasing the waste, pollution, health problems. The more generated MSW require more land for dumping, which India cannot afford to waste the land for dumping.

The purpose of this report is to identify existing regulatory framework for municipal solid waste management, issues in the operation of waste to energy technologies for processing of Municipal Solid Waste (MSW), advantages & disadvantages and financial, technical criteria of existing waste to energy technologies and provide a platform how to select best W to E processing technology.

This report provides an over view various stages of MSWM such as collection, segregation, transportation, storage, processing & disposal of waste.

This report starts with explaining the status of sate wiseMunicipal Solid Waste (MSW) generation in India, problems due to improper treatment on MSW and functions of municipal solid waste management.

The report contains the different type of technologies for the treatment and disposal of MSW, the two main groups of processing MSW are, biochemical & thermo chemical. It also explains the threethermo chemical sub technologies i) incineration, ii) gasification and iii) pyrolysis as well as latest technology that generates liquid fuel from plastic waste.

This report also give an idea how to identify best waste to energy technologies for treating of Municipal Solid Waste (MSW) based on impact of these technologies on environment, advantages, disadvantages, application of waste to energy technologies.

Chapter1. Introduction

1.1 Background

Urbanization has become a common feature in developing countries like India. Industrialization cause growth of industries, as a result people started moving towards the industrial areas for employment, this result the growth of population in cities and towns. It is estimated that by 2025, 37% of the population of India i.e., 450 million will live in urban areas.

Urbanization and rapid industrialization increases the average waste generation per capita per day. But the municipality authorizes are not able to process the waste as much fast as waste generation by urban areas because lack of proper drainage system, sewage system, solid waste management system, land available for dump of municipal waste etc.

The improper waste disposal cause environment and health problems. Accumulation of wastes causes spoilage of landscape, release of hazards gases. Discharge of urban sewage and industrial wastes into rivers cause soil, air and water pollution.

The rapid increase in industrialization and urbanization also require more electricity generation, which require more generating plants. In India most of the power generated by thermal power plants which uses coal as a fuel. The coal reserves in India may exhaust by 2040. So there is a need of alternative sources to decrease burden on thermal power plants. Waste to energy is one such process which uses waste as a fuel and generates energy. So by using Waste to energy plant we can process the waste at the same time we can generate energy, biogas, heat, electricity etc.

Waste to energy techniques work in multiple ways to reduce the amount of waste to be deposited in landfills while extracting valuable byproducts from the waste matter. The Asia Pacific region, with emerging economies such as China, Japan, and India, is leading the global waste to energy industry. Japan, with the capacity to convert over 60% of waste to energy, has the maximum level of sustainable waste management, whereas, India and China, the two most populous nations in the world, produce huge amounts of waste that could form the backbone of a currently tragically lacking waste to energy industry.

1.2 Problem statement

The main problems faced by municipalities are waste collection, processing and disposal or treatment of solid waste produced by urban areas. Moreover, the humidity & rains on the waste increases the bacterial multiplication and the spread of infectious diseases. The solid wastes are rich in organic contents that can be a good resource to produce energy.

Most wastes that are generated dumped into land yard and water bodies without proper treatment, causing severe land & water pollution. They also emit greenhouse gases like carbon dioxide & methane and cause air pollution & health problems. Any organic waste from rural areas and urban areas and industries is a resource due to its ability to get degraded, resulting in energy generation.

Municipal waste usually contains paper, cardboard, food wastes, plastics, glass, metals, wood, street sweepings, textiles, tree trimmings and landscape, general wastes from parks, beaches etc. Sometimes it includes electronic waste like batteries and consumer electronics also get mixed up with MSW. So different waste to energy technologies require for treating the different types of waste like dry waste, wet waste, plastic waste, electronic waste etc.

1.3 Rationale

The rationale of municipal solid waste management is based on the fact that everyone generates waste and improper waste management can be affects the health and environment. Poor waste management can also pollute the ground water. Some countries have achieved considerable success in solid waste management but in developing counties like India solid wastes have not received sufficient attention. This is because, very often, environmental issues compete with other sectors of the economy for very limited resources available. Thus, management of solid waste end up not getting the priority it deserves.

1.4 Current status & generation of MSW in India

As per the report given by Central Pollution Control Board (CPCB) that 1,43,449 metric tonnes of waste is generating daily in urban areas. There are several differ methods for collection, transportation and disposal of waste, that vary across cities and states. In general, there is;

i. Door step primary collection.

`ii. segregation & storage .

iii. No regular sweeping of streets.

iv. Secondary storage by the road side in open.

v. Waste transportation in open trucks.

vi. Processing and recycle of waste.

vii. Dumping of waste directly in land yard without proper treatment.

Uncontrolled dumping of wastes into land in the cities has created huge piles of waste, These millions of tonnes are cause air and ground water pollution that make a risk to environment & public health. These dumping yards may cause increasing of infectious agents causing diseases like, dysentery, cholera, typhoid and jaundice etc.

Table 1: Estimated waste generation in the country state-wise (As on 06.02.2015).

S.No	States	Quantity generated (TPD)	Collected (TPD)	Treated (TPD)
1	Andaman & Nicobar	70	70	05
2	Andhra Pradesh/ Telengana	11500	10656	9418
3	Arunachal Pradesh	110	82	74
4	Assam	650	350	100
5	Bihar	1670	-	-
6	Chandigarh	340	330	250
7	Chhattisgarh	1896	1704	168
8	Daman Diu & Dadra	85	85	Nil
9	Delhi	8390	7000	4150
10	Goa	183	182	182
11	Gujarat	9227	9227	1354
12	Haryana	3490	3440	570
13	Himachal Pradesh	300	240	150
14	Jammu & Kashmir	1792	1322	320
15	Jharkhand	3570	3570	65
16	Karnataka	8784	7602	2000
17	Kerala	1576	776	470
18	Lakshadweep	21	-	-
19	Madhya Pradesh	5079	4298	802
20	Maharashtra	26,820	14900	4700
21	Manipur	176	125	-
22	Meghalaya	268	199	98
23	Mizoram	552	276	Nil
24	Nagaland	270	186	18
25	Orissa	2460	2107	30
26	Puducherry	495	495	Nil
27	Punjab	3900	3853	32
28	Rajasthan	5037	2491	490
29	Sikkim	49	49	0.3
30	Tamil Nadu	14532	14234	1607
31	Tripura	407	407	Nil

32	Uttar Pradesh	19180	19180	5197
33	Uttrakhand	1013	1013	Nil
34	West Bengal	8674	7196	1415
Total		1,43,449	1,17,644	32,871

Source: Figures from EQI references & AR of SPCBs/IPCCs

As compare to waste generation only 22% of waste is treated to produce energy & recycle materials. The per capita average generation in India is 450 gm./day of MSW. It is estimated that the volume of waste generation is increasing at the rate of 5% per year more as compared that increase in the population and change in lifestyle of the people, it is assumed that urban India will generate 2,76,342 TPD by 2021, 4,50,132 TPD by 2031 and 11,95,000 TPD by 2050.

1.5. Waste prevention, minimization and concept of 5Rs

MSW consists of different components that can be used to recycle and reuse and to generate fuel. Annually, 80% of municipal solid waste is dumped at open land space without any treatment. By using appropriate technology, proper planning of MSWM and the concept of 5Rs -Reduce, Reuse, Recover , Recycle and Remanufacture the country can produce energy by using 65% waste and 10% to 15% for recycling this helps to reduce the quantity of wastes going to landfills below 20%.

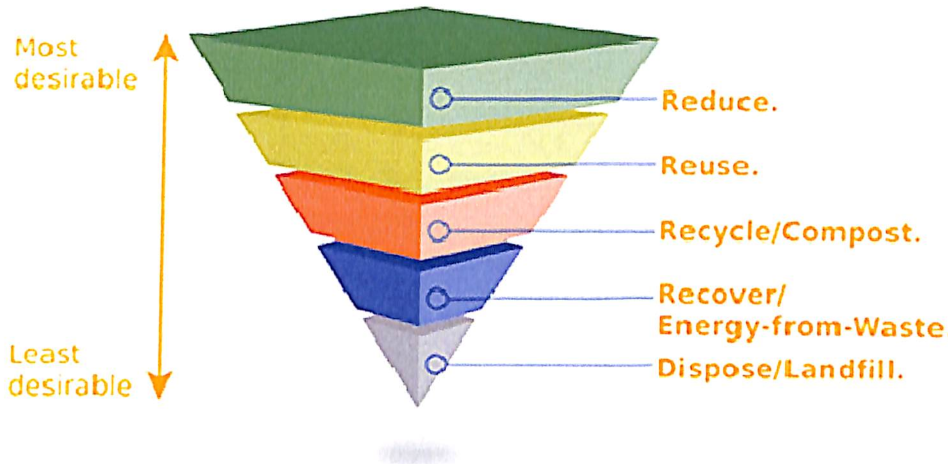

Figure 1: MSW processing diagram

Source: http://www.covanta.com

Reducing MSW generation at the first place and reuse the waste to the extent possible is the important part of waste minimization. Waste reduction avoids the unnecessary use of resources such as materials, water & energy and reduces the waste to manage. Reusing and recycling the waste material effectively also reduce the waste. Recycling involves reprocessing of waste materials to producing another new product.

The Indian waste contains high percentage of wet biodegradable waste and it cause contamination of air, soil, & water if disposed indiscriminately. Biodegradable can be used for generating compost which improve soil strength & for generation of biogas, which can used as fuel. Residual management is the final step of waste management that the waste cannot be used in any other way disposed into landfill. Residual disposal of liquid waste is normally into a sewer or septic tank.

It is important to manage liquid waste & residual solid properly. The improper disposal of waste can cause adverse environmental & health effects.

1.6 Objectives of Study:

The objective of the study is to prepare a report on energy generation using municipal solid waste and suggest suitable Waste to Energy (W to E) technologies for processing of MSW while ensuring integrated management of MSW in India.

1.7 Significance of Municipal Solid Waste Management (MSWM)

Though municipal Solid Waste Management is a service provided by the municipalities, efficient municipal solid waste management leading to pollution less environment, lesser health problems, improves the economic prosperity. The main benefits of efficient municipal solid waste management are:

1.7.1 Environment and health benefits

The effective solid waste management helps.

1. Reducing waste sent to the landfill, which decreases release of hazard gases and carbon emissions to atmosphere and meeting renewable energy targets.
2. Preventing contamination of soil & water.
3. Reducing the climate change due the emission of greenhouse gases from landfills.
4. In controlling or decreasing the spread of diseases.

1.7.2 Economic benefits

1. Recycling produce new products from waste.
2. By recycling, reusing and other process reduces waste going to landfills and reduces cost of landfills.

3. Helps in employment generation for rag pickers for waste collection and segregation.

4. Waste can be used as fuel for generation of energy.

An environmentally & economically sustainable municipal solid waste management system is effective if it follows an integrated approach i.e. it deals with all types of solid waste materials and all sources of solid waste.

1.8 Functional elements of municipal solid waste management

The municipal activities from the starting point of waste generation to final point disposal can be grouped into the following categories: (a) waste generation (b) waste segregation, handling & processing at the source (c) collection (d) sorting, processing and transformation (e) transfer and transport and (f) disposal.

Waste generation:

The activities of waste generation consists the materials that are no longer in use are gathered together or thrown away for disposal. At present waste generation is an activity that is not very controllable. In the future, however, more control is likely to be exercised over the generation of wastes. Reduction of waste at source point is more important for waste reduction.

Waste segregation, handling, storage, and processing at the source:

Waste segregation involves separation of different types of wastes like dry, wet, plastic etc for reuse and recycling at the source of generation. Waste handling is the process management of wastes from starting collection of waste to end point of loading of waste into containers. Processing at the source involves activities such as land filling.

Collection:

The functional element of collection, involves collection of waste door to door collection, by roads, parks sweeping. This waste is sorted and transported to end point through containers for disposal.

Sorting, Processing and Transformation of Solid Waste:

The sorting, processing and transformation is generally done in locations away from the source of waste generation. Sorting generally includes the separation of bulky items, electronics waste, separation of non-ferrous & ferrous metals and separation of dry and wet waste.

Waste processing is involves recycling and production of energy from waste. The Municipal Solid Waste (MSW) can be converted into energy by biological & thermal processes. The most commonly used biological process is aerobic composting and the most commonly used thermal process is incineration.

Waste transformation involves reduction in the volume, size, weight or toxicity of waste without resource recovery. There are different types of transformations techniques such as mechanical (e.g. shredding), chemical (e.g. encapsulation) or thermal (e.g. incineration without energy recovery) techniques.

Transfer and Transport:

The transfer and transport involves (i) the transfer of wastes from the smaller collection vehicle to the larger transport equipment and (ii) the subsequent transportation of the wastes, usually over long distances, to a processing site.

Disposal:

The final stage in the solid waste management is disposal of waste. Most of the waste disposed by land filling or uncontrolled dumping. Disposal of waste include the residential waste, residual waste after recycle, rejects of composting etc and waste from other processing units. The waste should be disposed such way that impact of waste decomposition on the environment is less.

Chapter2. Literature survey, regulation and research methodology

2.1 Literature review

Municipal solid waste management is a major environmental issue in India. Due to rapid increase in urbanization, industrialization and population, the generation rate of municipal solid waste in Indian cities and towns is also increased. Mismanagement of municipal solid waste can cause adverse environmental impacts, public health risk and other socio-economic problem. This paper presents an overview of current status of solid waste management in India which can help the competent authorities responsible for municipal solid waste management and researchers to prepare more efficient plans. (Neha, Gupta, , Krishna Kumar Yadav, Vinit Kumar, November 2015).

India produces 150 million ton of waste in a day and a large portion of it is left in the landfills at the city edges leaving a stinking odor and vultures floating over piles of unsafe material. Per capita waste generation in major Indian cities ranges from 0.2 Kg to 0.6 Kg. Only 10-20 per cent of the city waste is recycled in an environment-friendly way and the rest is allowed to lie in the landfills. The problem of land-starved city, leaves the planners with an extremely difficult choice, where to dump? (IshfaqHussainBhat, March 2016).

The waste generated by businesses and industries has similar characteristics to the waste originated in households. The disposal of solid waste is a major burning problem. This continues to grow with the growth of population and development of industries. Disposal of waste in open pits has become routine in majority of places. Semisolid or solid matter that are created by human or animal activities, and which are disposed because they are hazardous or useless are known as solid waste. Most of the solid wastes, like paper, plastic containers, bottles, cans, and even used cars and electronic goods are not biodegradable, which means they do not get broken down through inorganic or organic processes. Thus, when they accumulate they pose a health threat to people, and, decaying wastes attract household pests and result in urban areas becoming unhealthy, dirty, and unsightly places to reside in. Moreover, it also causes damage to terrestrial organisms, while also reducing the uses of the land for other, more useful purposes (Sumanth S. Hiremath, FEB 2016).

A new study by the Indian Institute of Science, Bangalore, has found that leachate from landfills is posing a major threat to the environment. Leachate is a contaminated liquid that drains through the bottom of the solid waste disposal facilities such as landfills. It contains numerous dissolved and suspended materials. These materials have a high value of Leachate Pollution Index (LPI) and pose a threat to the environment and human health. (Bangalore Mirror Bureau | March 21, 2016).

Waste to energy (W to E) is a waste treatment process that generates energy in the form of electricity, heat or fuels from both organic and inorganic wastes. Advanced waste to energy technologies can be used to produce biogas, syngas, and liquid biofuels. These fuels can then be converted into electricity. Waste feedstock includes agricultural waste, municipal solid waste and industrial waste. Energy can be recovered from waste by various technologies such as biological and thermal technology. Biological and thermal technologies used to convert waste matter into different forms of fuel that can be used to supply energy.(Joel John, March 2016).

The fuel used for waste to energy has either zero or almost negligible cost. This a highly reliance source of energy in the long run since waste will continuously be generated by the humankind, both organic and synthetic waste. In fact, many countries are exploring whether the landfill sites can be mined out and reused. India has enormous waste dumped on its landfill sites which can be dug and reused to fuel Indian households with clean energy. (RiaSidhwani, NOV 2015).

Waste to energy technologies can be used for a number of waste products to make the most of the energy that they possess. Waste can be in the solid, semi-solid, gaseous, or liquid state – waste to energy technologies can be applied to all of these. However, what is attracting the most attention from all parts of the globe is the transformation of municipal solid waste into energy. Thanks to thorough research and development activities in the area of the conversion of municipal solid waste into a power source, this sector is projected to gain a significant share in the overall energy mix in the coming years. (Qyresearch, March 2016).

2.2 Legislation and regulatory framework

According to the Indian constitution MSW falls under the state list. The primary function of municipal authorities is solid waste management. The Ministry of Environment and Forests (MoEF) issued several notifications to tackle the municipal solid waste. These includes

2.2.1 National Environment Policy, 2006

The National Environment Policy, (NEP) was announced in 2006. The main aim of NEP is conservation of critical environmental resources, inter-generational equity, efficiency in environmental resources use, environmental governance in the management of resources, enhancement of resources, livelihood security for the poor, integration of environmental concerns for socio-economic.

2.2.2 The Plastic Waste (Management and Handling) Rules, 2011

The Ministry of Environment and Forests, Government of India has notified the plastic Waste (Management and Handling) Rules 2011 to replace the earlier "Recycled plastic manufacture and Usage rules, 1999". Rule 6 of the said rules mandates that a plastic waste management system be put in place and identifies municipal authority as the agency responsible for implementation of the said rules within their jurisdiction.

2.2.3 National Urban Sanitation Policy, 2011

The National Urban Sanitation Policy pertains to management of human excreta and associated public health and environmental impacts. It is however recognized that integral solutions need to take account of other elements of environmental sanitation, i.e. solid waste management, generation of industrial and other hazardous wastes, drainage, as also the management of drinking water supply. The NUSP thus seeks to create fully sanitized cities through awareness generation, state sanitation strategies and integrated city sanitation.

2.2.4 Municipal Solid Waste (Management and Handling) Rules 2013

The Ministry of Environment and Forests, Government of India has notified the Municipal Solid Waste (Management and Handling) Rules 2013 to replace the earlier Municipal Solid Waste (Management and Handling) Rules 2000. According to MSW rules 2013, municipal authority responsible for implementation of rules and for the necessary infrastructure development for collection, storage, segregation, transportation, processing and disposal of municipal solid waste.

SPCB's and IPCC will monitor the progress of implementation of action plan and the compliance of the standards regarding ground water, ambient air quality and the compost quality. CPBP shall publish requisite guidelines for processing and disposal of municipal solid waste from time to time. Landfill sites shall be set up as per guidelines of Ministry of Urban Development. Existing landfill sites which are in use for more than five years shall be improved and the landfill site shall be large enough to last for at least 20-25 years.

2.2.5 Construction & Demolition (C & D) Waste

C&D waste is a significant and growing part of the disposed waste stream. C&D waste finds a brief mention in Schedule III of the Municipal Solid Waste (Management and Handling) Rules, 2000 and the ''Manual on Municipal Solid Waste Management'' of the MoUD, 2000 has a chapter on C&D waste which lays down basic guideline on its handling.

2.2.6 Swachh Bharat Abhiyan

Swachh bharat mission is a national campaign started by the Government of India 2 October 2014 to clean India's cities and villages.

2.2.7 Solid Waste Management Rules, 2015:

The MoEF is in the process of revising solid waste, plastic waste, biomedical waste, and e-waste management rules. A draft version was published in 2015, and soon the revised rules are expected to be enforced.

The present capacity of municipalities in India to manage the privatization process is quite limited. There is need for developing in-house financial and managerial capability to award contracts to private sector and monitoring services provided by the private operator since the onus of ensuring proper service delivery and compliance of standards lies with the local bodies.

2.3. Methodology

The selection of research methods depends on the research topic or researcher's interests. Silverman (2010), states that there is no correct or incorrect method to proceed. There are only methods which are suitable to our research topic and the working model.

Data gathering

Most of the data is collected from internet. I read lots of e-books & articles in the internet. I tried to gather the related information in the internet by using several key words: 'solid waste management', 'waste to energy, 'waste management', 'public private partnership', 'Current status of MSW', 'governance', 'waste problem', 'collection and transport methods', 'Issues in the Operation of Waste processing Technologies', 'significance of MSW', 'municipalities and waste management', 'roles and responsibilities' 'effect of MSW on public health and on environment 'and 'integrated waste management' etc.

Qualitative method

Qualitative method like observations, interviews & field notes were used to collect the data. Interviews were used to collect information from the municipal officials for solid waste management. Observations and field notes were made while visiting the W to E plants.

Chapter 3 Waste to energy technologies

3.1 Introduction

The choice of best technology is essential for treatment & disposal of municipal solid wastes. The choice of technology depends on the components of wastes.

Recovery of energy from the waste in the form of heat, electricity & fuel is done by using different technologies like including incineration, gasification, pyrolysis and anaerobic digestion. There are two main technologies which are used to convert waste into energy

1. Bio chemical waste to energy technology.
2. Thermo chemical waste to energy technology.

Bio chemical conversion of biodegradable MSW

Bio chemical conversion involves biological treatment using micro-organisms to decompose the biodegradable components of waste. There are two types of processes in bio chemical conversion namely

(a) Aerobic processes: Occurs in presence of oxygen. Vermi-culture, aerated static pile composting, in-vessel composting & windrow composting etc. are example of aerobic process.

(b) Anaerobic processes: Occurs in the absence of oxygen. Low-solids anaerobic digestion, high solids anaerobic digestion, and combined processes are examples of anaerobic process.

Compost is the utilizable product in the aerobic process. Methane gas is the utilizable product in the anaerobic process. Both processes have been used for waste processing in different countries, a majority of the biological treatment process adopted worldwide are aerobic composting and the use of anaerobic treatment has been more limited.

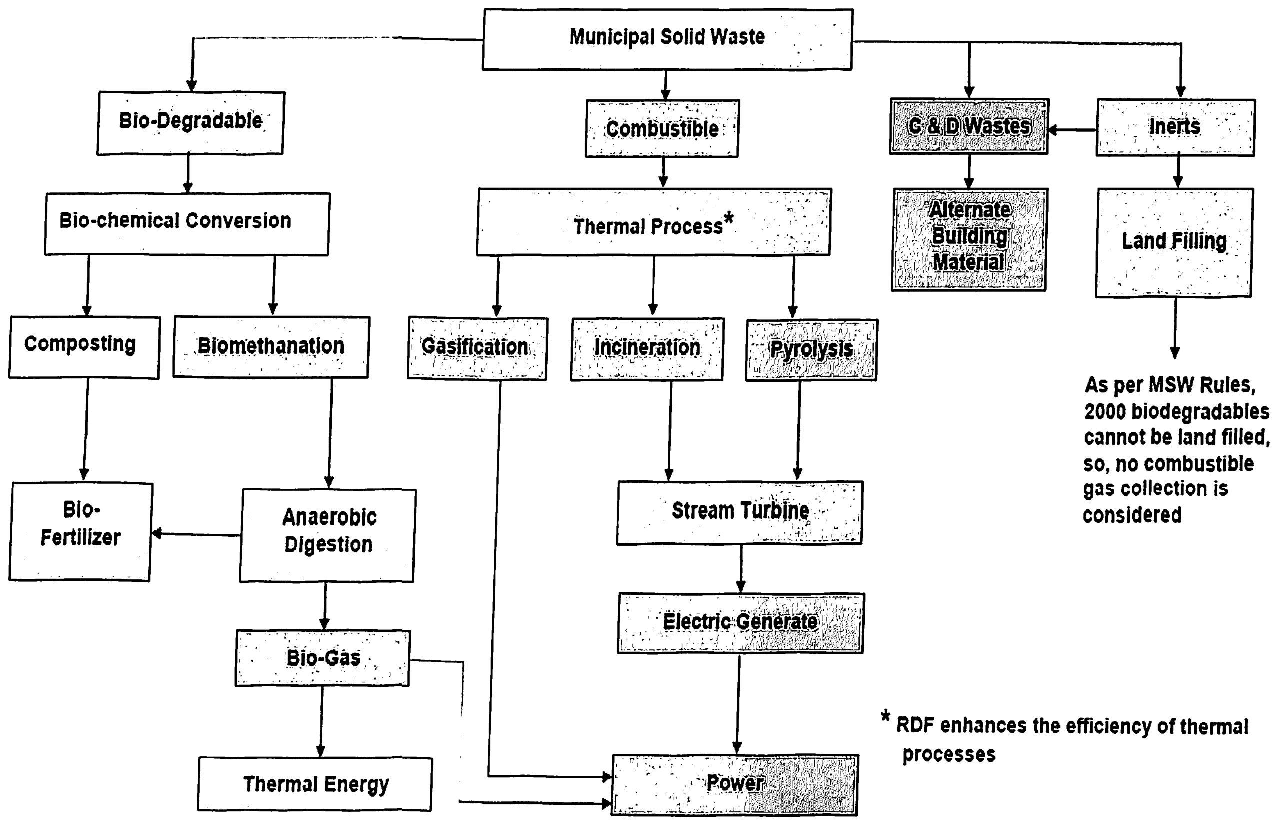

Figure 2: Options available for MSW treatment and utilization

Source : Planning commission of India,2014

Thermal processing of MSW

Thermal treatment converts the waste into liquid, gaseous & solid conversion products which release heat energy. There are three types of systems:

(a) Combustion systems (Incinerators): Thermal processing is done with excess amount of air.

(b) Pyrolysis systems: This process occurs completely in the absence of oxygen (low temperature).

(c) Gasification systems: This thermal process occurs with less amount of air (high temperature).

Combustion systems or incinerators are the most widely used thermal treatment process for MSW. Though pyrolysis is a widely used industrial process, the pyrolysis of municipal solid waste has not been very successful.

Mass fired combustion systems (MASS), fired combustion systems and Fluidized Bed (FB) & Refuse Derived Fuel (RDF) combustion systems are extensively used for energy recovery in different countries.

The energy recovery through thermal processing is done for municipal solid waste having relatively high calorific value. In Indian MSW, the presence of inerts in solid yields to a low calorific value of the MSW. However, removal of inerts from Indian MSW as well as development of combustion system for low-calorific value wastes can result in a reversal of this position in the future.

Other processes

New biological and chemical processes which are being developed for resource recovery from MSW are:

(a) Fluidised bed bio-reactors for cellulose production and ethanol production.

(b) Hydrolysis processes to recover organic acids.

(c) Chemical processes to recover oil, gas and cellulose.

(d) Others.

3.2. Bio-chemical waste to energy technologies:-

The biological processes that are commonly used for MSW management in India.

3.2.1 Biomethanation

Biomethanation or methanogens is a process, which involves formation of methane by microbes. This process takes place under oxygen. Any bio-degradable waste, organic matter, sewage sludge, municipal solid waste can be used for this process. Gas is produced due to decompose the organic matter by anaerobic bacteria. This gas contains 50-60% methane and is known as biogas. Enrichment is done to increase methane content up to 90% and more, which is at par with natural gas. The enriched gas can be compressed and filled in cylinders for commercial purpose.

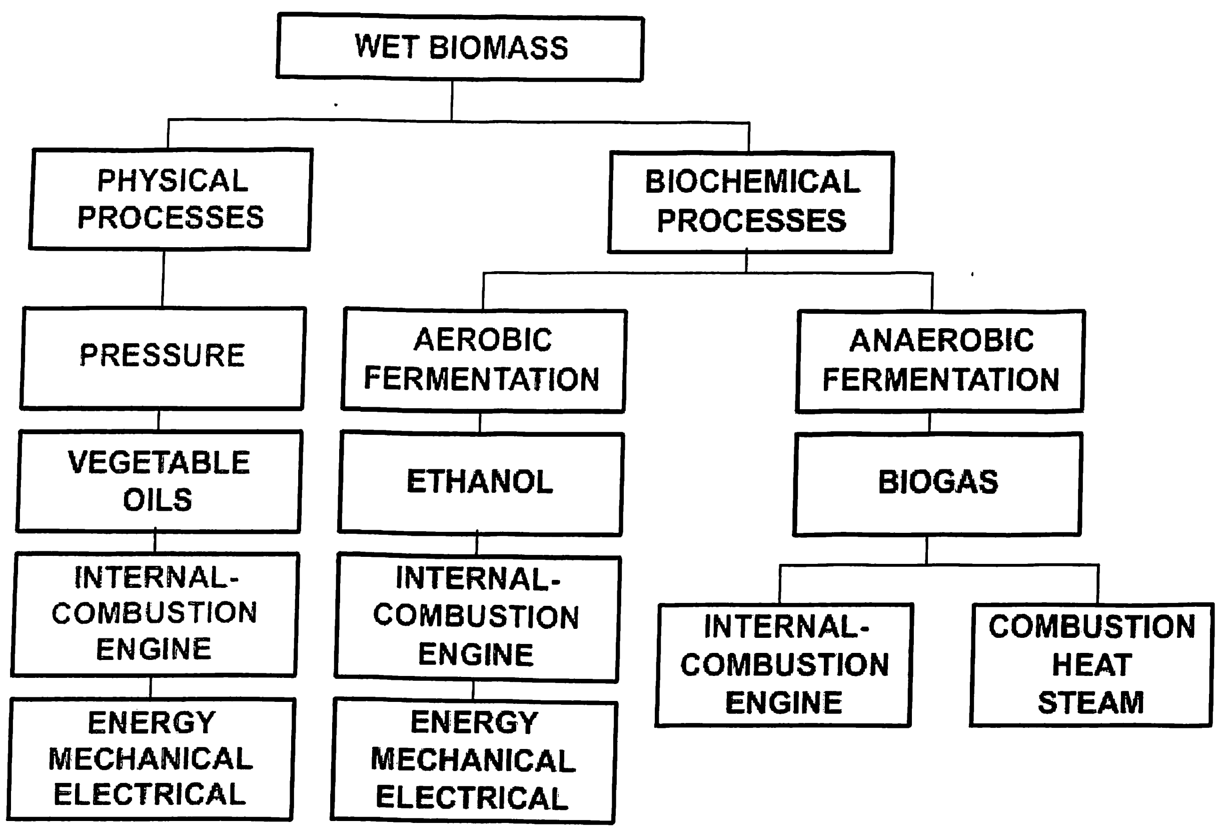

Figure 3: Biochemical processes

Source: http://www.probiomasa.gob.ar

In the biomethanation process, decomposition of complex organic compounds occurs due to bacteria fermentative digestion.. The biomethanation process consists of three main stages. The first stage is hydrolysis in which anaerobic bacteria breakdown complex organic molecules in to smaller compounds such as amino acids, fatty acids, glucose and glycerol. Next stage is acidogenesis in which acidogenic bacteria converts sugar, aminoacids and fatty acids in to alcohols, organic acids, acetate, ketones, CO2and H2. The last stage is methanogenesis stage in which methanogenic bacteria convert these intermediate products to biogas which is mainly a mixture of CO2 & methane.

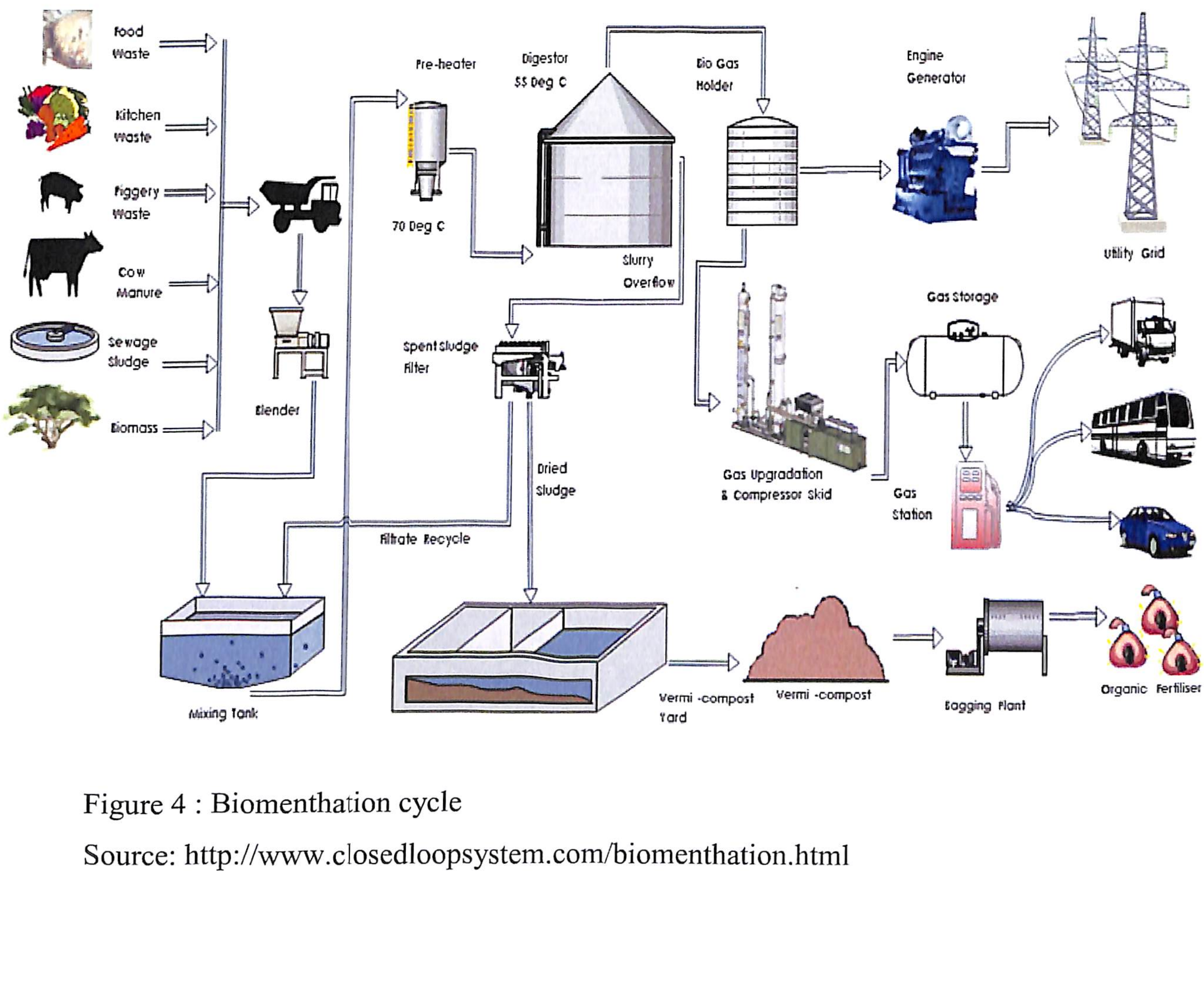

Figure 4 : Biomenthation cycle

Source: http://www.closedloopsystem.com/biomenthation.html

3.2.2 Composting

Composting is a natural process of decomposition of organic matter under aerobic conditions. It this technology the waste is buried in pits to decay for 3 to 6 months to, mechanized processing. Large quantities of biodegradable wastes can be decomposed by microbial composting. Introduction of odor masking agents & consortium of microbes further reduce the processing time. Vermi composting is the process of composting the waste using earthworms after initial pre-processing of waste under a shed. Here the earthworms ingest the organic waste and excrete, the excreta is collected is called vermi casting and it is used as bio-organic fertilizer. This technology is found suitable for small towns. The decomposed material is called as bio-organic fertilizer used to improve moisture retaining capacity, soil health, returns nutrients to soil and is generally.

3.3 Thermo-chemical waste to energy technologies

Thermal technologies are processes that converts MSW in to energy in the form of electricity, fuel or heat. The various types of thermo-chemical processes are gasification, pyrolysis, incineration or mass burning. MSW after limited or full pre-processing is used in most of these thermal technologies.

3.3.1 Combustion

Combustion involves direct burning of MSW in the presence of oxygen which gives heat. It is the simplest and most widely used method for domestic cooking, heating and for industries generation of heat and steam. Combustion reactions are almost always exothermic that give off heat.

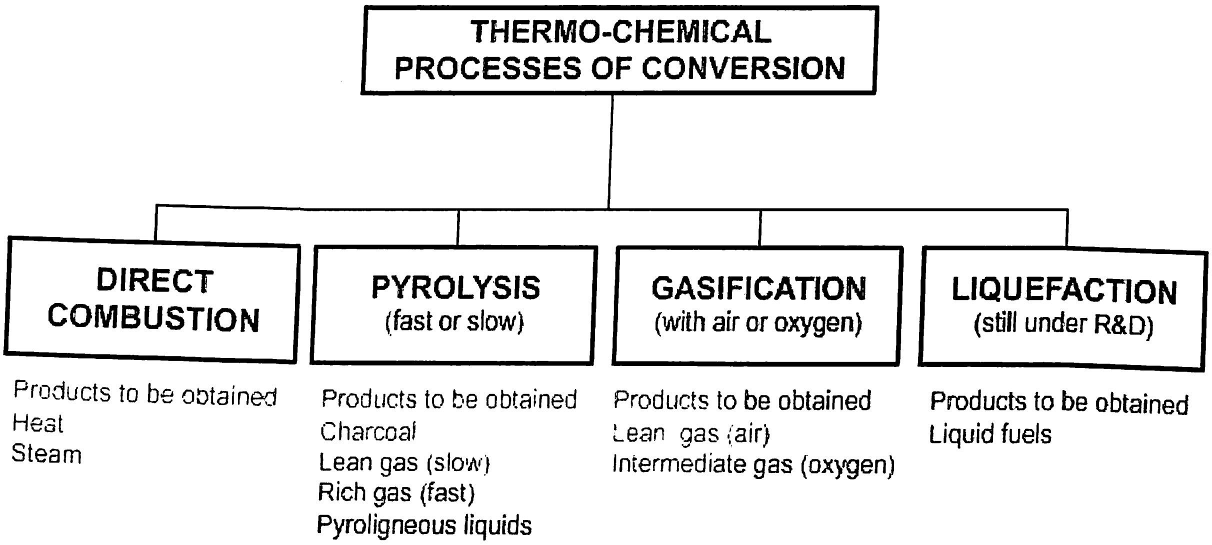

Figure 5: Thermo-chemical processes of biomass conversion into energy

Source: http://www.probiomasa.gob.ar/en/biomasa.php

3.3.2 Gasification

Gasification involves the burning of MSW in the controlled presence of oxygen which produces gas known as synthetic gas or syngas. The gas is a low-heating value fuel, with a calorific value between 1000- 1200 kcal/Nm3 . The process of gasification is took place in a closed container known as "gasifier", in which fuel is introduced together with a lower amount of air than that required for complete combustion. The resulting gas from gasification can be used in a boiler to generate steam or in a burner to generate thermal power.

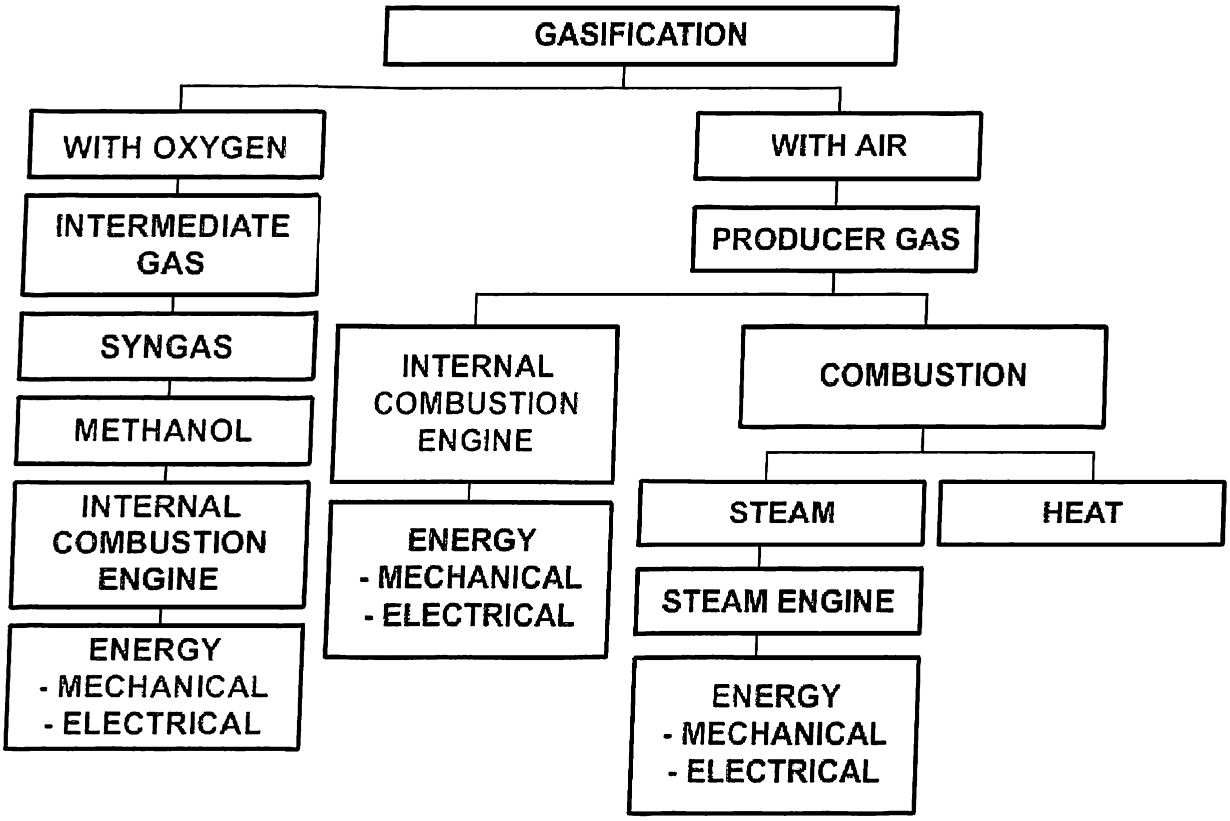

Figure 6: Gasification and its products

Source: http://www.probiomasa.gob.ar/en/biomasa.php

3.3.3 Pyrolysis

Pyrolysis is the thermal decomposition of organic material through the application of heat without the addition of extra air or oxygen . The products of pyrolysis include variable combination of solid (charcoal), liquid (pyroligneous) and gaseous (producer gas) fuels. The solid charcoal is main product of pyrolysis and liquid fuel pyroligneous and gaseous fuel producer gas is the by-products of this process.

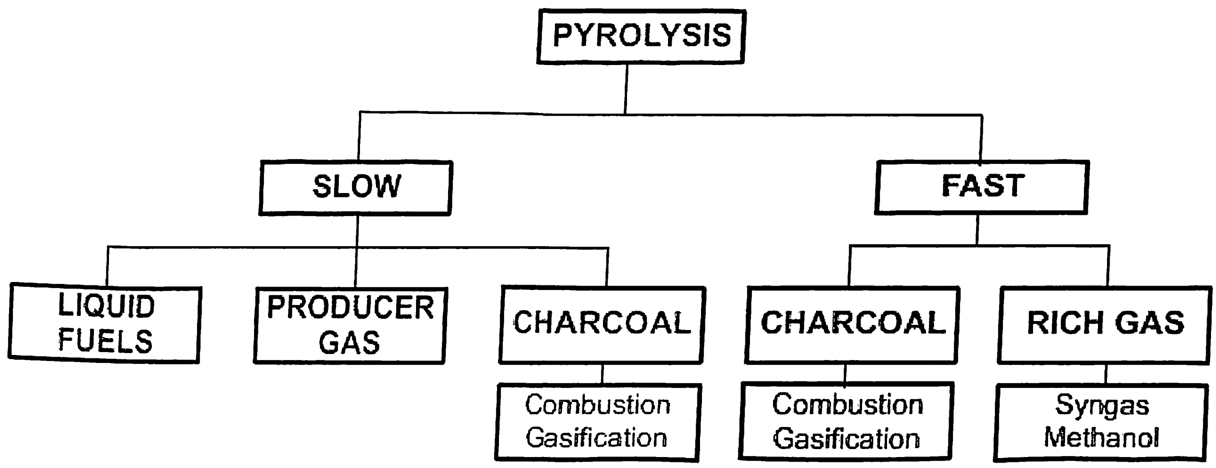

Figure 7: Pyrolysis and its products.

Source: http://www.probiomasa.gob.ar/en/biomasa.php

3.3.4 Refuse Derived Fuel (RDF) :

Refuse Derived Fuel (RDF) is produced from combustible components of MSW. The combustible fraction of the waste is shredded, dried and baled to transfer the waste into fuel pellets. RDF fuels are smaller in size, more homogeneous and easier to burn MSW resulting in a more efficient combustion process. It is much easier to transport and store fuel pellets to power plants or industries than raw MSW.

3.3.5 Catalytic conversion of waste plastic to liquid fuel :

Polymeric wastes can be converted into liquid fuel by using catalytic conversion and pyrolysis technologies. Pyrolysis is used in large size conversion plants and catalytic conversions are used in small batch operation. By blending soiled plastic wastes with chopped polymeric waste with molten bitumen is used to strengthening roads.

3.4. The energetic and economics of W to E

Rapid growth in industrialization and urbanization require more power supply. Waste to energy technologies provides an opportunity of tapping potential energy from MSW to meet part of the energy demand. The current composition of MSW in India contains low calorific value (less than 2,000 Kcal/Kg) which is not suitable as a raw material for W to E plants. The calorific value can be increased by mixing with high energy biomass.

The selection of technologies is depends on the economic conditions, desired output form of the energy, environmental standards, and end use requirements. The waste to energy conversion is important from the energetic point as well as the economics point of view because it decreases the direct load on fresh resources and produce energy at reasonably low cost.

Chapter 4: Operation of waste to energy plants in India

At present India is producing 1500MW energy from waste using biomethanation , gasification and incineration of RDF pellets. Operations of some power plants in India are discussed below.

4.1 Biomethanation plants:

It is based on the thermal chemical energy and involves complete oxidative conversion. It is the most prominent technology in India. Efficiency of the plant is 50-70%.

i) Biomethanation plant based on cattle dung at Luhiana, Punjab

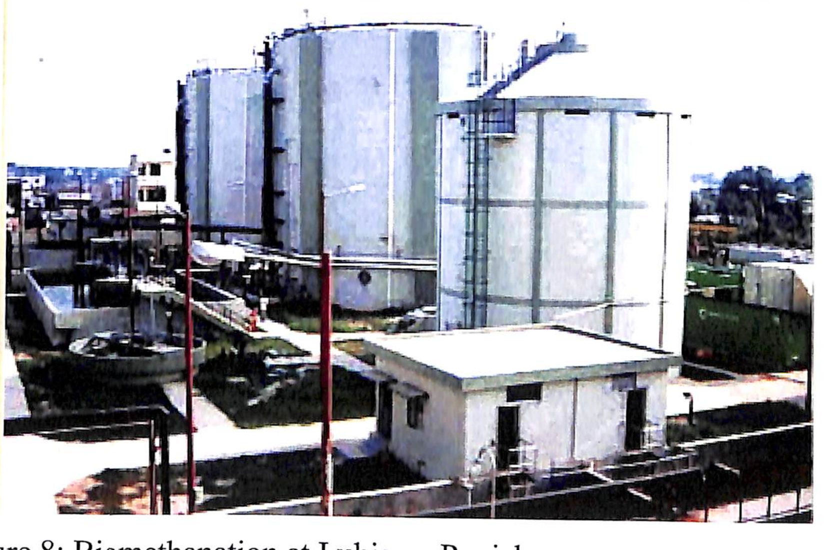

Figure 8: Biomethanation at Luhiana, Punjab
Source : http://www.bombaychamber.com

The plant was commissioned in June 2004 at Haebowal dairy complex in Ludhiana. Dairy complex is consisting 1490 dairies speared over 50 acres, having 10,50,000 animal population and generating 2500 tonnes of animal droppings per day. The plant is generating 0.965 MW electrical energy using 235 tonnes of waste per day.

ii) Biomethanation plant based on abattoir waste at Medak, Andhra Pradesh.

The has an installed capacity of slaughtering and processing 500 - 600 buffaloes and 1500 - 2000 sheep per day. The plant is treating both solid and liquid waste from the slaughterhouse. The plant was developed in two stage digestion process which handles 60MT of slaughter house wastes per day and generating 1300 cubic metre biogas from liquid wastes & 2500 cubic metre biogas from solid wastes

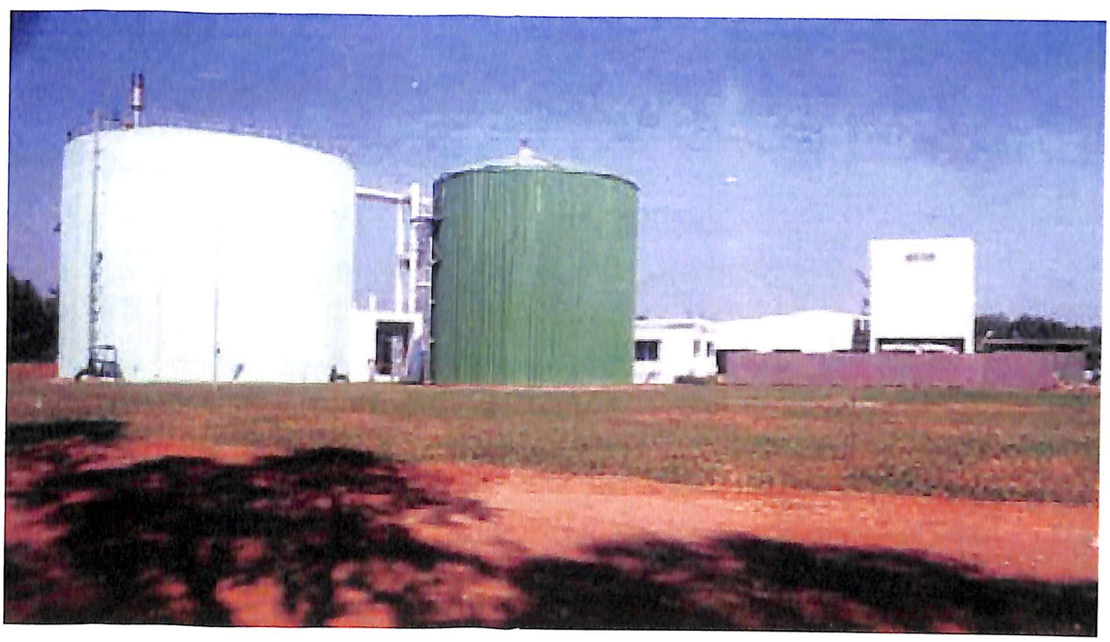

Figure 9: Biomethanation at Medak, Andhra Pradesh

Source : http://www.bombaychamber.com

iii) Biomethanation plant based on vegetable waste in Chennai, Tamilnadu.

The plant was commissioned in 2005 at Koyembedu Market Complex (KMC), Chennai having capacity of treating 30 tonnes vegetable market wastes per day and producing 2500 cubic meter bio gas per day.

Figure 10: Biomethanation in Chennai, Tamilnadu.

Source : http://www.bombaychamber.com

The biogas produced is utilizing in a 230 kW imported gas engine having in built co-generation unit for generation of electricity and thermal energy.

4.2 Gasification plants

It is based on the thermal chemical energy and involves complete oxidative conversion. It is the emerging technology in India. Efficiency of the plant is 70-80%.

i) Biomass Gasification plant in Kuttam, Tirunelveli district, Tamilnadu:

The plant was commissioned in 2007 having a capacity of 1.5 MW biomass gasification power. It is the first high capacity biomass gasification and 100 %

producer gas based captive power project in India. Prosopis Juliflora is the major fuel for this project activity which is available abundant in this region. The biomass supplied to the two numbers of gasifier with a capacity of 900 kg per hour.The producer gas generated in the gasifier is then supplied to the six numbers of 240 kW producer gas engine.

ii) Biomass Gasification plant in at Palladam, Coimbatore District, Tamilnadu:

Figure 11: The reactors at Arashi Hi-Tech Biopower Ltd at Sultanpet, near Coimbatore.

Source : http://www.thehindu.com

The plant was commissioned in 2007 having a capacity of 1 MW biomass gasification power. Coconut shells are used as fuel. The biomass supplied to the two 500 kW gasifier is converted into producer gas ,then the generated producer gas is supplied to the five numbers of 250 kW producer gas engine. Only about 30 per cent of the input energy gets converted into electricity and fed to the grid. The rest can be used for any heating application. Another by-product is charcoal.

iii) Biomass Gasification plant in at Kabbigere , Karnataka:

Figure 12: The A 500 unit gasifier plant at Kabbigere in Madhuguri taluk

Source : http://www.thehindu.com

The plant was commissioned in 2008 having a capacity of 500 kW biomass gasification power. The gasifier plants will generate power by burning wood in a controlled manner. The plani is supplying 500kW power to 500 households in the five villages surrounding Kabbigere.

4.3 Incineration plants:

It is based on the thermal energy and involves complete oxidative conversion. It is the prominent technology in India. Only very few plants are operating successfully in India. Efficiency of the plant is 50-60%.

i) Timarpur- Okhla waste to energy plant, New Delhi:

In 1987 Incineration-cum-power generation station was commissioned at Timarpur.

Figure 13 : Incineration plant at Timarpur- Okhla, New Delhi

Source : http://cdn.downtoearth.org.in

The Okhla & Timarpur Plants are converting MSW to Refuse Derived Fuel (RDF), and having capacity of processing 1300 TPD at Okhla and 650 TPD at Timarpur. RDF from Tomarpur is transported to Okhla. Okhla having a power generation plant of capacity 16MW.

The other technologies like pyrolysis, plasma arc gasification etc. are still in research stage in India and some of them are failed because of lack of professionalism, qualified technical operator and not able to segregate waste as per plant requirement .

Chapter 5 Issues in the operation of waste processing technologies

5.1 Background:

Most of the municipal solid waste generated is going into landfills without proper treatment and the solid waste processing technologies in India are very limited. Many of the mechanical compost plants set by the Government of India are closed down because of various reasons, including the lack of maintenance & decreased in the efficiency after a few years of operation.

Again Government of India set up waste to energy plants under Public Private Partnership (PPP). But these plants also did not operate as per their installed capacity. The plants were closed down due to low calorific values of waste, problems of marketing of compost, public outcry, and improper choice of technology and due to non availability of the right quantity of wastes at the time of generation.

5.2 Waste to energy challenges:

A) Waste-gas cleanup:

The gas generated by processes like pyrolysis and thermal gasification must be cleaned of tars and particulates in order to produce clean, efficient fuel gas.

B) Conversion efficiency:

Some waste-to-energy pilot plants, particularly those using energy-intensive techniques like plasma, have functioned with low efficiency or actually consumed more energy than they were able to produce.

C) Lack of versatility:

Many waste-to-energy technologies are designed to handle only one or a few types of waste (plastic, biomass, or others). However, it is often impossible to fully separate different types of waste or to determine the exact composition of a waste source. For many waste-to-energy technologies to be successful, they will also have to become more versatile or be supplemented by material handling and sorting systems.

D) Regulatory hurdles:

The regulatory climate for waste-to energy technologies can be extremely complex. At one end are regulations that may prohibit a particular method, typically incineration, due to air-quality concerns, or classify ash byproducts of waste-to-energy technologies as hazardous materials. At the other end, while changes in the power industry have allowed small producers to compete with established power utilities in many areas, the electrical grid is still protected by yet more regulations, presenting obstacles to would-be waste-energy producers.

E) High capital costs:

Waste-to-energy systems are often quite expensive to install. Despite the financial benefits they promise due to reductions in waste and production of energy, assembling the financing packages for installations is a major hurdle, particularly for new technologies that aren't widely established in the market.

F) Opposition from environmental and citizen groups:

By burning of waste in incineration based waste to plant can produce significant pollution, so people have often opposed such systems.

5.3. Importance of segregation, collection and transportation

The solid waste is collected by municipal authorities is mixed with different types of wastes. Segregation is the process of separating different types of wastes. If the waste is transported to processing unit without segregation this substantially adds to the cost of operation and increases the burden on the sanitary landfills. So it is important to segregate the waste at time of collection.

The most importance point of MSW is reducing waste generation and practicing separation of dry and wet waste at source level and optimum utilization of reusable material and recycling of various components of waste.

In order to ensure that different types of wastes does not land up at the waste processing units, the collection of municipal waste should be done under in three different streams as mentioned below:

i. Domestic or commercial wastes
ii. Street sweeping and silt from drains
iii. Construction and demolition wastes

The waste from domestic and industries should be directly delivered to the waste processing units for segregation, reuse & recycle, whereas the street sweeping and silt from the drains should be directly taken to the disposal facilities. This would keep away inert wastes from biodegradable and recyclable/ combustible wastes and facilitate smooth processing of MSW. The construction and demolition wastes can be reused for making bricks, paver blocks, and aggregate as well as for bio-engineering works.

In order to reduce the cost of transportation, a transfer station may be set up at strategic locations in the cities where processing unit is more than 15 km away from the collection area. Sanitary landfills may be constructed on the site as per the MSW Rules, 2000 in large cities and regional facilities may be used for smaller towns for waste disposal.

The municipal authorities should also take care of plastic reuse, recycling and energy recovery from plastic waste according plastic waste management & handling Rules 2011. This would facilitate deriving energy from plastic wastes.

5.4 Centralized and decentralized approaches for MSW-Management

Municipal waste can be managed through a centralized approach or a decentralized approach or a combination of the two. Currently both centralized and decentralized systems are in practice in different cities in the country.

A. Decentralized approach:

Decentralized solid waste management systems helps to reduce the waste generated at source level by involving community in separation and processing of waste by adopting practices of reuse, recycling, composting etc. Such decentralized systems encourage citizens to become responsible for their own waste management.

Some of the advantages of decentralized waste management are:

i) Enhances income and job opportunity for the poor.
ii) Enhances and improves environmental awareness of the beneficiaries.
iii) It reduces the cost incurred for the collection, transportation and disposal of waste .

B. Centralized approach :

Centralized waste processing approach intended for cities producing small but significant quantities of waste. Centralized approach is recommended for technologies such as incineration, pelletisation, produce Refuse Derived Fuel (RDF), gasification, biomethanation. Centralized compost plants may however be set up where suitable land or small entrepreneurs for setting up decentralized facilities are not available.

Selection of a centralized or decentralized model of solid waste management, is principally dependent on technology, quantity & quality of waste, availability of land, health risk and capital cost.

Table 2: Selection of a centralized or decentralized approach

Type	Selection criteria
Centralized	. Land is not available close to the community for decentralized model. .Economies of scale makes the project viable . .In large cities high proportion of combustibles like paper, plastics etc in waste warrants setting up of centralized facilities.
Decentralized	. Land for composting/biogas are available in local area . Availability of informal workers for processing of waste . High degree of organic content in waste . Markets for compost/biogas is available . Possible to manage health risks adequately . Operational expenditure is generally low

Source : Planning commission of India.

Chapter 6: Data analysis

In order to find the appropriate waste to energy technological model for processing of municipal solid waste one should have understand the advantages & disadvantages, environment impact , technical, financial criteria of operating power plants. Most of the data is collected from internet and qualitative methods like observations, interviews & field notes were also used to collect the data.

6.1 Suitability of MSW processing technologies

The of suitability of MSW processing technology based advantages, disadvantages and application is also considered in this study along with the environment, technical, financial criteria of operating power plants.

S.No	Technology	Advantage	Disadvantage	Application
1	Composting	•It is a old concept for recycling of waste • Increases the strength of soil • Composting can decompose many organic biodegradable materials	• Suitable for only organic biodegradable fraction of MSW • Require more land than other waste management technologies • Operations can get obstructed during heavy rains • Emits bad odor during the process	Mechanized plants in large cities such as Mumbai, ,Ahmedabad, Bhopal, Delhi, Kolkata, Bangalore etc.
2	Anaerobic Digestion/ Biomethanation	• Also suitable for small amount of waste. • Gases emission to the atmosphere is prevented. • Free from bad odor ,rodent and fly menace, free from visible pollution and social resistance. • Provides a source for	• Not suitable for wastes containing less biodegradable matter. • Heat released in less,resulting in lower and less effective destruction of pathogenic organisms than in aerobic composting •It is more capital intensive	Biomethanation projects for MSW are in initial stages of development and their commercialization is being demonstrated. 4 MW plant is commissioned in Solapur.

		decentralized power generation.	compared to composting and landfill • The liquid sludge can be used as rich organic manure.	
3	RDF/ Pelletes	• The RDF pelletscan be Conveniently stored and transported. • More homogeneous fuel with a higher heat content than unprocessed waste. • An RDF waste processing system offers the potential for increased material recovery.	• Not suitable for too wet MSW during rainy season. •Processing equipment is energy-intensive and requires frequent maintenance.	Technology Information Forecasting and Assessment Council(TIFAC) of Department of Science and Technology (DST) had initially perfected the technology of processing MSW to separate combustible fraction and densification into fuel pellets to a scale of 2tons per hour at Mumbai. Calorific value in excess of 3000 K. Cal.
4	Incineration	• Operation is not affected by weather. • Destroys or reduces toxins • Relatively noiseless and	• Least suitable for disposal of aqueous, high moisture content, low calorific value and chlorinated waste	An Incineration plant for 3.75 MW power generation from 300 TPDMSW was installed at Timarpur, Delhi in the year 1987 could not operate successfully due to low net calorific

		odorless. • Land requirement is less • Complete destruction of pathogens	• Reduces the potential beneficial use of bio solids. • High Capital and operation & maintenance cost. • Highly skilled and experienced staffs are required • Discharges to atmosphere require extensive treatment to assure protection of the environment.	value of MSW. Jindal Plant of 16 MW is currently working at Okhla.

5	Pyrolysis/ Gasification/ plasma arc process	• High recovery rate of resources. • Reduce the biodegradable content of residual waste reducing the production of landfill gases when sent to landfill. • All of the biomass components can be processed into a fuel product.	• Capital intensive. •Requiring proper treatment, storage, and disposal for hazardous wastes • Requires drying of soil. • Ineffective in destroying or physically separating in organics from the contaminated medium.	No such plants has so far come up in India or elsewhere for the disposal of MSW. It is an emerging technology for MSW and yet to be successfully demonstrated for large scale application.
6	Sanitary landfills/ Landfill gas recovery	• Filled land can be used for other community purposes. • Can handle large amounts of wastes, less cost. • Potential for recovery of landfill gas as a source of energy. • No open burning, ultimate	• Air pollution from toxic gases and volatile organic compounds • Landfill can pollute air, water and also the soil. • Inefficient gas recovery process. Balance gas escapes to the atmosphere • Large land area requirement.	There is hardly any scientifically designed sanitary landfill site. Most of them are crude dumping sites and few can be said to be controlled dumps.

		disposal, little odor.	• Many insects and rodents are attracted to landfills and can result in dangerous diseases.	

Table 3: Advantages and disadvantages for various W to E technologies.

6.2. Impact of waste to energy technologies on environment

The impact of technologies on environment is also considered along with the and advantages & disadvantages of technologies. Below table gives the environmental implications i.e. in terms of air, land & water pollution.

S.No	Associated factors	Composting	Biomethanation	Incineration and RDF Burning	Gasification	Landfilling
1	Atmospheric pollution					
	(a) Air pollution	Low	Low	High	Medium	Medium
	(b) Emission control systems	-	-	Required	Required	-
	(C) Odour issues	Present	Present	Present	Present	Present
	(d) Release of green house gases	Uncontrolled	Controlled and utilized	Controlled and utilized	Controlled and utilized	Mostly uncontrolled.
2	Leachate pollution					
	(a)Water pollution	High	High	Low	Low	Moderate to high
	(b) Requirement of Waste water treatment	Required	Required	-	-	Required
	(c)Quality of Treated water	May be discharged into water bodies	May be used in processor discharged into water bodies.	Medium	Medium	Medium to high
3	Waste generation during pro	high	low	low	low	Nil

S.No	Associated factors	Composting	Biomethanation	Incineration and RDF Burning	Gasification	Landfilling
4	Care for fire and safety issues	Required	Required	Required	Required	Depends on methane Concentration.
5	Volume reduction of waste	15- 30%	45 - 50 %	75 - 90%	90%	70 - 80 % if waste contains biodegradables

Table 4: Impact of waste to energy technologies on environment

6.3 Technical criteria for selection of appropriate W to E technology :

S.No	Associated Factors	Composting	Biomethanation	RDF Burning	Incineration	Landfilling
1	Land Requirement	High	Low to Moderate	Low to Moderate	Low	Very high
2	Requirement for segregation before reaching site	High	Very high	High	High	Only inert waste is placed in landfills.
3	Location of the plant	At least 1km away from residential areas.	At least 500 m away from residential areas	At least 500 m away from residential areas	At least 1km away from residential areas.	At least 1km away from residential areas.
4	Direct energy recovery capacity	No	Yes	No	Yes	Not as per MSW Rules, 2000

Table 5: Technical criteria for selection for selection of appropriate W to E technology

6.4 Financial criteria & managerial criteria for selection of appropriate W to E technology :

S.No	Associated factors	Composting	Biomethanation	RDF Burning	Incineration	Landfilling
1	Capital investment for 500 TPD plant	15-20 Cr	75-80 Cr	17-20 Cr	Very high	High
2	Requirement of labour	Labour intensive	Less labour intensive	Labour intensive	Not labour intensive	Labour intensive
3	Type of labour required	Skilled & semiskilled	Skilled	Skilled & semiskilled	Highly skilled required	Skilled and semiskilled

Table 6: Financial criteria & managerial criteria for selection for selection of appropriate W to E technology

Chapter 7: Conclusion and recommendations

7.1 Conclusion:

The analysis of operating power plants based on advantages & disadvantages, environment impact, technical, financial criteria will helps in identifying appropriate technology for MSW processing. It is important to know that identification of technology alone may not be a solution for the IMSWM (Integrated Municipal Solid Waste Management) to success and hence a accurate study was carried out to find suitable combination of technologies based on analysis. The proper integrated MSW management system is essential for managing the waste scientifically & for utilizing of all components of waste.

7.2 Recommendations:

As per Indian context the following waste to energy technologies are recommended for processing of municipal solid waste

1. Wet biodegradable wastes can be processed by using biomethanation or vermi composting technologies.

2. Dry combustible wastes having high-calorific value can be processed by using incineration, gasification or pyrolysis technologies.

3. Dry combustible wastes having high-calorific value can converted into Refuse Derived Fuel (RDF) which can be used as feedstock to power plants.

4. Catalytic conversion and pyrolysis are used to convert plastic wastes to fuel oil.

5. Combinations of different waste to energy technologies can be used based on a range of population and quantity of wastes generated.

For successful waste to energy processing the combination of technologies suggested.

7.3 Scope for future work:

The waste generation is increasing day by day and it is expected that 300 - 400 million tonnes waste going to generate per year by 2030. This will increase the organic fraction of MSW. It is expected that 5200MW energy can be produce from MSW by 2017. The encouragement of Public Private Partnerships (PPP) in MSW by government will bring in outside technologies, expertise, and project management skills to improve service and delivery efficiency. At present India is using biomethanation, incineration and gasification methods for generate waste to energy. By PPP in MSW sector it is expected that the process of waste segregation, handling, storage, and processing will become more efficient and new technologies like pyrolysis, plasma arc gasification etc. are going to introduce in India.

Bibliography

•Central pollution control board, "Action plan for management of municipal solid waste" 2015.

•Frost and Sullivan, "Analysis of Municipal Solid Waste-to-Energy Market in India," 2011.

•India MSW to energy (status, opportunities and bottlenecks) 2015 by EAI (Energy Alternatives India).

• Kalyani, K.A. and Pandey, K.K. (2014). Waste to energy status in India: A short review. Renewable and sustainable energy reviews.

•Manual on Municipal Solid Waste Management, Ministry of Urban Development Expert Committee, 2000.

•Mehtab Singh Chouhan, Sanjay Verma, Sarita Sharma, Niraj Metha: Review on waste to energy potential in India, 2015.

•Municipal solid waste management manual 2014, by Central Public Health & Environmental Engineering Organization (CPHEEO).

•Report of central pollution control board on "status of compliance by CPCB with municipal solid wastes (management and handling) rules, 2000"

•Report of the Task Force on Waste to Energy (Volume II), Planning Commission of India, May 2014 .

•Report of the Task Force on Waste to Energy (Volume I), Planning Commission of India, May 2014 .

.www.bombaychamber.com
.www.closedloopsystem.com
.www.covanta.com
.www.cpcb.nic.in
.www.eai.in
.www.mnre.gov.in
.www.moee.gov.eg
.www.moud.gov.in
.www.probiomasa.gob.ar
.www.thehindu.com

•Toolkit for Solid Waste Management, Jawaharlal Nehru National Urban Renewal Mission, Ministry of Urban Development, Government of India, November 2012 .