Major Project

Dissertation on

"STUDY OF POWER GENERATION FROM MUNICIPAL SOLID WASTE AT TIMARPUR OKHLA WASTE MANAGEMENT PLANT, DELHI"

Submitted to Delhi Technological University in partial fulfillment of the requirement for the award of Degree of

Master of Technology

In

Thermal Engineering

by

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2K13/THE/11

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DECLARATION

I hereby declare that the work presented in this report, titled **"STUDY OF POWER GENERATION FROM MUNICIPAL SOLID WASTE AT TIMARPUR OKHLA WASTE MANAGEMENT PLANT, DELHI"**, in partial fulfillment for the award of the degree of M.Tech in thermal engineering, submitted in the Department of mechanical engineering, Delhi Technological University, Delhi, is original and to the best of my knowledge and belief, it has not been submitted in part or full for the award of any other degree or diploma of any other university or institute, except where due acknowledgement has been made in the text.

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CERTIFICATE

DELHI TECHNOLOGICAL UNIVERSITY
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This is to certify that report entitled **“STUDY OF POWER GENERATION FROM MUNICIPAL SOLID WASTE AT TIMARPUR OKHLA WASTE MANAGEMENT PLANT, DELHI”** by **DHIRAJ** is the requirement of the partial fulfilment for the award of Degree of **Master of Technology (M.Tech)** in **Thermal Engineering** at **Delhi Technological University**. This work was completed under my supervision and guidance. DHIRAJ completed his work with utmost sincerity and diligence. The work embodied in this project has not been submitted for the award of any other degree to the best of my knowledge.

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ABSTRACT

With the advancement in technology the power consumption is rising steadily. This necessitates that in addition to the existing source of power such as coal, water, petroleum etc. other sources of energy should be searched out and new and more efficient ways of producing energy should be devised. Power generation from municipal solid waste becomes attractive way for energy generation due to their high energy potential and less pollutants. Energy generation from waste uses municipal solid waste as fuel and helps in finding a solution for some of present biggest challenges for society like greenhouse gas reduction, dependence on fossil fuels and generates clean and renewable electricity.

Present work deals with study of various waste to energy generation processes. Timarpur Okhla Integrated Waste processing plant generates clean and renewable energy. It reduces dependence on conventional sources of energy which are reducing day by day. This plant reduces greenhouse gas emissions so it is generating environmental friendly energy. This plant is sustainable solution to waste management problems. In this report efficiency of this plant is being calculated and a proposal is suggested to improve the efficiency of the plant.

The results & discussion of the experimental work have been outlined in chapter 5 of the thesis From results it is found that if we use reheating and bleed steam for closed feed water heating then thermodynamic efficiency and net work output per unit mass flow rate increases.

The conclusion derived from present project work has been presented in Chapter 6 of this thesis.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

NOMENCLATURE

h	Enthalpy (J/Kg)
T	Temperature(K)
P	Pressure(bar)
J	Joule
q	Heat supplied (Joule)
w	Work done(Joule)
^{o}C	Degree Celsius
x	Dryness fraction
s	Entropy(J/kg K)
v	Specific volume(m^3/kg)
kW	Kilo watt
kg	Kilogram
K	Kelvin
J	Joule

Chapter-1

INTRODUCTION

1.1 Introduction:

India is one of the most rapidly developing countries in the world. It is witnessing growing industrialization and thus development. Such rapid development needs energy to progress, which further makes India an energy hungry nation. Currently India depends mainly upon fossil fuels and thus has to pay a huge bill at the end of every contractual period. These bills can be shortened and the expenditures brought down by using and exploiting non-conventional sources of energy.

India holds a huge potential for such non-conventional sources of energy. The rapid development of India is not just pressing hard upon its resources but forcing expenditures on the same. There are also some neglected side effects of this development process like, generation of waste. A population of 1.2 billion is generating 0.5 kg per person every day. This, sums up to a huge pile of waste, which is mostly land filled in the most unhygienic manner possible. Such unmanaged waste not only eats up resources but demands expenditure as well. This can lead to the downfall of an economy and degradation of the nation.

Thus, waste to energy can be a solution to both the problems stated above, using which not only can we reduce the amount of waste, but also produce energy from the same, thus achieving our goal of waste management as well as energy security.

1.2 Different renewable energy sources:

Renewable sources of energy are those sources of energy which are continuously replenished by natural processes such as biomass, bio fuels, geothermal, solar power, wind power, tidal power. As conventional sources of energy like fossils fuels are reducing day by day which cannot be reproduced. One of main problem associated with fossil fuels is that they cause a lot of pollution. Renewable sources of energy reduce dependency on fossil fuels and are clean sources of energy. In my thesis main focus is on biomass and bio fuels renewable source of energy.

(a) Biomass:

Biomass accounts for all the living matter, which exists in the thin layer of Earth called the Biosphere. Based on the cyclic process, which involves energy supplied from the sun, through storage in plants and eventual natural recycling via a series of chemical and physical processes in plants, the atmosphere, the living matter and eventually radiation from the Earth as low-temperature heat, biomass is thus potentially an enormous store of energy, which is restored continuously. Biomass comprises a potential source of energy utilization for humans. Today, efforts are focused in capturing biomass at the stage of stored chemical energy, which in turn is providing a fuel. Biomass is considered by many as a 'green' process for fuel production; providing the restraint that the human consumption doesn't exceed the natural level of recycling, in bio-fuels there is no additional generation of heat as well as carbon dioxide, which could have both been emitted during any conventional fuel production process. If consumed ay this rate, no detrimental environmental effects will occur and thus a new sustainable system of energy production is available for further utilization and exploitation.`

(b) Biofuels:

Biofuels consist of variety of fuels which are obtained from biomass. These can be solid, liquid or gaseous fuels. Some examples of liquid biofuels are bio ethanol and oils like biodiesel. Some examples of gaseous biofuels are biogas, landfill gas etc. Biofuels are obtained from different types of raw materials and in different type of ways. These include the energy derived from waste residues' utilization, either of organic origin (e.g. plants, animal by-products) or of urban and industrial wastes and the majority of the content of each household's dustbin.

1.3 Hierarchy of solid Waste management:

Our first priority is to reduce the waste produced as possible as we can. Then our second priority will be reuse of the items in the waste if we can. Our third priority will be to segregate the item which can be recycled. After it energy can be generated from the waste by using various wastes to energy generation process. Now the residue left can be land filled. So land filling will be our last priority. Hierarchy of solid waste management in decreasing order of priority is given below in figure 1.1:

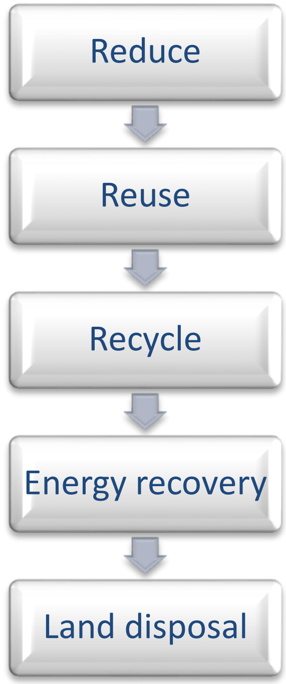

Fig. 1.1: Hierarchy of waste

1.4 Types of waste to energy processes:

A brief description of waste to energy is given as follows:

1.4.1 Thermal conversions:

Thermal conversion is the component of a number of the integrated waste management solutions proposed in the various strategies. Thermal conversion processes which are used for generating energy from waste are incineration, pyrolysis and gasification. They result in the production of various byproducts which can be subjected to various energy and resource recovery techniques for treatment.

(a)Incineration:

Incineration is a process in which power is generated by combustion of organic matter of waste. Heat produced by combustion is used to generate steam in a boiler and that stem is expanded in a turbine to obtain power output. Incineration products are ashes, flue gases and heat. Ash is mainly formed by burning of non organic content of waste. Flue gases cause air pollution. So incinerators are equipped with air pollution control accessories. Flue gases are treated before going into the atmosphere.

Incineration mostly takes place at temperature between 750 to 1000 ℃ . Incineration reduces the mass of waste by 70 percent and volume of waste by 90 percent approximately. Power generation by incineration process is considered on the most economical and reliable methods because of the following reasons:

(i) Most of the pollutants generated by this process are not in significant quantities.

(ii) It reduces the volume and mass of the waste in a significant amount. Only a small volume of residue is left. Heat of combustion recovered by this process is used in boiler for steam generation.

(iii) Waste before combustion may contain some object able matter. Residue left after mass burning process is mostly germ free residue.

(b) Pyrolysis:

Pyrolysis is thermal treatment of organic matter of waste at elevated temperature in absence of oxygen. Pyrolysis has many advantages:

(i) It reduces the volume of waste in a large amount (50 to 90 %)

(ii) It produces solid, liquid and gaseous type of fuels from waste.

(iii) Capital cost of pyrolysis is less than the incineration process.

(iv) It convert waste to energy so very important process for energy generation from a renewable energy source.

(v) By this process transportable fuel is obtained.

(vi) Once started, the process is self-sustaining. Pyrolysis is an indirect gasification process with Inert gases as the gasification agent.

Pyrolysis is mainly of two types:

(i) Fast pyrolysis

(ii) Slow pyrolysis

(iii) flash pyrolysis

Slow pyrolysis is also called conventional pyrolysis. It involves slow heating rate with solid, liquid or gaseous fules in large amounts. This pyrolysis is mainly used for charcoal production and one of the oldest processes. But now a day's fast pyrolysis is mostly used which involves faster heating rate of biomass at higher temperature. Fast pyrolysis produces tar at low temperature near 850-1200 k and gas at higher temperature near about 1000-1300 k.

Parameters	Conventional pyrolysis	Fast pyrolysis	Flash pyrolysis
Temperature (K)	550–900	850–1250	1050-1300
Heating rate (K/s)	0.1–1	10–200	>1000
Particle size (mm)	5–50	<1	<.2
Residence time (s)	300–3600	0.5–10	<.5

Table 1.1: Operating parameters for pyrolysis process

Constituent	Amount (vol%)
CO	**35.5**
CO2	**16.4**
CH4	**11.o**
H2	**37.1**
Calorific value(kcal/Nm3)	**3430**

Table 1.2: Composition of pyrolysis gas from MSW

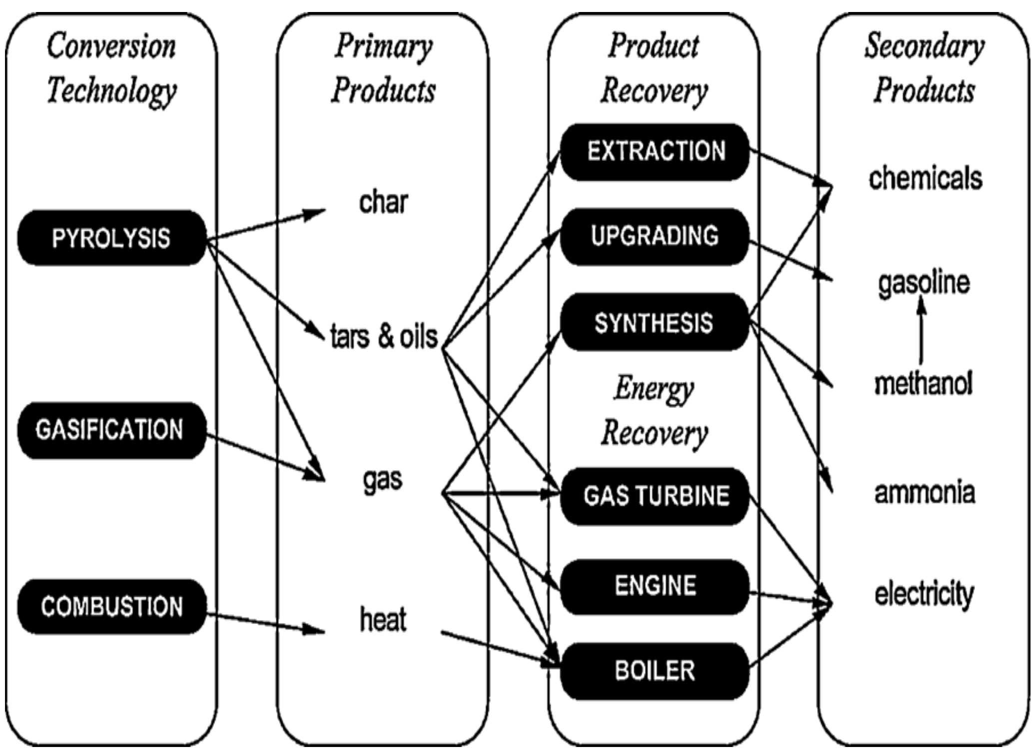

Fig. 1.2: Thermal conversion process and products

(c) Gasification:

Gasification is the method of waste to energy which involves partial combustion of carbon based material of biomass into charcoal and gas in first stage. Then product gases mainly CO2 and H20 reduced to CO and H2 by charcoal. Methane gas and some hydrocarbons are also produced in gasification process. Gasification is the thermo chemical conversion of carbon based material into gaseous product with the help of a gasification agent. A gasification agent helps the conversion of carbon based material into gaseous product at a faster rate with the help of heterogeneous reactions. If gasification occurs with the help of a oxidizing agent then it called direct gasification. And if gasification occurs without oxidizing agent then it is called indirect gasification.

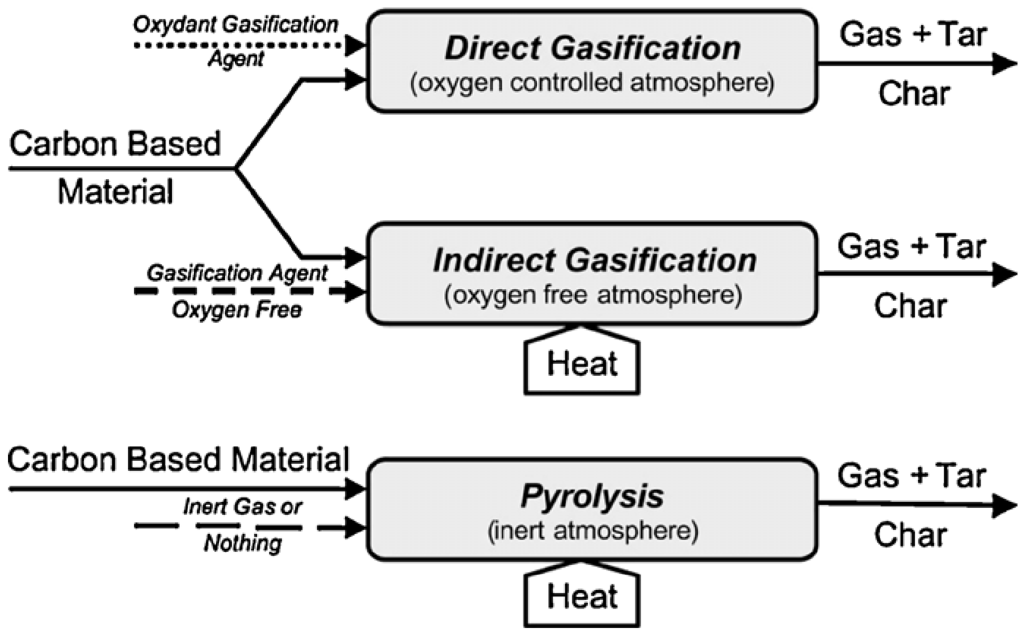

Fig.1.3: Gasification and pyrolysis processes

A gasification system mainly consist of three parts:

(i) gasifier which helps in producing gaseous fuel.

(ii) gas clean up system which removes harmful matter from combustible gas

(iii) energy recovery system.

Gasifiers are mainly of three types: updraft gasifier, downdraft gasifier and cross draft gasifier based on the direction of flow of air as shown in the fig. 1.4:

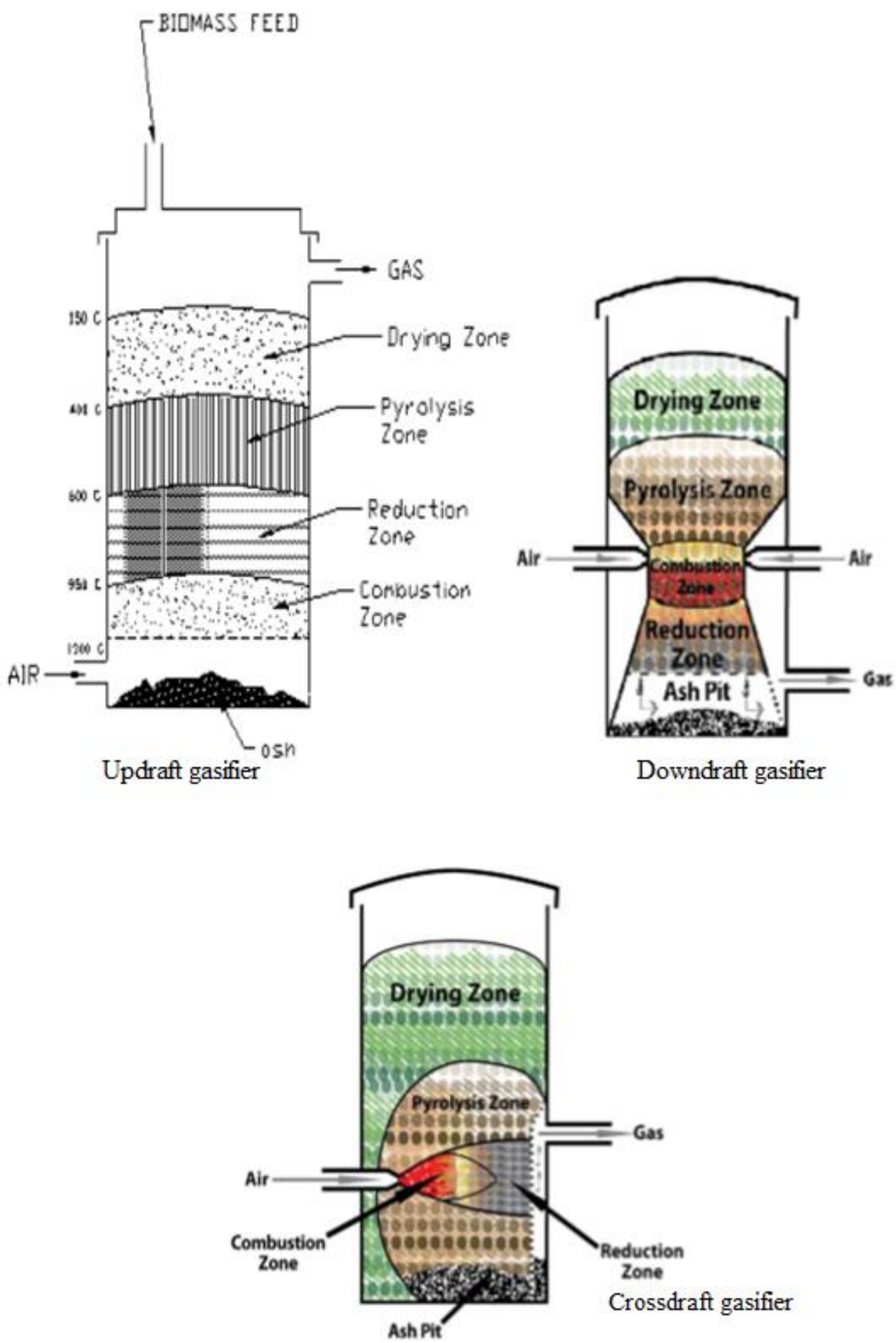

Fig. 1.4: Types of gasifiers

Four distinct processes take place in a gasifier as the fuel makes its way to gasification. They are:

a) Drying of fuel

b) Pyrolysis – a process in which tar and other volatiles are driven off

c) Combustion

d) Reduction

1.4.2 Biochemical conversion:

This waste to energy process involves use of enzymes, micro organisms and bacteria for breakdown of the biomass. It converts biomass into gaseous or liquid fuels such as biogas and bio ethanol. Mostly used biochemical processes are anaerobic digestion (bio methanation) and bio fermentation. Biochemical conversion is the one of the environment friendly waste to energy generation processes. Anaerobic digestion involves decomposition of organic matter of biomass in oxygen free environment and converts into biogas:

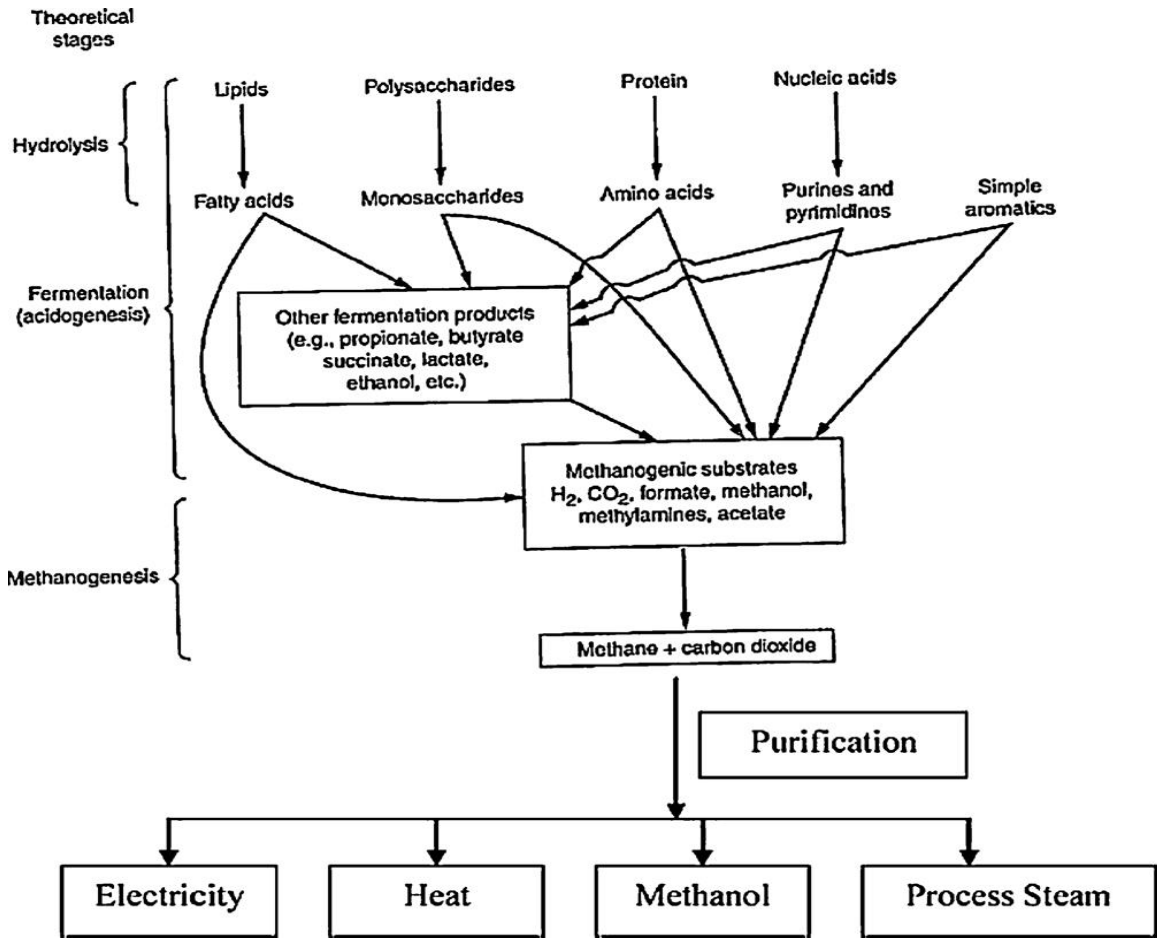

Fig. 1.5: Flow sheet of anaerobic digestion process

This biogas can be used either as transport fuel or used to produce both heat and electricity. In anaerobic digestion methane gas is also produced which can be converted into methanol. Almost every organic material can be convertd to fuel by anaerobic process. Figure 1.5 shows steps involved in anaerobic process.

1.5 Worldwide status of waste to energy (WTE):

The idea of waste to energy has created since a while now. The developed nations have begun actualizing it effectively as measure of waste management and in addition energy security. Increasing development prompts a change in ways of life and status, prompting a blossoming measure of waste generation. Hence, numerous nations have made a step forward and began recovering energy from waste. Poland utilizes agrarian biomass to create power. Toward the end of 2012, there were 29 agricultural biogas plants in Poland with average capacity of 1 MW. Malaysia has been very active as far as WTE methods are concerned. For 2010 Methane emissions from Malaysian landfills were equivalent to 2.20 $\times 10^9$ kWh of power and were relied upon to create USD 219.5 million. The appraisals for 2015 and 2020 are USD 243.63 million and USD 262.79 million individually. Italy has seen establishment of numerous anaerobic co-digestion plants of capacity between 50 kW and 1 MW. Farming biomass has been utilized as feedstock as a part of numerous African nations including Ghana to deliver decentralized rural energy. The aggregate output they get is 12.5 kW electric power utilizing two generators rated 5 kVA and 7.5 kVA. The created power is supplied to the community utilizing a local grid of 230 V for 12 h for every day .Singapore has been long concentrating on the energy recovery from food waste produced and consequently has planned numerous approaches to advance the same. Canada has additionally put its foot on the pedal and quickened the framework to change over sustenance waste to energy and has composed different framework outlines to meet the obliged standards. Its framework outline delivers 134.6 MWh every year of surplus energy.

In this way, the world is moving quickly in adapting this innovation, which does help the countries with waste management, as well as with energy security.

1.6 Waste generation and energy recovery potential in India:

Changing ways of life and increasing PPP of urban Indians has increased the per capita waste generation rate in India. It was 0.44 kg/day in 2001 .but it has increased to 0.5 kg/day in 2011. This has prompted an increment of half in the waste created by Indian urban areas in a span of 10 years since 2001. The aggregate Municipal Solid Waste (MSW) created in India is evaluated 68.8 MTY or 188,500 TPD. Such an increment in the measure of waste created has not just laid a weight on the assets of the country, however has additionally turn into a risk to the wellbeing, security and environment of the country. Energy recovery potential of different wastes is shown in figure 1.6:

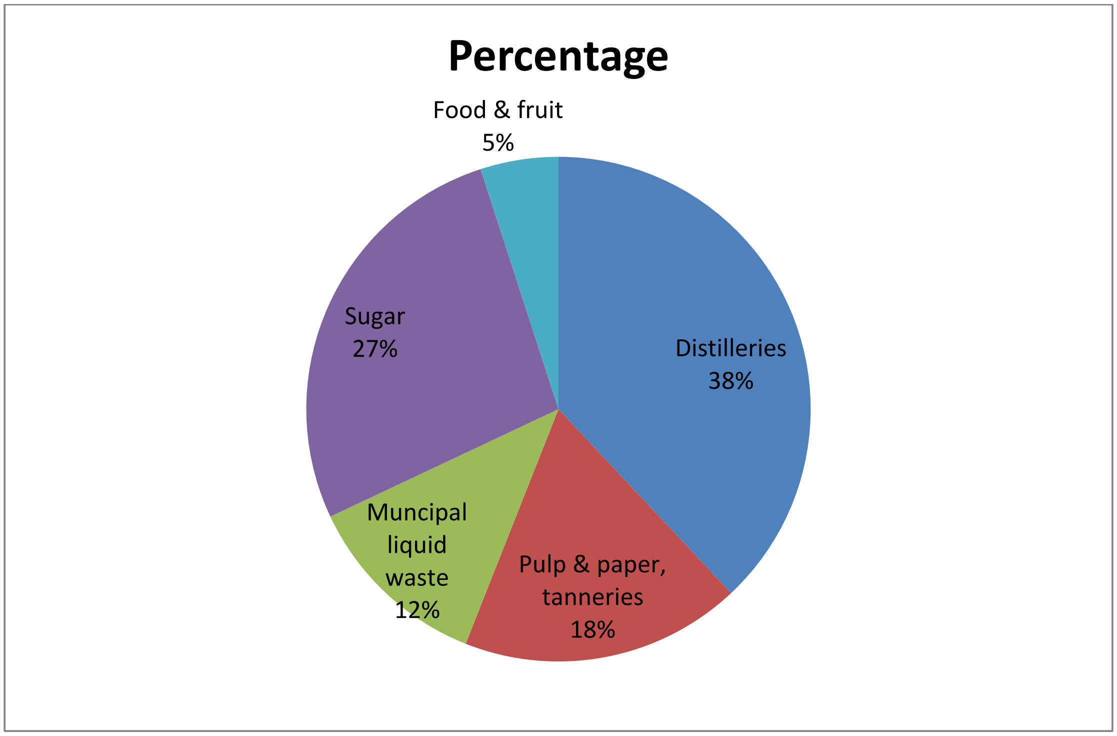

Fig. 1.6: Energy recovery potential (MW) of different wastes

As per 11th planning commission the estimated potential for MSW to energy is given in table 1.3.

Period	**Projected MSW generation (TPD)**	**Potential for power generation (MWe)**
2007	148000	2550
2012	215000	3650
2017	304000	5200

Table 1.3: Municipal solid waste to energy: estimated potential.

Source: 11th Planning Commission.

1.7 Status of waste to energy in India:

The objective of WtE combustion is treating MSW to reduce its volume and generating energy and electricity during this process. In India installation of various WtE plants has been witnessed in the recent past and several projects are known to be under pipeline .In India at present 48 WtE plants are available including 32 proposed, 4 under development and 11 are in operation as presented in figure 1.7. One of the plants is shutdown because of some technical issues in the plant.

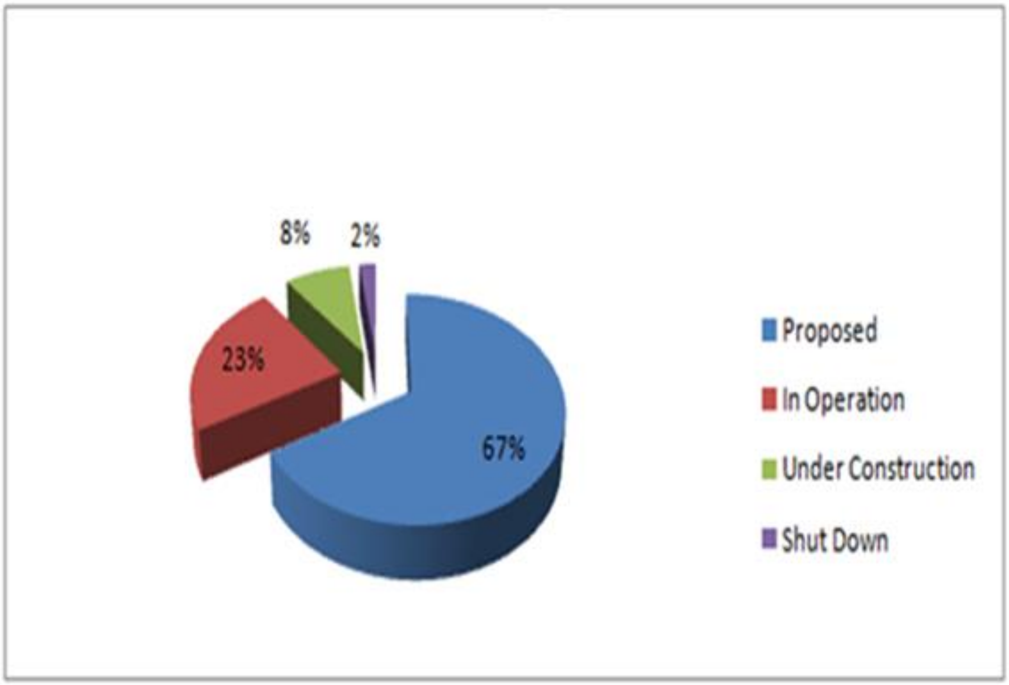

Fig. 1.7: Status of waste to energy plants in India

In India, various WtE technologies are used considering the properties of the waste. Fig.1.8 shows the type of technologies used and the status of plants in India. Fig.1.8 shows that bio methanation is the most widely used technology in India. One reason behind this wide usage could be the high organic content in Indian MSW due to one is the Ramky's Integrated Waste Management Plant in Delhi. Both of these plants are part of the integrated waste management services. the presence of food waste. One of the RDF plant presently under construction is the Gazipur. WtE plant and second one is the Ramky's Integrated Waste Management Plant in Delhi. Both of the plants are part of the integrated waste management services

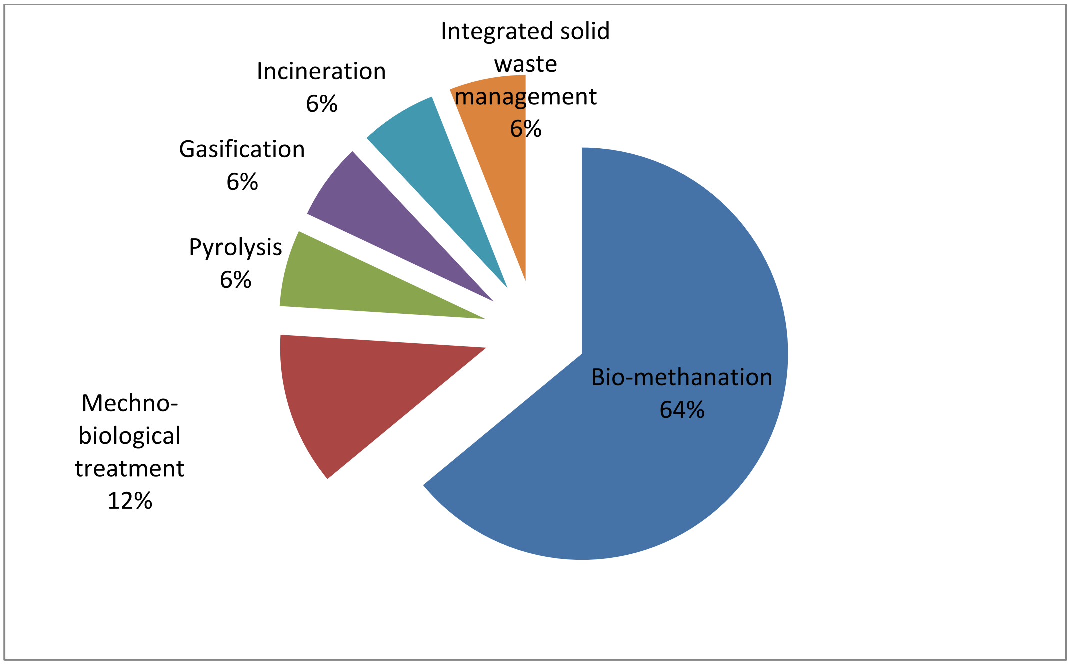

Fig. 1.8: Types of WtE technologies used in India

A WtE plant is set up while considering the raw material availability and equipments required for the processing of that raw material. India, being a multi-state country has different raw material availability in different areas. 18 plants in the country are dependent on MSW for power generation whereas 15 plants use biomass. The plants with their corresponding usage of raw materials are given in the Fig.1.9.

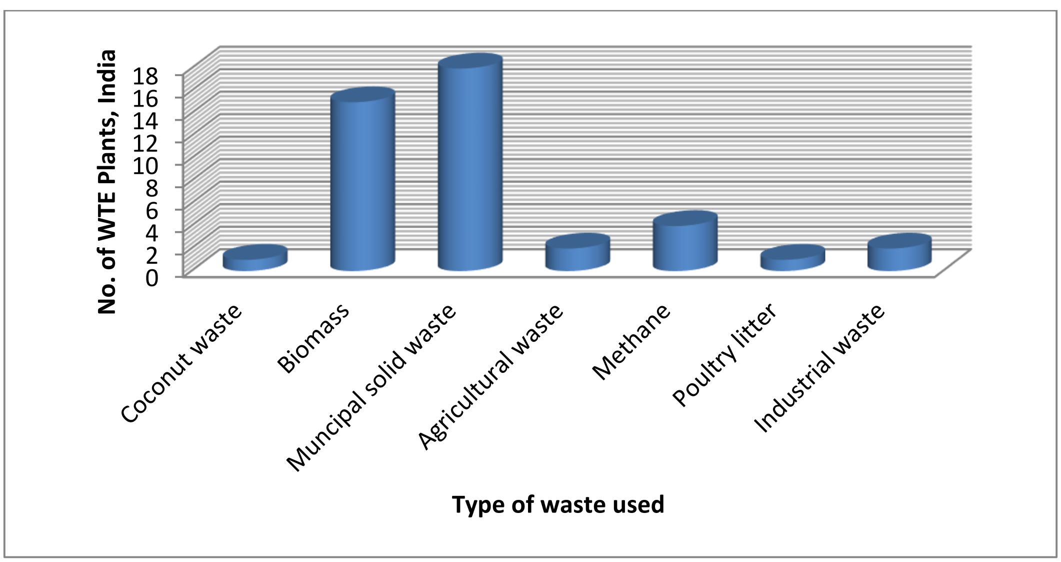

Fig. 1.9: Review of raw Material used by WtE plants in India

Incidentally one plant proposed in South Andaman will use coconut waste as raw material. There are 3 plants in Delhi and they all use MSW as raw material. The plant in Ludhiana, Punjab uses cattle dung & is running satisfactorily. It produces 2MW/day power by using 235TPD of the waste.

As of now Delhi is delivering 16 MW/day power from waste & will have the capacity to create an extra 25MW/day after the fulfillment of construction of two more projects. Gujarat is creating 3.5 MW/day power from waste. Every state furnished with WTE innovation is creating power from waste and some of the projects that are under proposed stage will be delivering power from waste once finished.

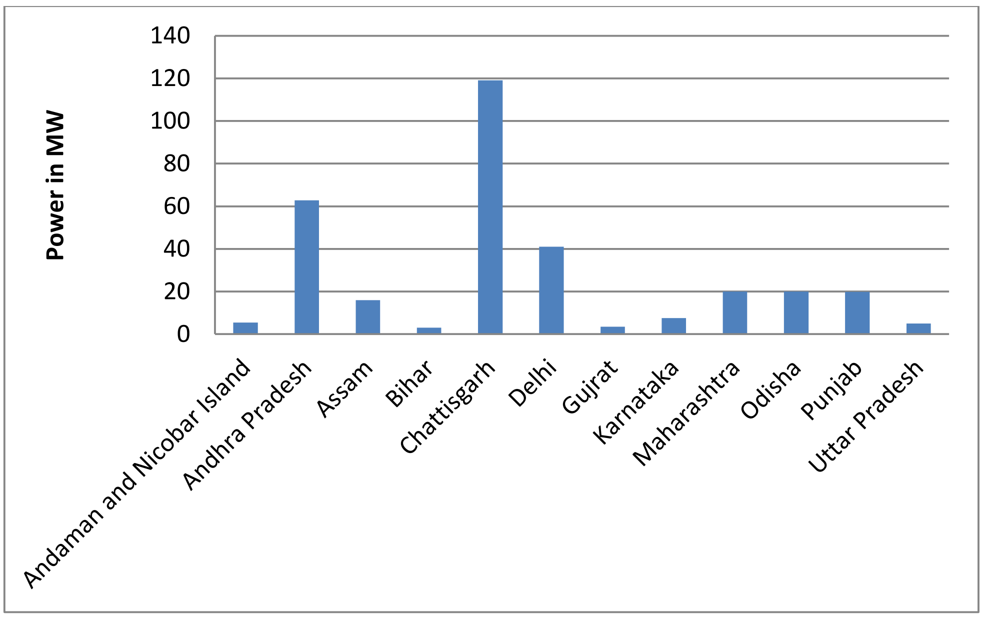

Fig. 1.10: Power generation in MW by each state in India

Chhattisgarh has 7 proposed projects that will have the capacity to create 119MW/day of power in future.

1.8 Aims and objectives of the present thesis :

1. To study the various, waste to energy generation processes and their technologies.

2. To study the present status of waste to energy plants in India and worldwide.

3. To study the working of Timarpur Okhla waste management plant and its various technologies related to RDF plant and power plant.

4. To assess thermodynamic efficiency of timarpur plant which is working on simple rankine cycle.

5. To suggest methods to increase net work output and thermodynamic efficiency of plant by use of reheating and bleeding steam for closed feed water heating.

6. To compare results of existing and suggested technologies and suggesting better technology for Timarpur plant with increased efficiency and power output.

CHAPTER-2

LITERATURE REVIEW

2.1 LITERATURE REVIEW:

The energy crisis and environmental degradation are currently two vital issues for global sustainable development ***(R.P. Singh et al, 2011)***. Rapid industrialization and population explosion in India has led to the migration of people from villages to cities, which generate thousands tons of municipal solid waste daily, which is one of the important contributors for environmental degradation at national level. Improper management of municipal solid waste (MSW) causes hazards to inhabitants. The management of MSW requires proper infrastructure, maintenance and upgrade for all activities. In this paper, an attempt has been made to provide a comprehensive review of MSW management to evaluate the current status of waste to energy facilities for sustainable management, which will be helpful in tackling this huge quantity of waste and the problem of energy crisis. A critical review of known MSW management practices/processes in Indian scenario, which will give an idea to investors about the market potential, the maturity of the practicing technologies, and the environmental and economical aspects was also evaluated with its advantages and disadvantages.

A feasibility study Power generation from MSW of Haridwar city has been carried out **(*Siddharth Jain et al, 2010*)**. This paper reports the results of physical, proximate and TGA/DTA analysis, used to select the Most appropriate method of energy conversion. Based on the energy potential available, the feasibility of Energy conversion through biogas production using available waste has been carried out. The cdm benefits Have also been considered. The cost of generation with and without cdm benefits is Rs. 1.36/- and Rs. 1.41/- Per kwh respectively as compared to cost of energy from grid [Rs. 3.50/- per kwh]. Therefore power Generation from MSW of Haridwar city using bio methanation conversion technology is feasible.

An analysis of power generation from municipal solid waste (MSW) incineration Plants in Taiwan is carried out ***(Wen-Tien Tsai et al, 2010).*** This paper gave a concise summary of current status of domestic Energy consumption & power generation, MSW generation & MSW incineration treatment, and electricity Generation from MSW incineration plants since 2000. Based on the electricity generation in 2008 (i.e., 2967 gwh), the environmental benefit of mitigating CO_2 emissions and the economic benefit of Selling electricity were preliminarily calculated to be around 1.9×10^6 tons and US$ 1.5×10^8, respectively. However, since the heat content of incinerated MSW and the methodologies were used on the Recommendation of the (IPCC) Intergovernmental Panel on Climate Change, the net emissions of CO2 Equivalent from methane (CH4) & nitrous oxide (N2O) have been estimated to be at around 76,000 and 88,000 tons/year compared to coal and oil, respectively.

Municipal solid waste (MSW) is an important source of methane emission which is a greenhouse gas (GHG) and has high potential for its use as energy source ***(Monojit Chakraborty et al, 2013)***. In this paper A study has been carried out to find out the energy generation potential of MSW being dumped in Delhi's three landfills viz. Ghazipur (GL), Bhalswa (BL) and Okhla (OL). Five technologies for waste to energy generation, namely biomethanation, incineration, gasification/pyrolysis, refused derived fuel (RDF) and plasma arc gasification have been evaluated for computation of possible energy (WTE) generation potential of MSW under ideal conditions using the MSW specific characteristic parameters. Bulk waste with and without pre-segregation of reusable high carbonaceous materials have been considered to develop range of energy generation potentials under two scenarios of with and without segregation of MSW. USEPA-landgem model version 3.02 has been used to get LFG generation potential of Delhi's landfills. The potential of biomethanation process for producing energy has been found to be in the range of 3–10, 3–8 and 2–8 MW/day from the MSW deposited in GL, BL and OL respectively. The energy generation potentials of the MSW deposited in GL, BL and OL have been found to be in the range of 8–24, 7–22 and 7–19 MW/day for incineration process; 17–32, 16–29 and 11–25 MW/day from gasification/pyrolysis process; 9–19, 8–18 and 6–15 MW/day for RDF process; and 17–35, 16–32 and 11–28 MW/day for plasma arc gasification process respectively. The lower values in these ranges depict the energy generation potential for segregated waste while the higher values are for the bulk.

The energy requirement pattern of world is growing up and developing technology. The available sources, while exhausting and not friendly to the environment, are highly used ***(Abdulhakim Amer A. Agll et al, 2014).*** Looking at partial supply and different options of environment problems associated with usage, renewable energy sources are getting attention. MSW (Municipal solid waste) composition data had been collected from 1997 to 2009, in

Benghazi Libya, to evaluate the waste enthalpy. An incinerator with capacity of 47,250 kg/h was confirmed to burn all the quantity of waste generated by the city through the next 15 years. Initial study was performed to investigate energy flow and resource availability to insure sustainable MSW required by the incinerator to work at its maximum capacity during the designated period. The primary purpose of the paper is to discuss the design of Rankine steam cycle for the generation of both power (PG) and combined heat power (CHP). In the power generation case, the system was found to be able to generate electrical power of 13.1 MW. Including the combined heat power case, the results showed that the system was able to produce 6.8 million m3/ year of desalinated water and generate 11.33 MW of electricity. In conclusion, the CHP designed system has the greatest potential to maximize energy saving, due to the optimal combination of heat production and electricity generation.

Unlike that of western countries, the solid waste of Asian cities is often comprised of 70–80% organic matter, dirt and dust ***(Tapan Narayana, 2008)***. Composting is considered to be the best option to deal with the waste generated. Composting helps reduce the waste transported to and disposed of in landfills. During the course of the research, the author learned that several developing countries established large-scale composting plants that eventually failed for various reasons. The main flaw that led to the unsuccessful establishment of the plants was the lack of application of simple scientific methods to select the material to be composted. Landfills have also been widely unsuccessful in countries like India because the landfill sites have a very
Limited time frame of usage. The population of the developing countries is another factor that detrimentally impacts the function of landfill sites. As the population keeps increasing, the garbage quantity also increases, which, in turn, exhausts the landfill sites. Landfills are also becoming increasingly expensive because of the rising costs of construction and operation.
Incineration, which can greatly reduce the amount of incoming municipal solid waste, is the second most common method for disposal in developed countries. However, incinerator ash may contain hazardous materials including heavy metals and organic compounds such as dioxins, etc. Recycling plays a large role in solid waste management, especially in cities in developing countries. None of the three methods mentioned here are free from problems. The aim of this paper is thus to compare the three methods, keeping in mind the costs that would be incurred by

the respective governments, and identify the most economical and best option possible to combat the waste disposal problem.

Human activities inevitably result in wastes ***(Paul H. Brunner et al, 2014)***. The higher the material turnover, and the more complex and divers the materials produced, the more challenging it is for waste management to reach the goals of ‘‘protection of men and environment’’ and ‘‘resource conservation’’. Waste incineration, introduced originally for volume reduction and hygienic reasons, went through a long and intense development. Together with prevention and recycling measures, waste to energy (WTE) facilities contribute significantly to reaching the goals of waste management. Sophisticated air pollution control (APC) devices ensure that emissions are environmentally safe. Incinerators are crucial and unique for the complete destruction of hazardous organic materials, to reduce risks due to pathogenic microorganisms and viruses, and for concentrating valuable as well as toxic metals in certain fractions. Bottom ash and APC residues have become new sources of secondary metals, hence incineration has become a materials recycling facility, too. WTE plants are supporting decisions about waste and environmental management: They can routinely and cost effectively supply information about chemical waste composition as well as about the ratio of biogenic to fossil carbon in MSW and off-gas.

Due to the lack of appropriate policies in the last decades, 60% of Brazilian cities still dump their waste in non-regulated landfills (the remaining ones dump their trash in regulated landfills), which represent a serious environmental and social problem ***(BrazilMarcio Montagnana Vicente Leme et al, 2014)***. The key objective of this study is to compare, from a techno-economic and environmental point of view, different alternatives to the energy recovery from the Municipal Solid Waste (MSW) generated in Brazilian cities. The environmental analysis was carried out using current data collected in Betim, a 450,000 inhabitant’s city that currently produces 200 tonnes of MSW/day. Four scenarios were designed, whose environmental behavior were studied applying the Lifecycle Assessment (LCA) methodology, in accordance with the ISO 14040 and ISO 14044 standards. The results show the landfill systems as the worst waste management option and that a significant environ-mental savings is achieved when a wasted energy recovery is done. The best option, which presented the best performance based on considered indicators, is the direct combustion of waste as fuel for electricity generation. The study also includes a techno-economical evaluation of the options, using a developed computer simulation tool. The economic indicators of an MSW energy recovery project were calculated. The selected methodology allows to calculate the energy content of the MSW and the CH4generatedby the landfill, the costs and incomes associated with the energy recovery, the sales of electricity and carbon credits from the Clean Development Mechanism (CDM). The studies were based on urban centers of 100,000, 500,000 and 1,000,000 inhabitants, using the MSW characteristics of the metropolitan region of Belo Horizonte. Two alternatives to recovering waste energy were analyzed: a landfill that used landfill biogas to generate electricity through generator modules and a Waste-to-Energy (WtE) facility also with electricity generation. The results show that power generation projects using landfill biogas in Brazil strongly depend on the existence of a market for emissions reduction credits. The WtE plant projects, due to its high installation, Operation and Maintenance (O&M) costs, are highly dependent on MSW treatment fees. And they still rely on an increase of three times the city taxes to become attractive.

With rapid economic growth and massive urbanization, China faces the problem of municipal solid waste (MSW) disposal and the pressing need for development of alternative energy ***(Hefa Cheng et al, 2010)***. Waste-to-energy (WTE) incineration, which recovers energy from discarded MSW and produces electricity and/or steam for heating, is recognized as a renewable source of energy and is playing an increasingly important role in MSW management in China. This article provides an overview of the WTE industry, discusses the major challenges in expanding WTE incineration in China, namely, high capital and operational costs, equipment corrosion, air pollutant emissions, and fly ash disposal. A perspective on MSW as a renewable energy source in China is also presented. Currently, only approximately 13% of MSW generated in China is disposed in WTE facilities. With the significant benefits of environmental quality, the reduction of greenhouse gas (GHG) emissions, and government policies and financial incentives as a renewable energy source, WTE incineration industry is expected to experience significant growth in the coming decade and make greater contribution to supplying renewable energy in China.

Significant environmental and social problems are associated with rapidly increasing quantity of municipal solid waste (MSW) in recent times ***(Ashutosh Kumar et al, 2013)***. Of various MSW management techniques, land filling is found as the cheapest to manage about 80% of the MSW all over the world. The present paper is concerned with the estimation of GHG emission potential using software Land GEM, version 3.02, from three landfill sites of Delhi namely: Ghazipur (GL), Bhalswa (BL) and Okhla landfills (OL) sites. The results obtained by different researchers using different methodologies viz.. Default, Modified Triangular, First Order Decay (FOD) and In-situ Closed Chamber (ICM) Method are compared with the results of this study and found to be better match with FOD while nearly matching with ICM. The dynamic cost analysis has revealed that GL, BL and OL sites have an economically feasible potential of 3, 2 and 1.5MW of electricity without subsidy and CDM. The work concludes that Land GEM, version 3.02, is relatively better model for estimation of GHG emission potential of landfills and its use is recommended to assess the energy recovery potential from landfills having capacity more than 2.5 MMT wastes.

(Michele Bianchi et al, 2014) focus on possibilities to maximize waste conversion through integration of a Waste-To-Energy (WTE) plant with a gas turbine (GT). In particular, this study investigates the feasibility of utilizing the hot gases leaving the GT mainly to superheat the steam leaving the WTE steam generator. A parametric investigation on the steam production is carried out and the optimum plant match condition in terms of plants capacity ratio is identified and discussed. Detailed modifications to a typical WTE cycle arrangement are presented, in order to evaluate the resulting performance enhancement. Numerical results of a conventional reference WTE plant repowering with different GT commercial units are shown and discussed. Performance indexes, specifically introduced in order to assess the proposed integrated configuration and to allocate power output to each input fuel are illustrated and applied on the considered plant. Results of the study suggest possibilities to create new advanced WTE-GT integrated power Plants or to repower existing WTE plants, in order to increase waste to energy conversion.

Municipal solid waste (MSW) in Kirkuk city in the north of Iraq poses a serious problem having adverse effects on environment and health of the citizens ***(Sameer S. Mustafa et al, 2012)***. Both quantity and volume of MSW have continued to increase with the rapid growth of city population. The population of Kirkuk city, on average, has increased by 3% per annum over the past two decades. The population of Kirkuk city is predicted to increase from 1,050,000 in 2008 to 1,445,556 in 2020. The generation of waste is expected to grow in the future with the rise of city population. The daily waste generation is projected to 1000 tone in 2011. By 2021, the daily waste will amount to 1200 tones. The waste to electricity suggested project in Kirkuk and the choice of electricity generation technology, would lead to improved electricity supply and efficient waste management in the city, and is expected to contribute to technology transfer in this new area. Landfill or Biodigestor Technology seems to be the most preferred technology for Kirkuk city to start with. Potential Power for a plant sourcing from the MSW mass to be fed into the national grid was estimated at 5 MW. Equivalent CO_2 emission in the absence of waste to electrical energy project and the emission by proposed project were calculated. The reduction in CO_2 emission is 87.4%.

CHAPTER-3

GENERAL DESCRIPTION OF TIMARPUR OKHLA WASTE MANAGEMENT PLANT

3.1 Introduction:

Timarpur project is the first project of its kind in India aims to convert 33 percent of Delhi garbage into electricity which is required for serving 6 lekh homes. It's first of its kind with 16 MW power generations.

Fig. 3.1: Timarpur Okhla Waste Management Plant

Earlier design:

This project was earlier visualized to be developed at two different areas, i.e. Timarpur and Okhla. Around 650 Tonne per Day (TPD) of Municipal Solid Waste (MSW) was visualized to be processed at the Timarpur site while 1300 TPD of MSW was visualized to be processed at Okhla site for the preparation of Refuse Derived Fuel (RDF). Moreover, 100 TPD of green waste (waste gathered from garden like dry leaves, cut grass, etc) was to be used at Okhla site for production of biogas through biomethanation plant. The project was also visualized to produce power to the tune of 16 MW by using the RDF obtained from the project activity.

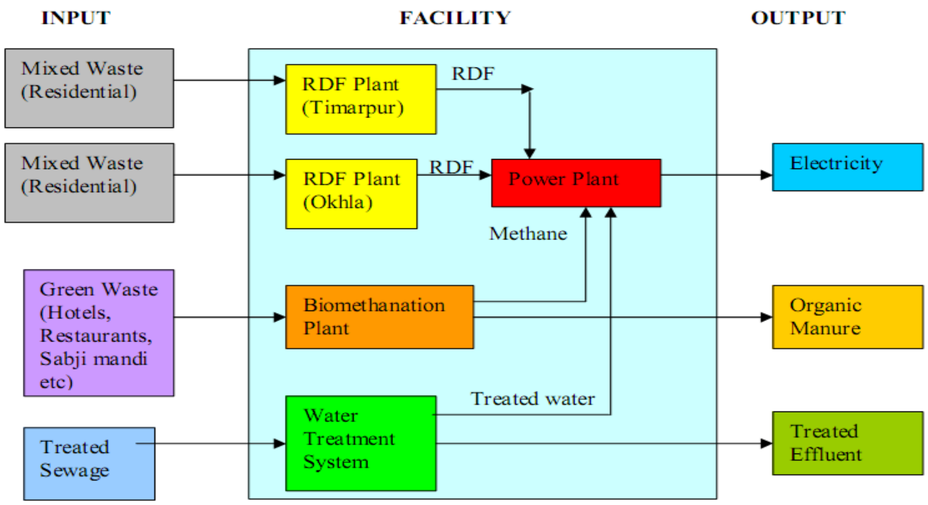

Fig. 3.2: Earlier design

Design implemented:

However, after accessing the success rate of existing technologies and availability of better technologies for such project activities the board took a decision to implement the project activity with a better technology and some design changes. The Timarpur site has been dropped from the project and the whole waste is now processed at the Okhla site.

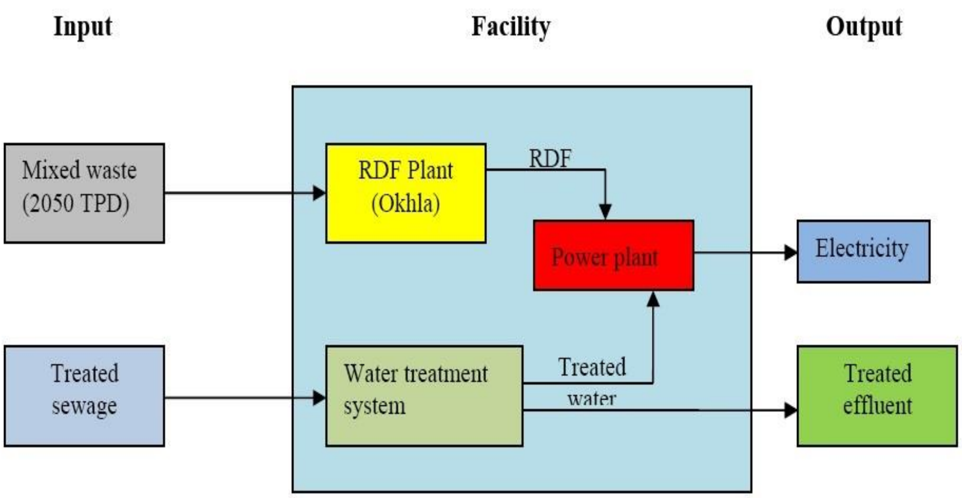

Fig. 3.3: Design implemented

Further, the visualized plant of biomethanation is dropped as the green waste visualized in the initial phase is not supplied to the project activity and a separate tender has been floated for the same. Therefore, the timarpur okhla plant is processing of 2050 TPD of MSW to produce around 16 MW of power using a turbine at the Okhla site.

3.2 Physical/Geographical location:

The Timarpur okhla waste management company is situated in Delhi, India as indicated in the map below. The closest international airport is Indira Gandhi International airport. The location detail of the timarpur okhla waste management plant along with the map is given below:

Location	Latitude	Longitude
Okhla	28˚33'	77˚17'

Table 3.1: Location of plant

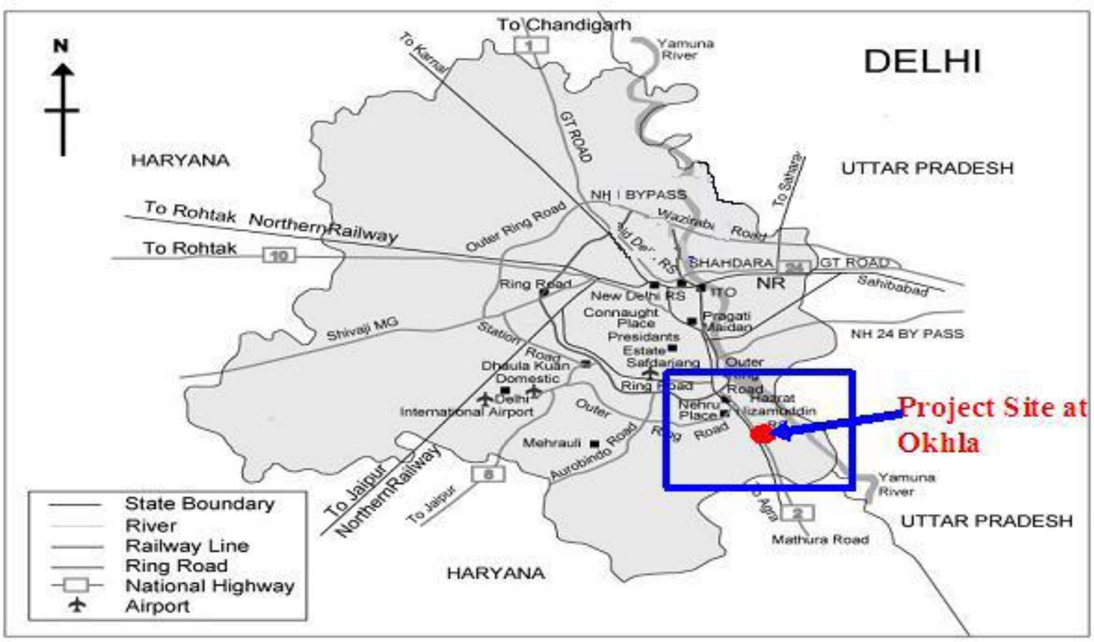

Fig. 3.4: Location of plant

3.3 Working of Okhla waste to energy Plant:

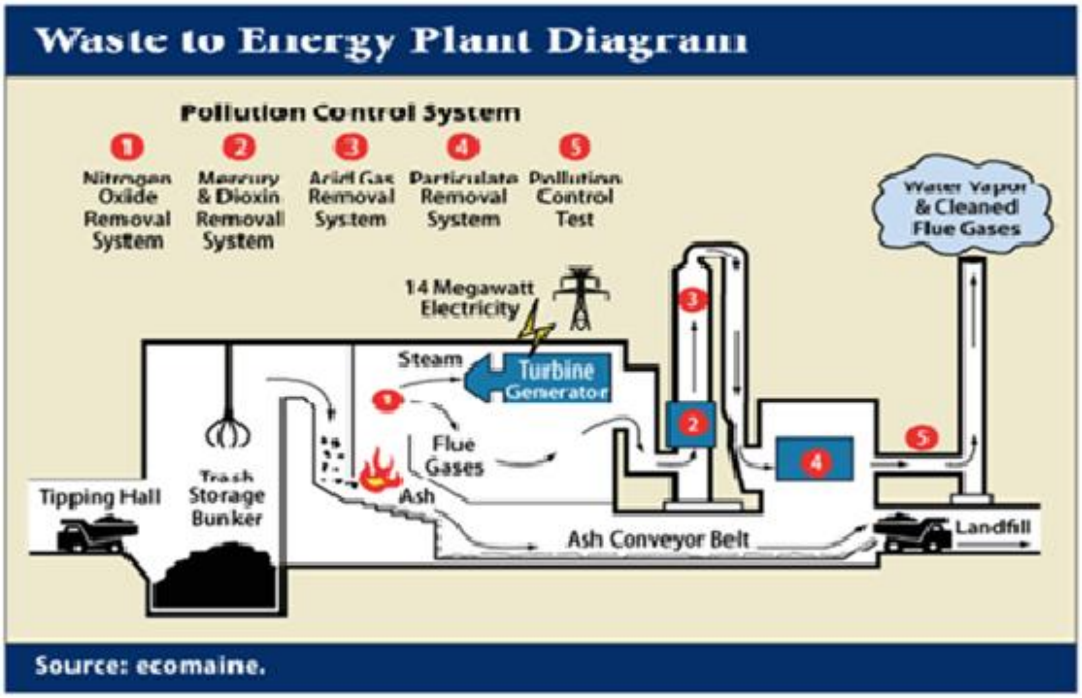

Fig.3.5: Waste to energy diagram

a) MCD and NDMC deliver MSW to the plant according to the agreement to TOWMCL Site in compactors or tipper trucks in a few shifts, according to agreement.

Fig. 3.6: NDMC Truck entering the facility

b) After entering the plant trucks will enter a reception hall which is at negative pressure. The reason for having reception hall at negative pressure is to prevent bed smell from going into neighborhood. The air which is sucked can be used to increase the combustion rate.

Fig. 3.7: NDMC truck at the facility

Fig. 3.8: NDMC truck ready to unload the MSW

c) The trucks will empty the waste in reception hall after closing the reception hall. After which waste is sent to segregation process where Recyclable materials are segregated from waste and sent to recycle industry.

Fig. 3.9: MSW being unloaded at the facility

Fig. 3.10: The waste being transferred for segregation process

d) Now MSW is stored in a MSW pit where it will be mixed with the help of large cranes to make it a homogenous fuel and it is pressurized to reduce the moisture in it.

e) After it RDF is sent to a combustion chamber with a predrying zone.

f) Building near the tipping and bunker area is kept at negative pressure and sucked air is utilized in the combustion process to control smell.

g) The heat of the combustion of waste is used to boils water in the boiler.

h) Steam obtained from boiling water is used to run a turbine which produces power.

i) Electricity is then distributed to the local grid.

j) Ash which is left after combustion either can be land filled or can be used to make bricks which can be used for the construction of roads.

k) all the gases after combustion should be collected and filtered before going to the atmosphere otherwise it will cause air pollution.

l) Very good air pollution control technology is used to reduce the air pollution .this technology works at standards which are higher than standard set for pollution control. gases after combustion is passed through this technology.

n) Monitoring of various parameters is done in control room.

Fig. 3.11: Online monitoring being done at the facility

3.4 Technologies of plant:

The Timarpur okhla waste management facility process 2050 TPD of MSW at Okhla to generate electricity after segregation, screening, sorting and magnetic separation. The technology used in this plant produces homogeneous RDF and at the same time recyclable material in the process of segregation of the MSW. By using RDF as fuel, 16 MW power will be produced. The entire process of RDF generation and ultimately using it to generate power is explained below:

3.4.1 Technology adopted in the RDF Plant*:*

The transformation procedure of Municipal Solid Waste (MSW) into Refuse Derived Fuel (RDF) consists of the following operations:

- Receipts of leaves and plant waste directly to the RDF storage pit.
- Receipt of MSW in the pits.
- Manual separation and dismissal of unwanted items and odd size objects
- Screening to remove minus 15 mm size.
- Screening to remove Grits.

Drying of the screened sorted refuse inside of the Stoker zone (The boiler has an in-built drying zone at the inlet) .MCD and NDMC deliver MSW according to the agreement to TOWMCL site in compactors or tipper trucks in a few shifts, according to regulation . After weighment and examination, trucks are conveyed to MSW storage region and the material is emptied into the pits containers. Slat conveyors installed beneath the containers convey the material to the primary belt. The inert material like construction debris is removed manually from the belt conveyors. The main conveyor release the MSW to a manual inspection conveyor. From the slow moving inspection conveyor, all the unwanted and odd sized objects are handpicked at the manual separation station. These are mainly hard plastics, ceramics, any dead animal, thermocole, tyres or rubbers. The material after manual inspection is passed through magnetic separator to remove ferrous objects. The same is then taken by the conveyors to a rotary screening Trommel having minus 15 mm holes for screening. The screened material from the trammel is released into the secondary conveyors for carrying and discharging the prepared material into the storage pit. Depending upon the quality of MSW and possible dewatering in the pit, the material can be directly used for power generation using a specially designed boiler coupled with large pre-drying section (This RDF technology can be used without any additional drying other than what is provided within the boiler itself). Grab Cranes, outfitted with continuous online monitoring arrangement to evaluate the measure of MSW, get this material from the storage pits through Grab buckets and deposit it on to a main conveyor through the feeding Hopper which directs the material to a closed pre-processing hall.

3.4.2 Technology adopted in the power Plant:

Conventional Rankine cycle is utilized for electricity generation. The power plant comprises of three major parts:

- With a view to enhance the power and efficiency, it is proposed to uttilize HP feed water heaters
- Stoker Boiler system which can dry and fire RDF and generate steam needed for power generation.
- Bleed cum condensing Steam turbo generator with a capacity of producing 16 MW of power.
- Plant water system to meet power plant water needs such as power cycle make up, auxiliary system cooling requirements etc.

Boiler:

Boiler should be capable of firing RDF. RDF on burning contains some matter which can lead to corrosion of heating surfaces. For the most part RDF is set on fire in travelling grate type boiler and the grate in plant is specially designed for firing RDF in order to keep away from clinker formation with various properties like heat and wear resistant and more life. The combustion chamber is designed to avoid formation of various pollutants. The pressure parts are designed in such a way that erosion and corrosion is avoided by avoiding sharp changes in flow and high velocities of flue gases. The modified technology implemented involved reconfiguring of the boiler so as to pre-heat the MSW in the boiler itself rather than having a different plan for drying of the RDF. This has lead to improvement of the RDF combustion efficiency and hence power generation. Apart from this, an arrangement has been made to feed the MSW in a more homogenous manner in the boilers thus further improving the efficiency of the process. The boiler also has a good cleaning system which is used to remove dust on heating surfaces which cause obstruction in heat transfer eventually influencing steam generation. A combination of steam operated soot blowers and mechanical cleaning devices in satisfactory numbers are provided. Boiler is provided with a suitable Flue gas scrubbing, cleaning system and a Bag filter House to obstruct the dust emission to less than 50 mg/Nm3. A Chimney whose height is 60 m is used to vanish the flue gas over a wide area. Lime injection before the reactor and activated carbon injection before the bag house is proposed for capturing HCL, SO2, HF & heavy metals. The following is data related to the boiler used.

Normal steam generation	75.9 TPH
Steam pressure at superheated outlet	41 Kg/cm^2
Steam temperature at superheated outlet	415 ℃
Feed water temp at economizer inlet	130 ℃

Table 3.2: specifications of boiler

Turbo generator:

The turbo generator work at 40atm, 400c and has a capacity of 16MW. The turbo generator is a single extraction cum condensing type and of high efficiency. All casings and stator blade carriers are horizontally split and the design is such that to allow examination of the blades without disturbing shaft alignment or causing harm to the blades. The design of the casing and the supports is such that to allow free thermal expansion in all directions.

Air cooled condenser:

Air Cooled condenser (ACC) is being installed in lieu of the water cooled condenser, this is to decrease the utilization of water and use air instead. This is a step for the preservation of water. The ACC should be fin type.

Electrical arrangement:

The power plant is controlled from the control room with display and recording of main parameters would be displayed in the control room. Evacuation of power is carried out by installing a 33/11 KV sub-station in the plant and laying 33 KV transmission line to the 33 KV system of the 33 KV grid sub-station of BSES Rajdhani Power Ltd. The electrical system of the plant consists of the main turbo-generator unit, step up sub-station and plant auxiliary system. The produced power is stepped down to 433 V through transformers for total in-house power distribution. The balance is stepped up to 33 kV level and connected to the nearby sub-station which is situated at around 2.0 km from the plant.

Water system:

The main source of raw water available for the power plant is treated sewage water, which is made accessible from the sewage treatment plant. This treated sewage water is clarified in a clarifier and clarified water is stored in a storage tank. From this the cooling tower make up is provided after softening. Clarified water is further treated in a series of filters and supplied to the RO plant. Plant service water is also obtained after treatment of treated sewage to the desired standards. Potable water is taken from Delhi Jal Board.

Process Flow Diagram:

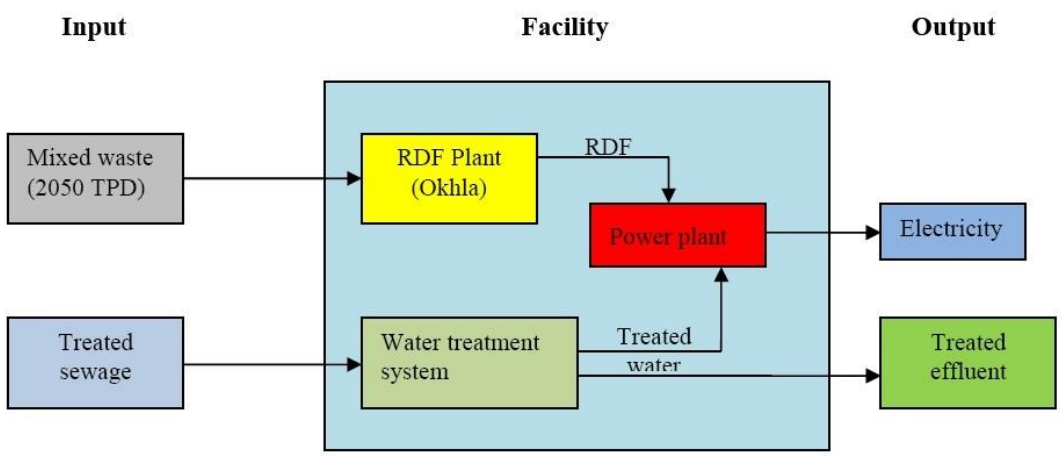

Fig. 3.12: Process flow diagram

CHAPTER-4

ASSESSMENT OF PLANT EFFICIENCY AND IMPROVEMENT

4.1 Introduction:

My aim in this chapter is to perform the Thermodynamic Efficiency Assessment of the timarpur okhla waste management plant in study. The cycle's thermodynamic efficiency and the cycle's thermodynamic efficiency for the case of use of reheat and bleed steam for the feed heating values, which are evaluated at the end of this step-by-step calculating process, are anticipating to detect whether the application of reheating and feed heating boosts the operating cycle's thermodynamic efficiency and power output. The process features the evaluation of the net work output per unit mass flow rate and the heat supplied to the boiler per unit mass flow rate. Moreover, taking into account the Generator/Gearbox thermodynamic efficiency loss accounted at 10%, the calculation of the overall plant efficiency is also taking place for both cases.

4.2 Operating conditions:

For 16 MW timarpur waste management plant under study ,the steam supply condition at turbine inlet are 40 bar and 400 °C the steam expanded in the turbine to condenser pressure of .1 bar. A number of assumptions are made in order to perform the assessment with the highest degree of accuracy:

• The condition line for turbine and pump is a straight line in the T-s diagram.

• The Generator/Gearbox thermodynamic efficiency loss is accounted at 10% and must be taken under consideration in the calculation of the overall plant efficiency.

4.3 Thermodynamic efficiency of cycle:

It is defined as the ratio of net work output per unit mass flow rate from the boiler to the heat supplied to the boiler per unit mass flow rate.

4.4 Overall plant efficiency:

The overall plant efficiency is defined as an indicator of how efficiently Power is extracted from the steam generated from the MSW mass burning in a predefined cyclic process.

4.5 Methodology:

In order to calculate thermodynamic efficiency of cycle, values of enthalpies of steam at various points is find out with the help of mollier diagram and steam table. h_1, h_2, h_3, h_4 are enthalpies at inlet of turbine, condenser, pump and boiler respectively.

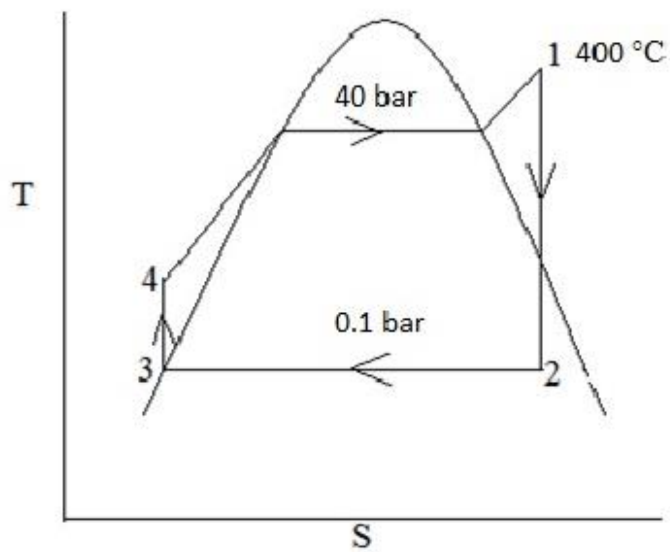

Fig. 4.1: T-S diagram for simple rankine cycle

At inlet condition on turbine, **40 bar 400℃**

h_1=3220 kJ/kg

s_1=6.72 kJ/kgK

At **0.1 bar**,

s_{f2}=.649 kJ/kgK

s_{fg2}=7.501 kJ/kgK

h_{f2}=191.8 kJ/kg

h_{fg2}=2392.8 kJ/kg

v_f=.001010 m^3/kg

For isentropic process $s_1 = s_2$

$6.72 = .649 + x_2 * 7.501$

$x_2 = .809$

h_2=191.8+.809*2392.8

h_2=2128.43 kJ/kg

h_3=h_{f3} =191.8 kJ/kg

Pump work, W_p=.001010(40-.1)*10^2

=4.03 kJ/kg

h_4=h_{f3}+ W_p

=195.83 kJ/kg

Turbine work, W_t =h_1-h_2

=3220-2128.43

=1091.57 kJ/kg

Net work output =Turbine work-pump work= W_t-W_p

= 1086.97 kJ/kg

Heat supplied to boiler=h_1-h_4

=3220-195.83

=3024.17 kJ/kg

Thermal Efficiency of the cycle(%) :

Net work output per unit mass flow rate / Heat supplied in the boiler per unit mass flow rate

=(1091-4.03)/(3024.17)

=**35.94%**

The Generator/Gearbox thermodynamic efficiency loss is accounted at 10% and must be taken under consideration in the calculation of the overall plant efficiency:

Overall Plant Efficiency (%) = Cycle Efficiency * 0.9

=32.35%

2nd Case by use of reheating and bleed steam for feed heating:

With a view to improve the power efficiency, plant is proposed to use feed water heaters.

If plant has one stage of reheat optimally placed which raises the steam temperature back to 400°C. One closed feed water heater with drain cascaded back to the condenser receives bled steam at the reheat pressure and remaining steam is reheated and then expanded in the l.p. turbine.

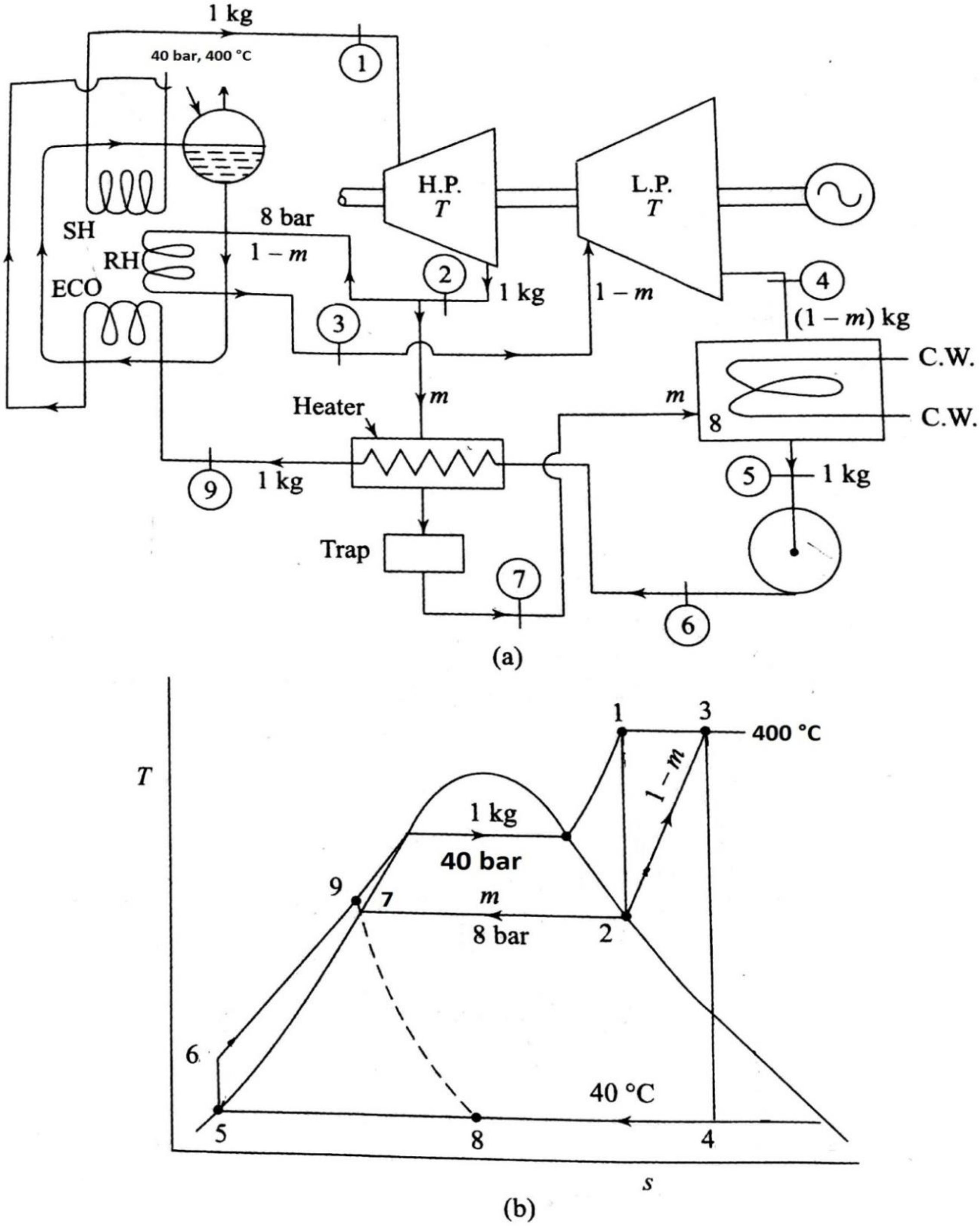

Fig. 4.2: Flow diagram & T-S diagram for 2nd case

The optimum reheat pressure is taken to be 20 % of boiler pressure which becomes .2*40=8 bar.

At 40 bar, 400℃

h_1=3220 kJ/kg

s_1=6.72 kJ/kgK

h_2=2767.5 kJ/kg

At 8 bar, 400 °C

h_3=3260 kJ/kg

s_3=7.53 kJ/kgK

At o.1 bar

s_{f4}=.649 kJ/kgK

s_{fg4}=7.501 kJ/kgK

h_{f4}=191.8 kJ/kg

h_{fg4}=2392.8 kJ/kg

v_f=.001010 m^3/kg

For isentropic process s_3=s_4

7.53=.649 + x_4 *7.501

x_4=.917

h_4=191.8+.917*2392.8

h_4=2386.82 kJ/kg

h_5=h_{f5} =191.8 kJ/kg

pump work, W_p=.001010(40-.1)*10^2

=4.03 kJ/kg

h_6=h_{f5}+ W_p

=195.83 kJ/kg

h_7 =720.9 kJ/kg

For closed feed heater let the temperature of the feed water leaving the heater is 3 °C below the Saturation pressure of the bleed steam.

Saturation temp. at 8 bar=170.4 °C

Hence T_9=170.4 -3=167.4 °C

h_9 =707.1 kJ/kg

For the close feed water heater, the energy balance gives:

$1(h_9 - h_6) = m\,(h_2 - h_7)$

m=0.2 kg

Turbine work, $W_t = (h_1 - h_2) + (1 - m)\,(h_3 - h_4)$

= 1107.38 kJ/kg

Net work output = $W_t - W_p$

= 1107.35 kJ/kg

Heat supplied=$(h_1 - h_9) + (1 - m)\,(h_3 - h_2)$

=2882.75 kJ/kg

Thermal Efficiency of the cycle(%)= (net work output)/(heat supplied)

= (1107.35) ÷(2882.75)

= **38.28 %**

Chapter-5

RESULTS AND DISCUSSIONS

5.1 Variation to thermodynamic efficiency:

Thermodynamic efficiency of the plant calculated as in first case is 35.94%. but when we use one stage of reheat and bleed steam for feed heating as in 2nd case thermodynamic efficiency obtained is 38.28. So thermodynamic efficiency of timarpur plant is increased by using one stage of reheating and closed feed water heating as shown in figure:

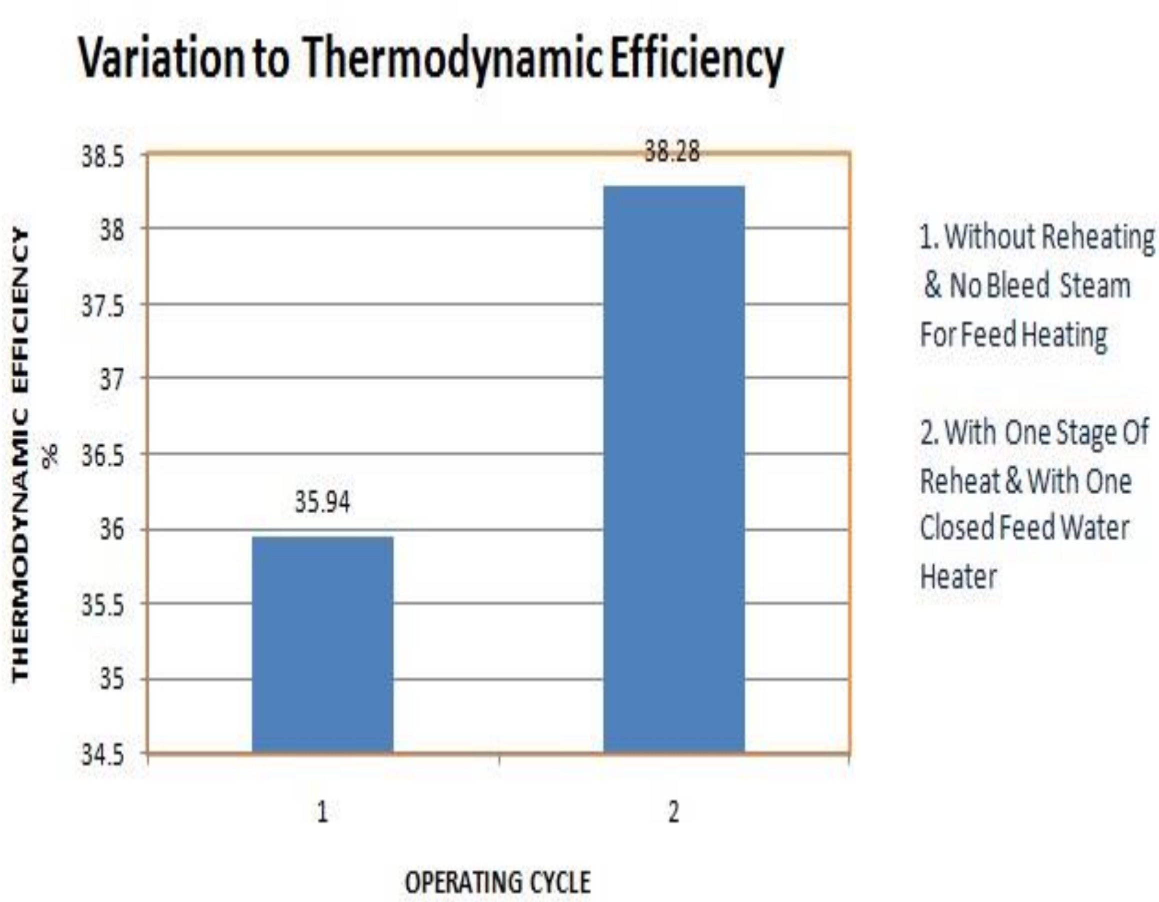

Fig. 5.1: Variation to thermodynamic efficiency

5.2 Variation to work output:

In 2nd case power output per unit mass flow rate also increased .it is 1107.38 kJ/kg in second case as comparison to first case which is 1086.97 kJ/kg as shown in figure 5.2.

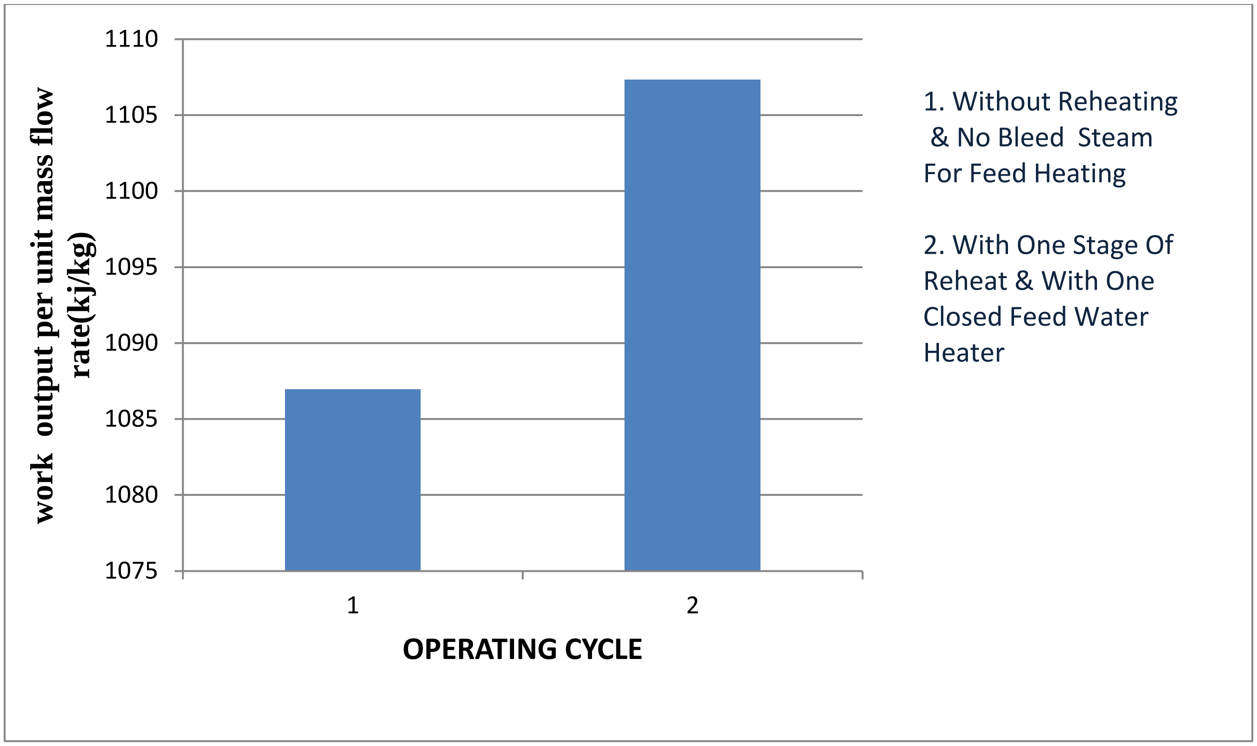

Fig. 5.2: Variation to work output

So we can say that by use of reheating and bleed steam for closed feed water heating thermodynamic efficiency and work output is increased.

Chapter-6

CONCLUSIONS AND SCOPE FOR FUTURE WORK

6.1 Conclusion:

The following are the different conclusions drawn from the present work:

- The various technologies for recovering useful energy from MSW already exists and are being extensively used in different countries for their benefits. Hence, an attempt is made in my thesis work to study and discuss the various technological options available for energy recovery/generation from municipal solid wastes in Indian context
- Energy generation from waste uses municipal solid waste as fuel and helps in finding a solution for some of present biggest challenges for society like greenhouse gas reduction, dependence on fossil fuels and generates clean and renewable electricity.
- Timarpur Okhla Integrated Waste processing plant generates clean and renewable energy. It reduces dependence on conventional sources of energy which are reducing day by day. This plant reduces greenhouse gas emissions so it is generating environmental friendly energy. This plant is sustainable solution to waste management problems.
- At presently timarpur okhla waste to energy plant is working on simple rankine cycle. As per my calculations and results it can be concluded that if we use reheating and bleed steam for closed feed water heating then thermodynamic efficiency and net work output per unit mass flow rate increases.
- Hence in totality it can be summarized that there is a need for integrated waste management system coupled with reduction in waste load. Further the energy potential of MSW can play an important role for the nation in ensuring sustainable development and attaining energy security.

6.2 Scope for future work:

The present study was concentrated to increase the thermodynamic efficiency and power output of timarpur waste management plant using single stage of reheating and single close feed water. The following works are suggested to be carried out in future:

- In place of single stage of reheat and single close feed water heater , multi stages of reheating and a number of feed water heaters can be used to increase the thermodynamic efficiency and net work output.

- Energy generation potential of various waste to energy process may be find out to know which waste to energy process is most feasible at that place.
- New techniques of electricity generation from municipal solid waste may be developed.

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