“Effective model of Waste Management for Waste to Energy”

A Thesis submitted in partial fulfillment of the requirements for the Award of Degree of Bachelor of Science in Electrical and Electronic Engineering.

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Certification

This is to certify that this project and thesis entitled "**Effective model of Waste Management for Waste to Energy** "is done by the following students under my direct supervision and this work has been carried out by them in the laboratories of the Department of Electrical and Electronic Engineering under the Faculty of Engineering of Daffodil International University in partial fulfillment of the requirements for the degree of Bachelor of Science in Electrical and Electronic Engineering.

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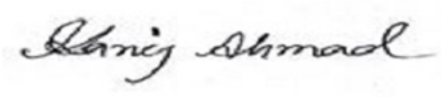

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The project and thesis entitled **"Effective model of Waste Management for Waste to Energy** ""submitted by **Abu Sumain Sojol,** ID No: 171-33-3870 and **Md.Shahadat Hossain,** ID No: 171-33-3893 has been accepted as satisfactory in partial fulfillment of the requirements for the degree of **Bachelor of Science in Electrical and Electronic Engineering**

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Q = overall energy required in the plastic pyrolysis process (kJ)

n_i =molar number of components i (mole)

H_i =enthalpy of component i (kJ/mole)

M=Number of trucks

C_i=Capacity of truck (m^3/ Truck)

V_i=Loading Volume ratio

d_i=Density of MSW (Tons/m^3)

T_{ij}=Number of Trips per Day

m=Number of elements in MSW

W_A=Weight of the element A

HHV_A=Heating value obtained from bomb calorimeter of the element A.

C=Weight of carbon Content.

H= Weight of Hydrogen Content.

S= Weight of Sulphur Content.

W= Weight of moisture Content.

O= Weight of Oxygen Content.

η_p=Efficiency of conversion in power plants.

η_g=Generation Efficiency.

η_t=Transmission Efficiency

Q = overall energy required in the plastic pyrolysis process (kJ)

n_i =molar number of components i (mole)

H_i =enthalpy of component i (kJ/mole)

List of Abbreviations

WTE = Waste to Energy

MSW = Municipal solid waste

LHV = Lower heating value

HHV = Higher heating value

BW = Burnable waste

E-waste = Electronic waste

FMIS = Fuel mixture injection system

PWG = Projected waste generation.

PBY = Population on that year.

AGP = Annual growth rate of population.

PCWB = Per capita waste generation (kg/cap/day).

AGW = Average growth rate in the per capita waste generation.

EP = Energy Potential

PG = Power to grid.

LFG = Landfill gas

DCC = Dhaka City Corporation

ADS = Anaerobic Digestion System

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First of all, we give thanks to God. Then we would like to take this opportunity to express our appreciation and gratitude to our thesis supervisor **Mrs. Kaniz Ahmed, Lecturer** of **Department of EEE** for being dedicated in supporting, motivating and guiding us through this project. This project can't be done without his useful advice and helps. Also thank you very much for giving us opportunity to choose this project.

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ABSTRACT

Production of waste is increasing day by day and it is creating a vast threat to our environment. This large amount of waste creating environmental pollution. But these wastes are a huge source of energy. Wastes can be converted into valuable resources by an environmentally friendly waste management system. Waste to Energy (WTE) study focuses on the process which utilizes wastes to generate energy in form of electricity. This thesis presents modeling and implementation of a effective waste management system to convert waste into resources and electricity. Also, discusses various methods to process different categories of waste to produce energy in form of electricity and estimate the total electricity production from a certain amount of waste. Also presents a futuristic model of a combined waste management system, which generates electricity from waste in a way, which uses every single municipal solid waste (MSW) and causes less environmental pollution. The main purpose of this thesis is to introduce a combined waste management system which is sustainable environment friendly and effective.

CHAPTER 1

Introduction

1.1 Background

Nowadays municipal solid waste creating huge problems for urban society all over the world. Dumping waste in an open dump yard creates pollution. Also, the land uses as a dump yard become useless. Open dump yard causes air pollution, soil pollution, and water pollution [1]. Surrounding areas of a dump yard become uninhabitable for people. Peoples who live beside a dump yard become unhealthy and live with a lot of health problems. Especially children suffer a lot. For this reason, people researching for a solution to utilize the waste and solve the problem. Waste to energy is the best way to solve this problem. This method not only solves the waste management problem but also generates electricity which helps us to fulfill the daily need.

As we can see the generation of waste is increasing day by day with respect to population. The need for electricity also increasing with respect to population and industries. This tremendous number of wastes is a great source of power. Waste which causes a negative impact on people's daily lifestyle can be used as a resource of electricity. [2] More waste generates more electricity. So, waste will not remain a burden anymore and the environment will save from pollution caused by MSW (Municipal Solid Waste).

There are different types of waste like burnable waste, bio/organic-waste, plastics, etc. Each type uses different methods to generate energy. By burning burnable wastes, a huge amount of heat can be generated. Also, bio-waste/organic waste which causes odor during decomposition can produce huge amounts of biogas which is a very good fuel and contains an excellent heating value. Plastic waste also a very good fuel but burning plastics directly in the open air causes huge air pollution. Also, cause asthma and heart diseases. By converting those plastics into fuel, air pollution can be reduced. And many other types of waste can be recycled like e-waste, metal, ceramics as they cannot be burnt to generate heat [3]. Like many other countries, generations of waste in Bangladesh also increasing day by day with respect to the growth of population and urbanization. A scenario of waste production in Bangladesh is given in Table 1.1.

Year	Total urban population	Urban population (% total)	Waste production rate (kg/cap/day)	Total waste production (ton/day)
1991	20872203	20.25	0.49	9873.6
2001	28808479	23.12	0.5	11695
2004	32765154	25.09	0.5	16382
2025	78440001	40.1	0.6	47064

Table. 1.1. Production of waste in Bangladesh.

Modern urban life generates a tremendous amount of MSW around the world. Within 2025 the generation of waste will reach 2.2-2.3 billion tons around the globe [4]. 2.3 billion tons of waste equivalent to 2.58×10^{23} MJ of energy which can satisfy 10% of global annual electricity needs. If this energy can be utilized, a huge amount of electricity can be generated.

Fig1.1: waste disposal

1.2 Problem Statement

Generation of waste is increasing because of fast population growth and ongoing economic development. Since the 20th century, the industry development has propelled urbanization. However, municipal waste pollution is becoming increasingly serious. Currently, about 10 billion tons of waste are produced annually all over the world. Which is six times the global grain output, 14 times the steel output. However, dumping and landfilling is still the most used way of waste disposal. Which encroaches on the land stinks and produces a large number of pollutants such as bacteria, viruses, methane, ammonia, and sulfide. Besides, the leachate produced by landfills is polluting the groundwater in the long run. The landfill is harmful to us and later generations. So, it becomes obsolete in more and more countries. Waste is mislaid resource. How to manage waste properly? And transform waste into useful products in a circular way is an important issue of considerable global concern needed to be addressed promptly. To handle waste in a scientific and environmentally friendly way can not only improve the ecological environment but create greater economic benefits. If this tremendous amount of waste is not managed, this will certainly cause a negative impact on our regular lifestyle.

Figure1.2: Landfill harmful waste

1.3 Thesis Objectives

The aim of current study is to undertake to see out the foremost effective and least polluting energy recovery technology among the opposite available options for the recovery of energy from municipal solid waste. The selection of technologies is going to be supported the local conditions of the study area.

This will help to develop a solid waste management system of Dhaka. Which will be reasonable, economically affordable and socially acceptable. In addition, this will ensure a far better quality of lifetime of present and future generations.

The leading objectives are to:

1) Identify the present solid waste generation from different towns in Bangladesh.

2) Measure the socio-economic-environmental potentials to implement energy recovery Principles in several solid waste management technologies in Dhaka

3) Design a combined waste management system to make sure more sustainable and effective system.

4) Build a system which is environment friendly and cause less pollution than any other existing technologies.

5) Ensure every types of waste are used so that nothing left behind which can cause environment pollution.

1.4 Thesis Overview

Generation of waste is increasing because of fast population growth and ongoing economic development. Waste creating huge problems for urban society all over the world. Dumping waste in an open dump yard creates pollution. Also, the land uses as a dump yard become useless. A proper waste management system is needed to solve this threat also convert waste into useable resources. This thesis discuss about possible sustainable solution of this problem. Overall simplified block diagram:

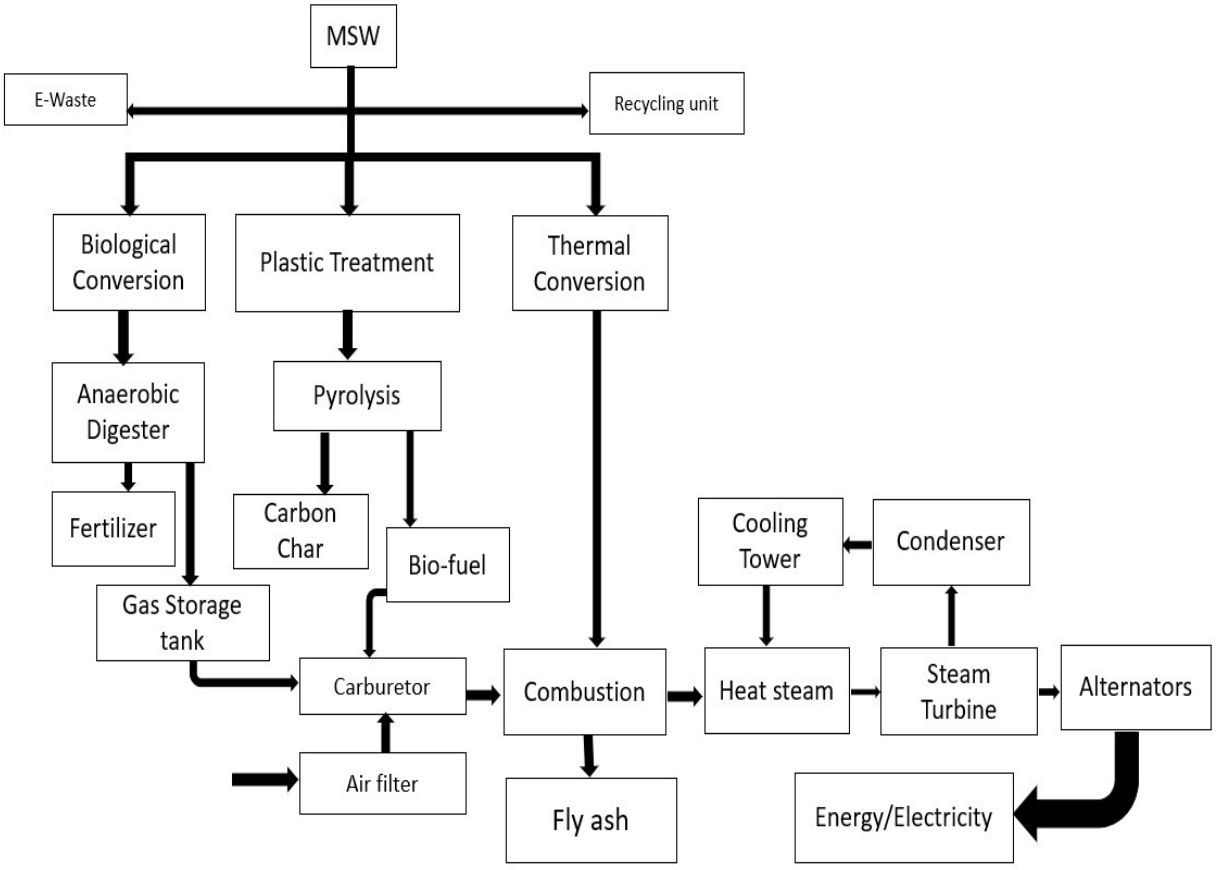


Figure 1.3: Overall Simplified Block Diagram of Thesis

CHAPTER 2

Literature Reviews

2.1 Overview of WTE

Waste to energy plant is a typical industrial building but the process going on inside is quite special. Waste to energy plant converts rubbish into electricity. Some plants supply heat to district heating systems too. How does it work? The most widely used technology takes waste and burns it. The created heat is used to make steam which drives a turbine that generates electricity. This technique is widely used around the world. Usually, all the plants are very big because this is a process that works best on a large scale. Incinerating waste creates emissions and residues and part of the process is focused on dealing with these. Achieving a high rate of efficiency with a low volume of byproducts is the aim. Many systems are found varying complexity but the working principles are same. To set up this kind of a waste to energy system a stockpile of waste, a furnace a boiler with heat exchangers, a water supply system, a turbine, and a generator is needed. The waste is collected and delivered to the plant where it is stored in large bunkers. Then it's transferred from the bunkers to the combustion chamber. The temperature in the combustion chamber is very high. The gas is in it or heated to over 850 degrees for at least two seconds to make sure all the waste gets burned completely to form stable and products. The residue left behind is called bottom ash and is non-hazardous. It's usually sent for recycling and is often used by the construction industry. Around 20% of the weight of the waste ends up as bottom ash. Tremendous amount of heat from the furnace rises in a series of chambers inside the boiler. The idea is to capture the thermal energy as efficiently as possible. In the boiler heat exchangers, which is a series of pipes filled with water a bit like a household radiator. The heat vaporizes the water to form superheated high-pressure steam. Superheated high-pressure steam is sent to the turbine where it encounters a series of turbine blades. The high-pressure steam directly forces the blades to rotate. Which rotate the generator and generate electricity. The electricity is fed to the power grid for use by industry and the local community.

Water travels through the system and follows a closed-loop cycle. After passing through the turbine, it is allowed to condense and then return to the heat exchangers to be heated again. Some ways to energy plants incorporate a district heating system into the cycle. The low-pressure steam from the turbine heats a second closed water tube leading out into the community where it, in turn, heats individual systems. Gas emissions from the boiler are known as flue gas must be treated before being released from the plants too many stacks. It's processed using a series of absorption scrubbing and filtering systems. There are two other types of waste products. The first is the wastewater that wet flue gas treatment plants produce. This is treated then release. The second is fly ash which can contains toxic chemicals or components and it can be consists of solid particles inside the flue gas. Fly ashes are sometimes treated sometimes not but either way, they must be disposed of as hazardous waste. Fly ash represents less than 5% of the waste input of WTE plant. Waste to energy technology is continually under development. The most advanced plants using the technology described here are up to 98% efficient and capturing the energy they generate. However, there is debate about the effects on the health of incineration and its byproducts and about the CO2 produced. There were various other forms of ways to energy processes some examples are gasification which produces combustible gases and anaerobic digestion which produces methane-rich biogas and pyrolysis which produces biofuel. There is also debate about the indirect environmental impacts of making biofuels whatever the process used the objective is to reduce volumes of waste and particular descend as little as possible to landfill. Waste to energy technologies recover value from waste and therefore a source of renewable energy.

2.2 Waste-To-Energy (W-T-E) treatment options

2.2.1 Anaerobic digestion system (ADS)

A process where biodegradable material is breakdown through microbes in the absence of oxygen is called anaerobic digestion. Special chambers are used for the digestion process. Controlled specific conditions are provided inside chambers such as temperature, moisture content, and pH, etc. The purpose of these conditions is to provide a suitable environment to microbes and allow them to increase their number and enhance the degradation process to produce methane. Organic waste may contain yard waste, food waste and other type of organic matter. The anaerobic digestion process is very successful and sustainable if the wastes are containing high quantity of organics waste, primarily this process produces methane (CH4) and carbon monoxide (CO) and also with small fraction of other gas gases. Anaerobic digestion basically consists of three steps. First organic material is prepared through sorting, segregation and size reduction. Secondly favorable environmental conditions are provided to ensure digestion process. These components are well mixed for approximately 5-10 days, but in colder climate slurry is mixed at low temperature for long time. In third step, the residual sludge is disposed of, if it is contaminated, after treatment it is disposed of. Anaerobic digestion occurs in four stages:

1. Hydrolysis 2. Acidogenesis

3. Acetogenesis 4. Methanogenesis

CH4 generation can take place in two ways, either it is collected directly from the landfill sites or bio waste treatment plant where pretreated waste are digested inside a digester.

Advantages

- Compared to thermal technologies ADS requires low capital, maintenance, and operational costs
- Large amount of energy can be recovered in the form of CH_4
- Pollution control is easier
- ADS (Anaerobic digestion system) reduces the risk of gas and production of leachate

- Well maintained ADS ensures very lower level of environment pollution
- After anaerobic digestion of bio waste, the waste can be used as fertilizer as those are neutralized

Disadvantages

- ADS technology works well when waste are pre-treated and must ensure no other plastic or metal or other kinds of material left inside the waste which create problem cause waste treatment is not easy process
- Bad odor is produced around the system area during processing of organic waste
- Market value of end product may be lower
- Toxic contaminants are found inside the end products and it is difficult to get rid of those toxic components

2.2.2 Combustion

Combustion is a process where waste are directly burn to generate heat which is used to produce steam from water. There are a lot of similarities with coal-based power plants. Here waste will work as a fuel by burning them in a combustion chamber we will get heat which will make vapor from water to rotate the turbine. While combustion a large amount of oxygen is needed to fulfill the burning process. As organic or waste which are wet and cannot burn directly those must be separated for better efficiency. Country like Bangladesh have high humidity as a results waste are usually filled with water. The presence of water at a significant amount cause huge problem while burning. And burning process take longer to burn and also generation of heat stay low. There for waste are reserve in a dry storage for 4-7 days and in this period waste become dry and burnable. After this process waste are cut into small pieces. After this process waste are directly send to the chamber for combustion. After burning remains end products ash, few amount of metal, some toxic particle.

Advantages

- Combustion system is very easy to understand
- Not need any kind of complex technology to build this kind of waste management system
- Combustion system has ability to recover energy and remaining ash can used as land fill
- Maintenance cost is very low and maintenance is very easy

Disadvantages

- As all kind of waste are directly burn inside a combustion chamber generation of smoke is very high and which causes huge air pollution
- Burning plastic directly causes air pollution and through this process toxic particles can be mixed with air which is very harmful for human
- Fly ash processing system is needed to reduce environment pollution which is a complex system and costly
- Combustion technology is not environmental friendly

2.2.3 Pyrolysis

Thermal degradation of plastic waste in the absence of oxygen is called pyrolysis. External source of heat is used for pyrolysis process. The produced products from pyrolysis are used as an alternative fuel. Which is sustainable fuel and end products are liquid fuel, gases and carbon char. Combustion process in pyrolysis requires high temperature. Pyrolysis technology convert plastic waste into carbon char, gases and fuel. As plastic is a huge threat for our future world. So, we must find a solution to destroy or reuse it in a proper way. So that our environment remains safe for future generations. Pyrolysis is very sustainable way and solution to plastic waste problem and can convert plastic into usable resources.

Advantages

- Pyrolysis system has ability to convert large amount of plastic waste into useable resources
- As pyrolysis occurs inside an oxygen free chamber so the system is more environment friendly
- Emission of toxic materials is very low

Disadvantages

- Pyrolysis is a costly technology and need higher capital and also higher operational costs
- End products are less valuable

2.2.4 Combined combustion

Combined combustion system is a system which is a combination of combustion, pyrolysis, and anaerobic digestion system. After separating MSW into four categories (recyclable, burnable, organic, plastic) the burnable waste goes through a drying section. This drying unit dried those waste and made them more burn efficient. After that those BW directly falls into the combustion Chamber. A mixture of gas and air is also injected in the combustion chamber by FMIS at the same time (FMIS uses gases from anaerobic digestion and pyrolysis fuel). Air and gas enhance the burn speed. At the same time air balancing starts working to maintain the proper air flow inside the chamber, to make full burning of the waste less carbon emission. After burning Ashes fall out through the bottom gate. Meanwhile water flows through economizer and those tubes inside boiler water become vapor it passes through the super heater. As a result, high speed steam directly falls on steam turbines. And the turbine started to rotate. Turbine is connected to an alternator by a shaft. Alternators turn this mechanical energy into electrical energy. FMIS also works as a backup system which ensures the simultaneous generation of heat inside the combustion chamber to make sure no lack of heat in the system.

Advantages

- Combine system is more sustainable than any other system
- Combine combustion is more efficient as burnable waste can burn properly and can generate more heat
- This system cause less pollution and emit less toxic particle

Disadvantages

- Combine system is very costly
- This system need bigger area
- Maintenance cost is very high and complex system

2.3 Primary operational element of MSW Control device

The actions associated with management of MSW from the factor of production to proper adjustment are composed into some straight factors

- ❖ Waste managing, sorting and processing at the unit
- ❖ Concourse
- ❖ Waste production
- ❖ Disposal
- ❖ Handling and transformation

Practical elements are quite interconnected however they are not always presented in all municipal solid waste management process.

In lots of underdeveloped or growing nations the process is limited to-

- ❖ Waste production
- ❖ Handling wastes at the unit
- ❖ Gathering
- ❖ Disposal at landfills

On the other hand, in most developed countries almost every functional elements are determined in the system.

2.4 MSW generation in Bangladesh

Waste production is increasing with respect growth of population. Also generation of waste is proportional to economic growth and living standard. Normally countries which have higher per capita or developed consume more goods and produce higher wastes than any other countries with lower per capita. But the lower per capita countries or less developed produce less renewable waste compared to the higher developed countries. So waste management system must be different in both kind of countries. Less developed countries produce high amount of organic waste than high developed countries. Bangladesh is a developing country so the wastes contain less recyclable waste than other developed country. Most of the waste in Bangladesh is organic. Here in Bangladesh nowadays waste generation rate more than 0.5 kg/cap/day. Tremendous amount of waste generating daily in Bangladesh and it is creating huge threat to Bangladesh.

The table below presents the production of solid and waste growth rate in urban area in Bangladesh.

Year	Total urban population	Urban population (% total)	Waste production rate (kg/cap/day)	Total waste production (ton/day)
1991	20872203	20.25	0.49	9873.6
2001	28808479	23.12	0.5	11695
2004	32765154	25.09	0.5	16382
2025	78440001	40.1	0.6	47064

Table2.1: Production of urban solid waste in Bangladesh

2.4.1 MSW in Dhaka City

The capital of Bangladesh is Dhaka. Also Dhaka is one of the most densely populated town around the World. About more than 20 million people are living in Dhaka. About 2900 are living in per square kilometer. Waste is generation in Dhaka is very high compared to other major cities in Bangladesh. As compared to other mega cities around the world Dhaka have very low category of waste management system and about 50% of waste are collected properly. Those 50% waste are transported to landfills and other disposed in unorganized way which is unhygienic and cause pollution. Drains are blocked and filled with plastic waste and in rainy season road are flooded because of blockage of drain due to waste. Also few are suffering with bad odor which also causes side effect to human health. As 70% of waste are organic the emission of CH_4 also increasing which creating greenhouse effect and temperature rising day by day. Also waste are producing a lot of toxic particle which are mixing with air and making the environment harmful for living people. According to the US Air Quality Index (AQI) Dhaka is marked as the most polluted city in the world. In case of livable city Dhaka at 147^{th} position compared with 150 cities around the world. And it is becoming worst day by day. In Dhaka people are generating around 0.29kg to 0.60 kg/cap/day. The more earning the higher tendency to generate more waste. Due to industrialization and rapid increase in urban population waste management have become very important topic for the government in Bangladesh. The table2.2 presents a scenario of waste generation in Dhaka city:

MSW	DCC (Ton/Day)
Organic matter	3647
Paper	571
Plastic	230
Textile & wood	118
Leather & rubber	75
Glass	37
Metal	107
Total	5340
Population	11.00
Per capita (kg/day)	0.485

Table2.2: Generation of waste in Dhaka.

2.4.2. Waste collection in Dhaka city.

In Dhaka city total waste management depends on Dhaka city corporation (DCC). Nowadays under DCC, workers go to each house and collect wastes and transport them to a dustbin station where all waste are gathered from a particular area. Poor people are chosen for this kind of job. In every house people put their waste in a particular container which is put outside of the door. Every morning workers under DCC come with a waste collecting van and collect all waste from each house. Then those waste transported to the station and every night big waste container truck transport them to nearby dump yard. Workers monthly salary is not so high as a result workers collect recyclable waste or renewable waste and sell those waste to hawkers. Some poor people with no job to do stay in landfill and collect resell able waste like metal, glass, some kind of plastic and sell them for living. Those scavengers live a very tough life as the level of air pollution is very high there and suffer from a lot of diseases.

All types of wastes collected from the Dhaka city are dumped to the land filling sites. In DCC, because of lack of funds, transportation vehicles, infrastructure a big amount of waste are left. In Dhaka city solid waste, electronic waste, plastic waste, many kinds of metal waste, construction waste, medical waste, organic waste, food waste and various kinds of industrial wastes are produced. Overall waste collection process shown in the given diagram below:

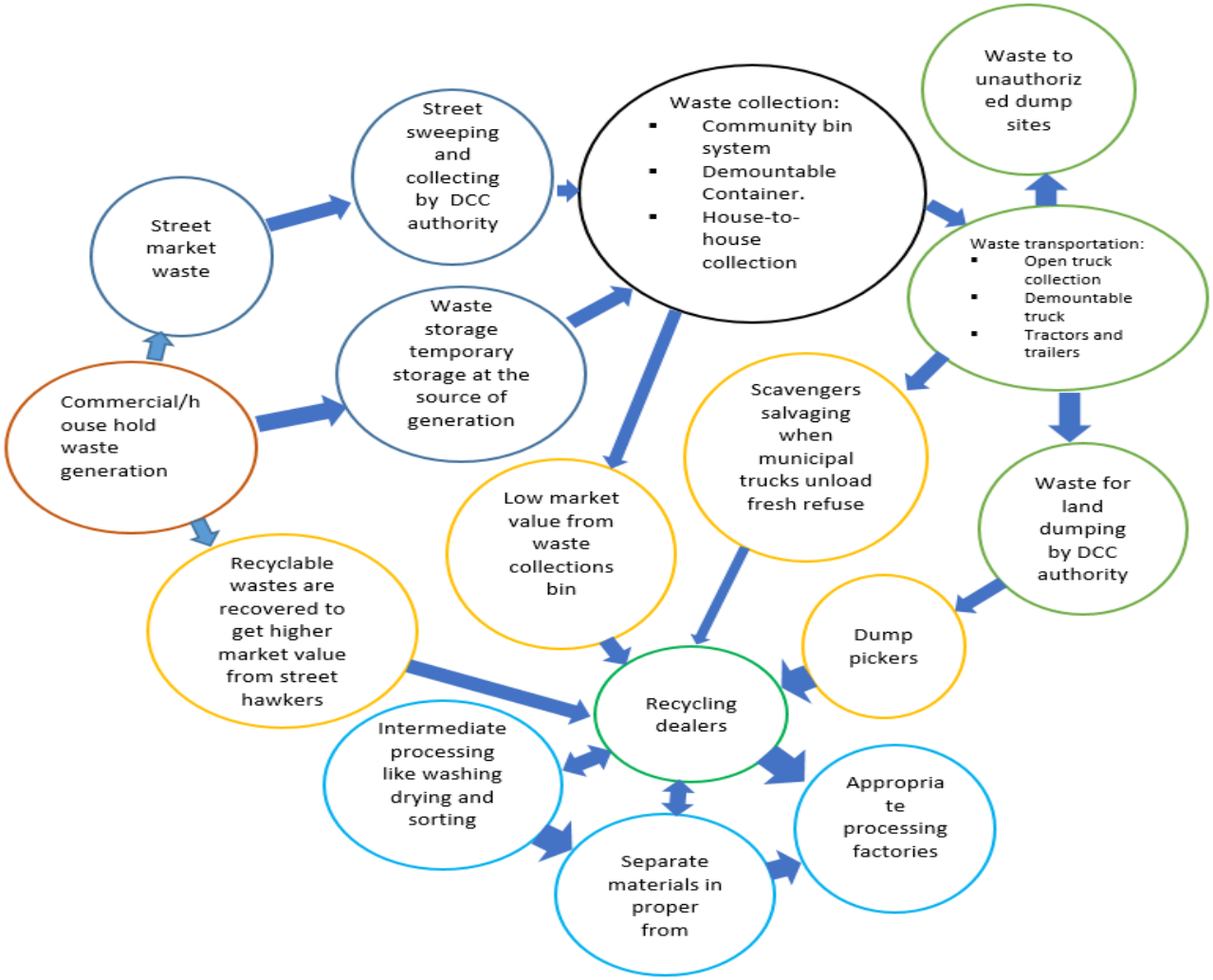


Figure 2.1: Simplified Block Diagram of Waste collection in DCC

CHAPTER03

Waste to energy

3.1: WTE overview.

Waste to energy (WTE) is not only the system which converts waste into electricity but also a proper waste management System which is environment friendly. Here our main goal is to use every single piece of waste. So that environment pollution due to waste is neutralized. Basically, waste based combined power plant uses three kinds of fuel gas, burnable waste, pyrolysis fuel. Here at first, separated E-waste and recyclable waste are sent to recycling unit. Plastics are very good fuel but directly burning those plastics cause a lot of air pollution. To lessen the pollution plastics are send to plastics treatment system which convert those plastics in fuel. And those waste which are organic and cause stinky smell in air, go through anaerobic digestion process by which we can collect bio gas which is very good fuel. Those organic waste after anaerobic digestion is neutralized and can used as very good fertilizer. These fertilizers are very much environment friendly and do not cause any pollution. The rest of the waste are burnable and these wastes can generate huge heat inside the combustion chamber. As humidity of our country is very high so we have to cut those waste into small pieces and keep them in a dry chamber for 5 days. In this time those wastes become dry and burn efficient then we put them in combustion chamber. Inside the chamber there are few high-power gas burners and the gas we are using here is collected from anaerobic digestion plant. Pre started fire burn those waste and generate huge energy. In case of short of gas or burnable waste we can use pyrolysis fuel as backup. A heat sensor is added inside combustion chamber whenever it detects low temperature inside the chamber it turned on the FMIS (Fuel mixture injection system). Fuel mixture injection system pump the fuel and make it a kind of mixture which work as gas and injects the mixture inside the combustion chamber. So, more heat generate inside the chamber and the lack of heat is neutralized. The overall waste to energy system uses every single piece of waste to make sure nothing left in the environment which can cause pollution. This system is efficient and cause less pollution than any other system.

3.2: Mechanism of waste to energy.

Waste to energy is a process by which waste can be turned into electricity and other useable resources. The main purpose of this system is to use every type of waste so that nothing is left to create a negative impact on the environment. Fig.1 presents the mechanism in a single flow chart.

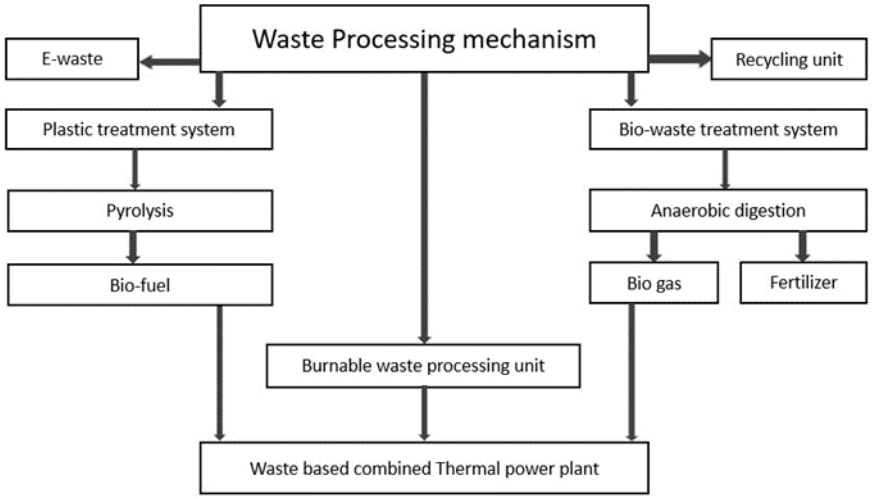


Fig. 3.1. Mechanism of waste to energy

This process is complicated because there are different kinds of waste and they all are mixed together. We cannot directly burn all the waste because it will create air pollution. [5] So initially all those wastes which are collected must go through a system, which separates them. After separation, the other process will start. The basic mechanism of this system is to separate all waste into specific categories and process them to generate electricity in a way, which is environmentally friendly. After the separation different types of waste go to different types of plant/unit which are specially for those types of waste.

3.2.1: Plastic treatment system.

Plastics take a long time to decompose and this type of character is so harmful to the environment. Usually, plastics take up to 1000 years to decompose but plastic bags we are using in our daily life take 10-20 years and plastic bottles take 450 years to decompose. [6] Most interesting here approximately 1.6 million barrels of oil are used to produce plastic bottles. 80-95% of fuel can be recovered from plastic by using the pyrolysis process. This plastic treatment system is a process by which waste plastics are converted into fuel. Fig.2 shows a schematic diagram of the plastic treatment system.

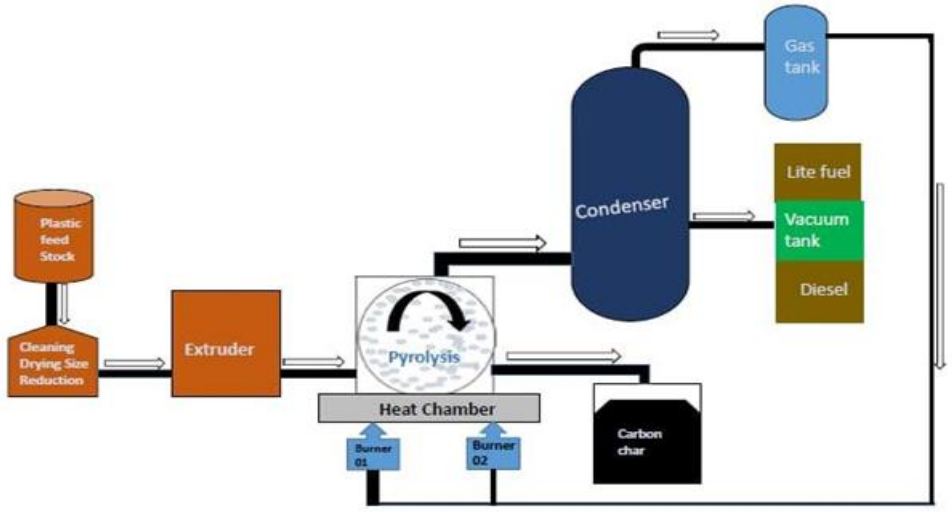


Fig. 3.2: Schematic diagram of plastic treatment system

Under this system, plastics go through a pyrolysis process in which under high temperature and constant pressure plastics change their molecular form and turned into fuel and gas [7]. Due to the anaerobic process, the emission of harmful gases and substances is very small. Less SO_x, HCl, and NO_x are produced by pyrolysis. After the filtering system, air pollution is effectively reduced. Harmful components like sulfur and heavy metals are fixed in carbon char and cause less pollution. Equation.1 presents mass flow for reactants and products in Polyethylene pyrolysis.

$$\text{Plastics} \xrightarrow{\text{Pyrolysis}} 15\%\text{LPG(gas)}+35\%\text{petrol}+45\%\text{Diesel}+5\%\text{Charbon Char}$$

Equation. 1. Mass flow for reactants and products in Polyethylene pyrolysis

Plastic pyrolysis, the overall energy required for all of the matters involved can be calculated,

$Q=\sum_{Out} niHi - \sum_{in} niHi$

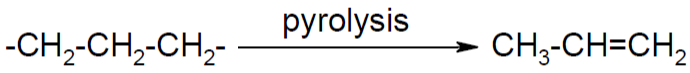
Where:

Q = overall energy required in the plastic pyrolysis process (kJ)

n_i =molar number of components i (mole)

H_i =enthalpy of component i (kJ/mole)

Equation.2 presents formation of a 1-alkene molecule from PE molecule pyrolysis.



Equation. 2. Formation of a 1-alkene molecule from PE molecule pyrolysis

Table.2 presents the amount of output products of 1 kg of plastic waste after pyrolysis.

1 kg of Plastics after pyrolysis	
LPG (gas)	150gm
Petrol	350gm
Diesel	450gm
Carbon char	50gm

Table3.1: Output products after pyrolysis.

3.3.2: Bio waste treatment system

Bio waste treatment is a system which uses organic waste to produce biogas and fertilizer. Dumping organic waste in an open place causes odor on its surrounding environment which

creates huge problems for nearby peoples and causes air pollution. Also, it is very harmful for human health. Bio waste treatment system is very effective, sustainable, and efficient system. In bio-waste treatment system those organic MSW go through anaerobic digestion process. Anaerobic digestion process is the most preferred technology to produce biogas and methane from organic MSW. Which can be used as an alternative fuel. Anaerobic digestion occurs in an oxygen free tank in which organic waste broke down and produce bio gas.

Anaerobic digestion

Anaerobic digestion is a process by which organic materials break down into Methane (CH_4) and Carbon dioxide (CO_2) in the absence of Oxygen. Anaerobic digestion occurs in an oxygen-free Also it occurs naturally. After anaerobic digestion, those organic waste turned into stabilized organic materials which can be used as bio fertilizers. Anaerobic Digestion is also known as Methane fermentation or Bio-methanation. Figure shows a schematic of anaerobic digestion

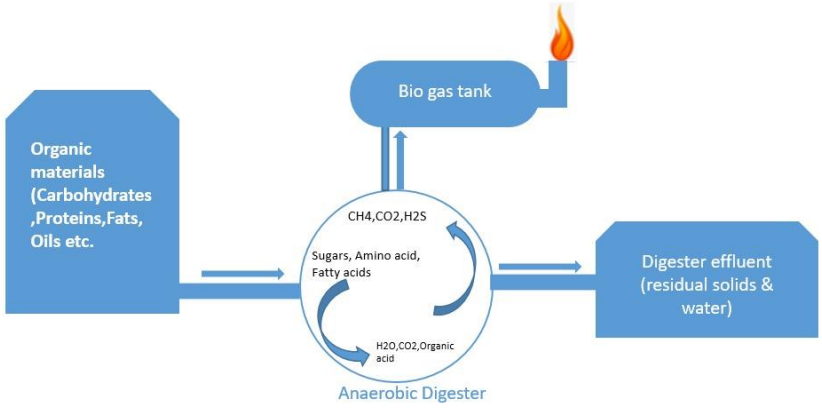


Figure3.3: shows a schematic of anaerobic digestion.

Anaerobic digestion occurs in four stages:

1. Hydrolysis
2. Acidogenesis
3. Acetogenesis
4. Methanogenesis

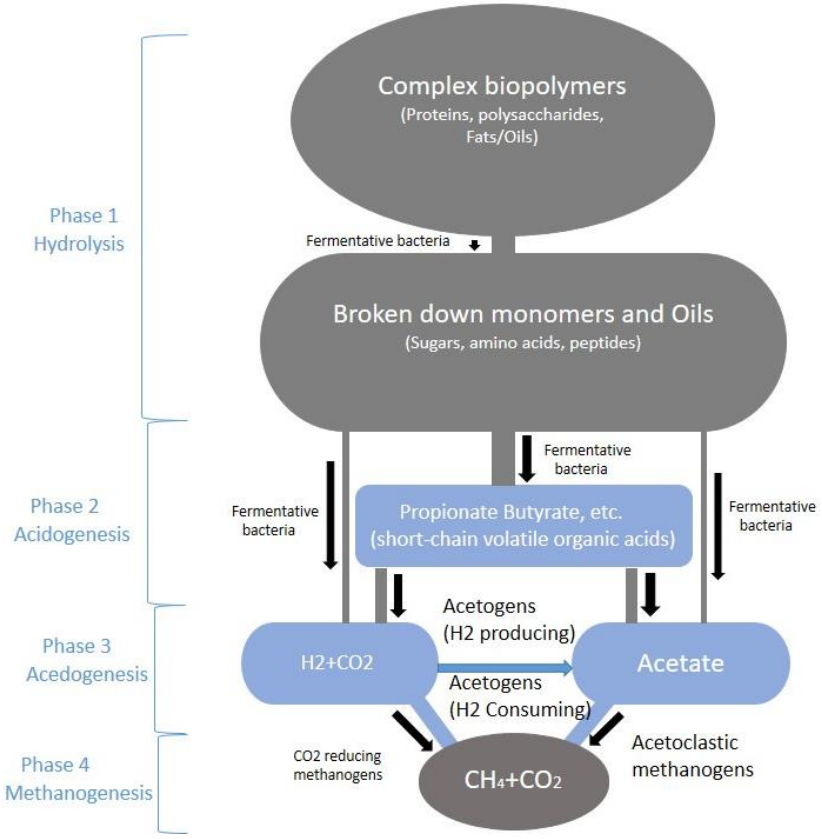


Figure3.4: shows the progression and types of products for each phase.

1. Hydrolysis

Hydrolysis is a reaction with water. This Reaction can be accelerated by using acid and base However, this occurs in enzymes as well. Cellulose, starch, and simple sugars are broken down by water and enzymes. In anaerobic digestion, the enzymes are exoenzymes (Cellulosome, protease, etc.) from a number of bacteria, protozoa, and fungi (Shown in Reaction 1).

(1) biomass + H_2O → monomers + H_2 (Reaction 1)

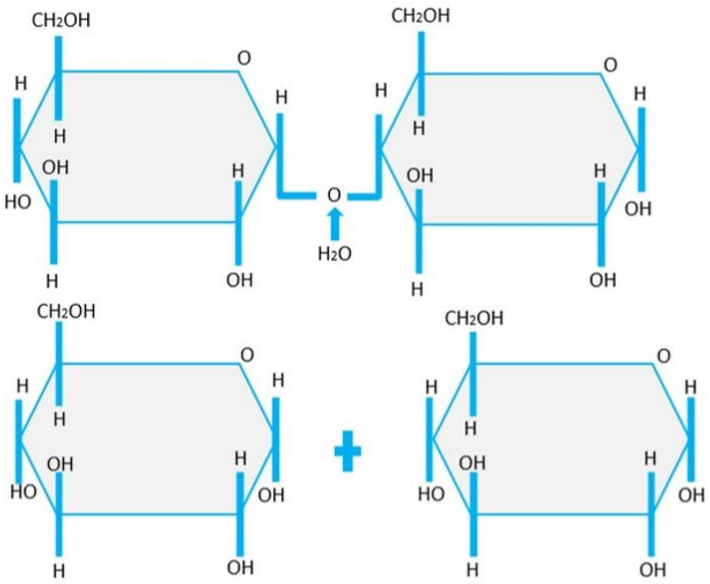


Fig3.5: The α-1,4 bond is attacked by water so that the water splits into H+ and OH- and forms the two glucose molecules

2.Acidogenesis

Soluble monomers are converted into small organic compounds during acidogenesis, such as short chain (volatile) acids (Shown in Reaction 2), ketones (glycerol, acetone), and alcohols (Shown in Reaction 3).

(2) $C_6H_{12}O_6 + 2H_2 \rightarrow 2CH_3CH_2COOH + 2H_2O$ (Reaction 2)

(3) $C_6H_{12}O_6 \rightarrow 2CH_3CH_2OH + 2CO_2$ (Reaction 3)

3.Acetogenesis

In Acetogenesis acetogenic bacteria attacked the acidogenesis intermediates ; the products from acetogenesis include acetic acid, CO2, and H2. The reactions 4-7 shows the reactions that occur during acetogenesis:

(4) $CH_3CH_2COO^- + 3H_2O \rightarrow CH_3COO^- + H^+ + HCO_3^- + 3H_2$ (Reaction 4)

(5) $C_6H_{12}O_6 + 2H_2O \rightarrow 2CH_3COOH + 2CO_2 + 4H_2$ (Reaction 5)

(6) $CH_3CH_2OH + 2H_2O \rightarrow CH_3COO^- + 2H_2 + H^+$ (Reaction 6)

(7) $2HCO_3^- + 4H_2 + H^+ \rightarrow CH_3COO^- + 4H_2O$ (Reaction 7)

Several bacteria contribute to acetogenesis, including:

Syntrophobacter wolinii, propionate decomposer

Syntrophomonos wolfei, butyrate decomposer

4.Methanogenesis

The last phase of anaerobic digestion is the methanogenesis phase. Several reactions take place using the intermediate products from the other phases:

(8) $2CH_3CH_2OH + CO_2 \rightarrow 2CH_3COOH + CH_4$

(9) $CH_3COOH \rightarrow CH_4 + CO_2$

(10) $CH_3OH \rightarrow CH_4 + H_2O$

(11) $CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$

(12) $CH_3COO^- + SO_4^{2-} + H+ \rightarrow 2HCO_3 + H_2S$

(13) $CH_3COO^- + NO^- + H_2O + H^+ \rightarrow 2HCO_3 + NH_4^+$

Several bacterial contribute to methanogenesis, including:

Methanobacterium, methanobacillus, methanococcus, and methanosarcina, etc.

3.2.3: Burnable waste treatment system

In Bangladesh, most of the wastes are wet because of high humidity and rain. Also, Bangladesh is a riverine country therefore water is very much available here. For this type of country burnable waste processing unit is needed. [3] This Waste processing unit reduces the size of those wastes and dries them. Waste must reserve in a dry chamber before burning in the combustion chamber. When those wastes are dry, it is easy to burn them also it can generate more heat. So burnable waste processing unit process the waste in a way, which provide efficient burning. After this process wastes are sent into the combustion chamber

3.2.4: E waste processing unit

Most of the E-waste can be recycled. E-waste processing unit separate those wastes into different categories, such as CRT television, Flat-screen televisions, Computers, Circuit boards, Printers, etc. The purpose of this unit is to collect those waste and store them in different categories. After this, some of those wastes are recycled and some of those can be export to other countries or other e-waste recycling factories.

Fig3.6: E Waste processing

3.2.5: Recycling unit

Recycling is a process in which waste materials are converted into new usable materials. The purpose of recycling units is to recycle those wastes that can reuse like metals, glasses, ceramics, etc. Those items after separation are washed, dried and after processing those items are sold to dealers and traded in the market. Then those recyclable waste are recycled by many recycling companies.

Fig3.7: Waste recycling process

CHAPTER 04

Waste Based combined power plant

4.1 Wasted based combined power plant

The reason behind calling it a waste-based combined power plant is that it uses three types of fuel Biogas, burnable waste (BW) and pyrolysis fuel at the same time. Other waste-based power plants directly burn the waste to generate heat. In that case generation of heat stay low especially for those countries which have high humidity. Also directly burning waste causes more pollution because burning products contain diverse types of gases and some of them cause air pollution. This system can solve that problem by processing those wastes. After processing burnable waste, biogas and pyrolysis fuel are used in combined power plant.

This system offers two processes to generate electricity which are shown in fig.

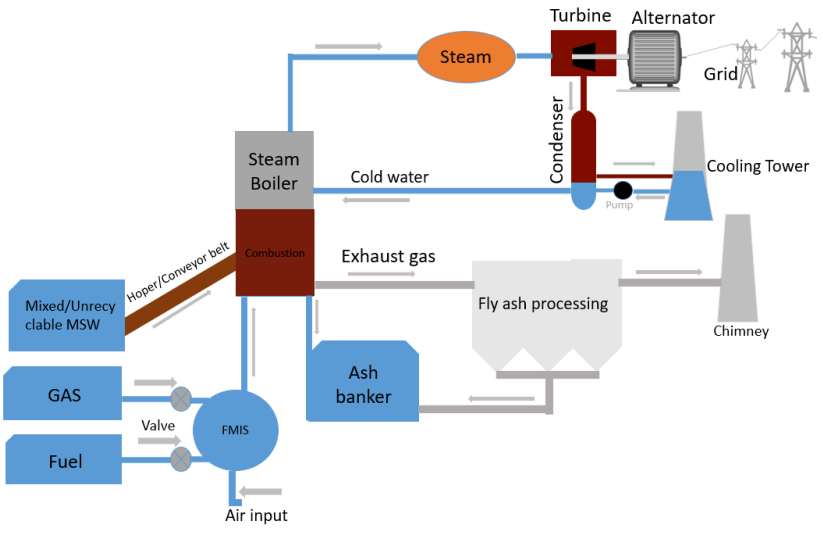


Fig4.1: Block diagram of Wasted based combined power plant

Process 1:

- When there is enough amount of burnable waste and gas, process 1 will continue
- Burnable waste will be burnt inside the chamber and gas burners will boost the burning process
- Gas burner will boost up the process to generate more heat and at the same time it will ensure the 100% burning of BW
- To ensure the proper burning a high-pressure air pump will pump air inside the chamber
- In presence of gas and air, proper oxidation occurs inside the chamber and BW burnt and generate heat at the maximum level which increases the efficiency of the system

Process 2:

- In case, there is a shortage of BW or Gas which causes a lack of heat inside the combustion chamber, process 2 will continue
- A temperature sensor will detect the lack of heat inside the chamber and FMIS will be turned on by a system that also calculates the amount of heat is needed
- FMIS will inject the gaseous mixture of pyrolysis fuel inside the chamber
- Injection of pyrolysis fuel will stable the heat needed inside the chamber

These two processes ensure proper burning of BW and generate heat at maximum level. Another advantage of this system is it can use biofuel, gas, BW at the same time to generate more heat in case of more demand for electricity.

4.1.1 presents Schematic Arrangement of waste based combined power plant:

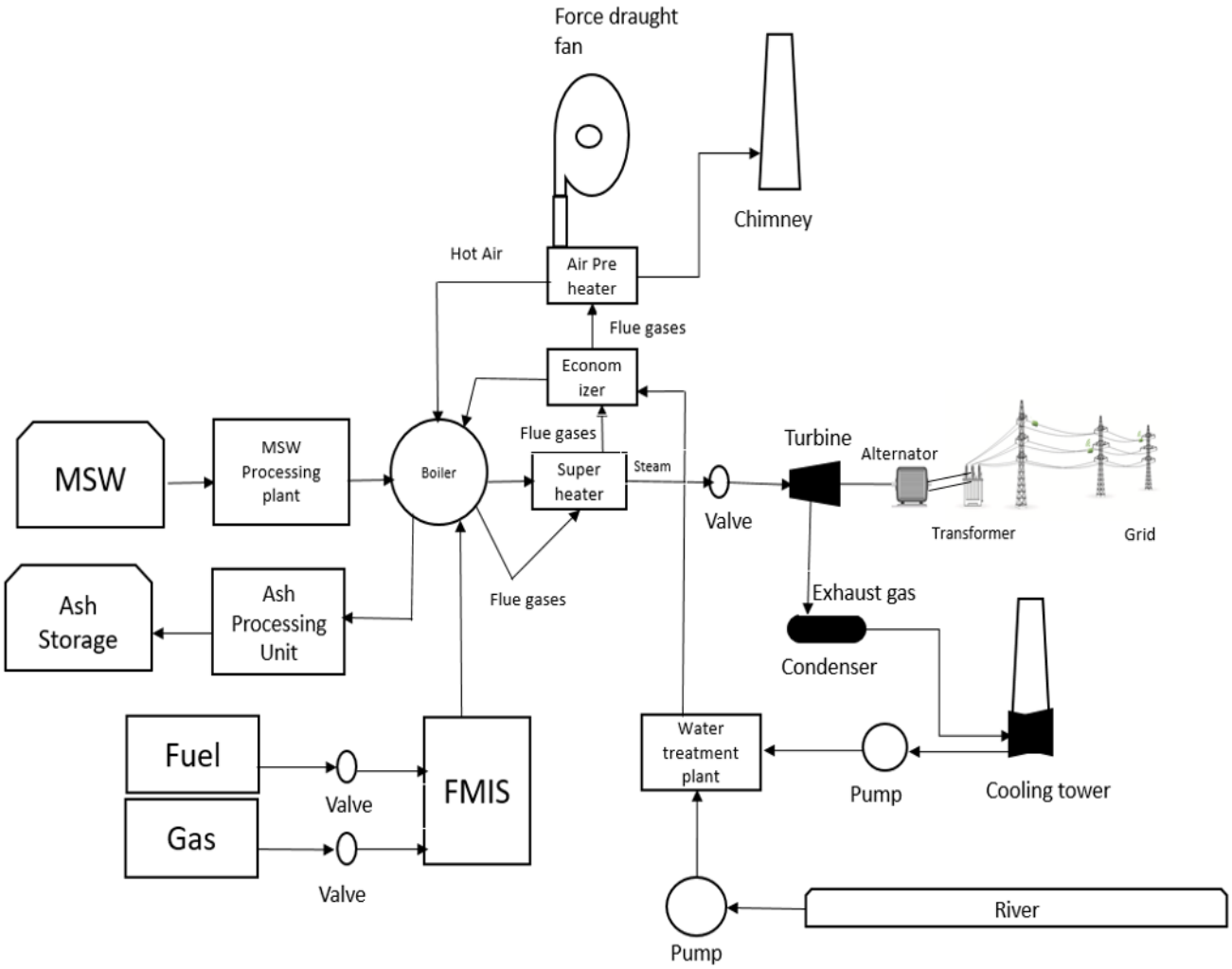


Fig4.2: Schematic Arrangement of waste based combined power plant

4.1.2 Working procedure

Waste based combined power plants produce electricity from municipal solid waste. This system is a combination of three system Anaerobic digestion, Pyrolysis, and Combustion. System start with the processing of burnable waste. Burnable waste goes through a drying section. This drying unit dried those waste and made them more burn efficient. Now a crane is used to move them into the hopper. From the hopper it directly falls into the combustion Chamber. A mixture of gas and air is also injected in the combustion chamber by FMIS (Fuel mixture injection system) at the same time. FMIS enhanced the burning speed. FMIS also work to maintain the proper air flow inside the chamber, to ensure complete burning of the waste and less carbon emission. After burning Ashes fall out through the bottom gate. Meanwhile water flows through economizer and those tubes inside boiler water become vapor it passes through the super heater. As a result, high speed and high-pressure steam directly falls on steam turbines. And the turbine started to rotate. Turbine is connected to an alternator. Alternators turn this mechanical energy into electrical energy. In case of lack of burnable waste, FMIS also works as a backup system and provide more fuel and gases from pyrolysis and ADS to the combustion chamber which ensures the simultaneous generation of heat inside the combustion chamber to make and no lack of power in the plant.

4.1.3 Equipment of waste based combined power plant

1.Steam generating equipment:

This is an important a part of waste based combined power plant. The steam generating plant consists of a boiler.

(a)Boiler:

Boiler is used to convert water into steam by using heat and pressure. A boiler is closed vessel where water is converted into steam by utilizing the heat of coal combustion. Steam is one in all the reliable sources of energy for our modern age.

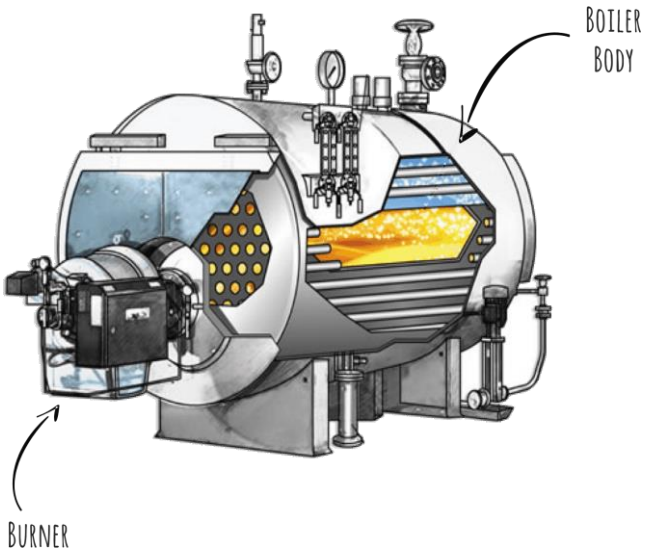


Fig4.3: Steam boiler

We have used steam from the very beginning of our first technological revolution in human history. It provides steam by using heat, sterilization, and lots of other applications that are very important to industrial facilities, among others. There are two types of boiler.

Water tube boiler

- The water flow inside the tube and the hot flue gases are surrounded the tube
- This is light in weight
- Water tube boiler is heated externally by using hot flue gas and fire
- Water tube boiler can take pressure more than 100 bar
- In water tube boiler the possibility of explosion is very high
- But the Efficiency of water tube boiler is high sometimes efficiency is around 90 percent

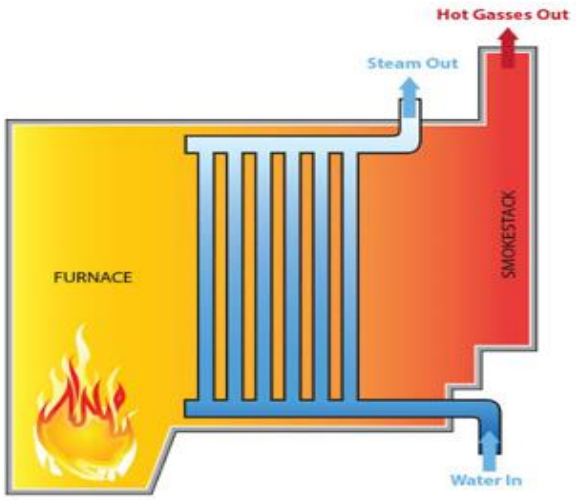


Fig4.4: Water tube boiler

Fire tube boiler

- In fire tube boiler flue gases flow inside the tube and water is surround the tube and absorb heat from the fire tube to convert into steam.
- Fire tube boiler is heavier than water tube boiler.
- Fire tube boiler also called as internally fired boiler.
- Here the pressure is restricted up to only 20 bar.

- In fire tube boiler the possibility of explosion is very low.
- Efficiency is less compared to the water tube and the overall efficiency is around 75 percent.

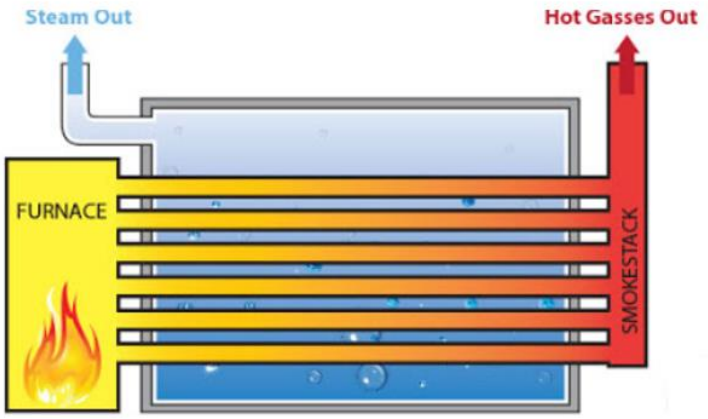


Fig4.5: Fire tube boiler

(b) Boiler furnace

A boiler furnace is very essential part of boiler. The primary function of boiler furnace is to provide adequate space for fuel particles to burn completely. And another purpose is to cool the flue gas to a temperature at which the heating surfaces can be operated safely. Boiler furnace walls are made from silica, fire clay, kaolin etc. which are refractory materials.

(c) Super heater

A device which superheats the steam is called super heater. The purpose of super heater is to raise the temperature of steam higher than boiling point of water. Super heater increases the efficiency of the plant. It is consisting of a group of tubes shown in figure.

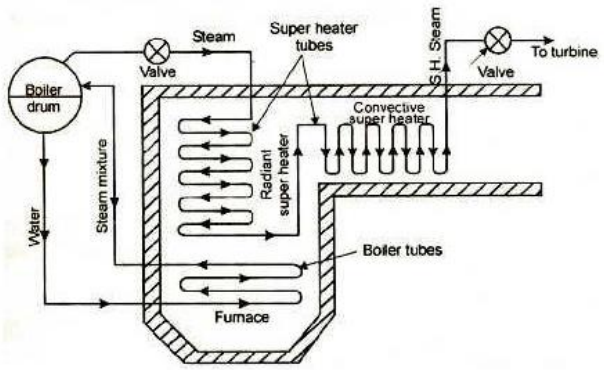


Fig4.6: Super heater

(d) Economizer

A device which heats the feed water on its way to boiler by deriving heat from the flue gases. In this way economizer increase boiler efficiency.

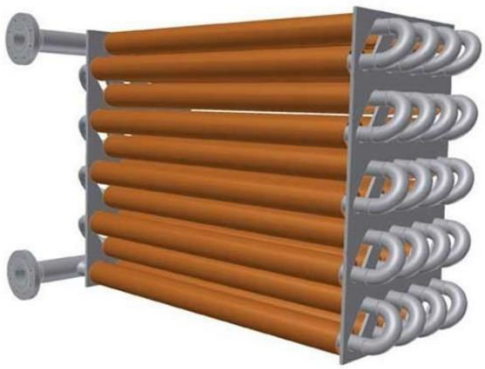


Fig4.7: Economizer

(e) Air-preheater

Super heaters and economizers cannot fully extract the heat from flue gases. Air pre-heaters recover some of the heat of flue gases.

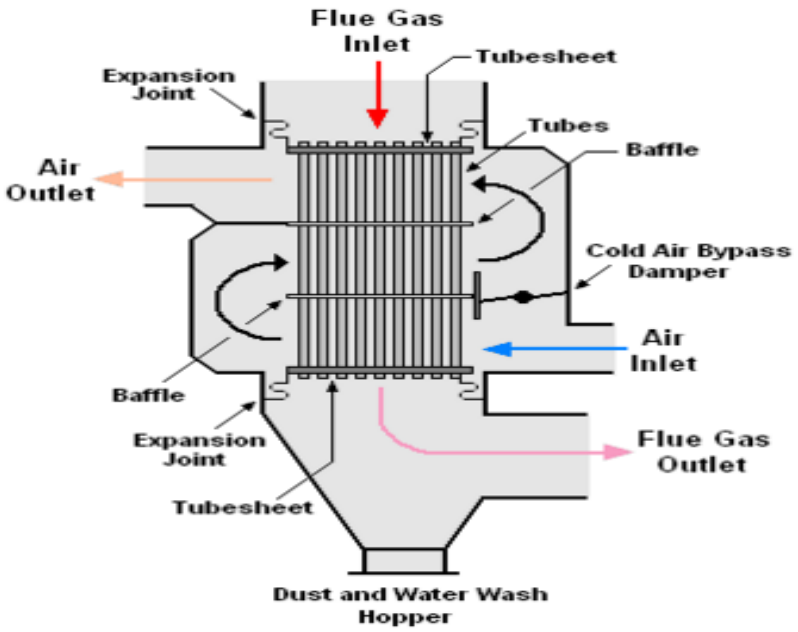


Fig4.8: Air pre heater

2.Condenser:

A condenser condenses the steam from the exhaust of the steam turbine. There are two types of condenser:

1. Jet condenser
2. Surface condenser

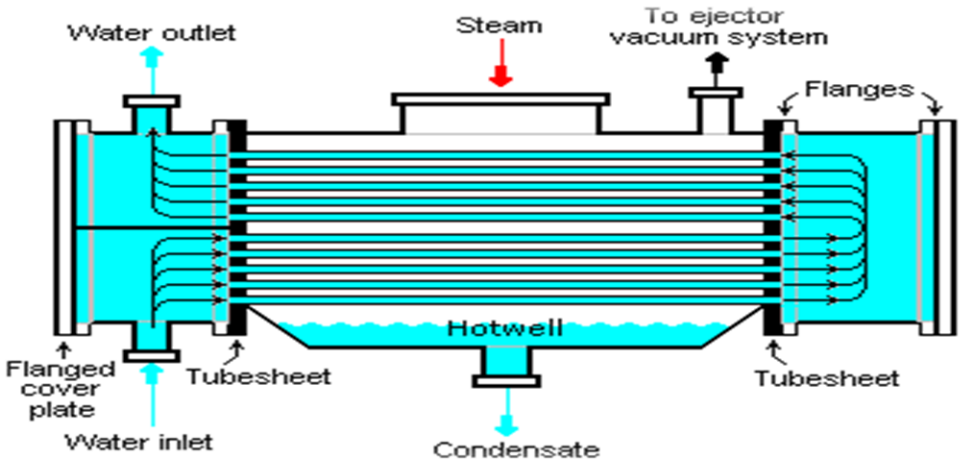


Fig4.9: Condenser

(a) Jet condenser

Jet condenser is a direct heat exchanger. In this type of condenser, vapor is condensed by direct contact of cold water. The cold condenser is usually spray cold water to convert vapor into condensate. The construction is simple. Installation of jet condenser and maintenance cost is low. It requires less floor space compared to the surface condenser. Not suitable for high capacity plants. If the condensate extraction pump fails, there is a greater possibility of flooding of condenser.

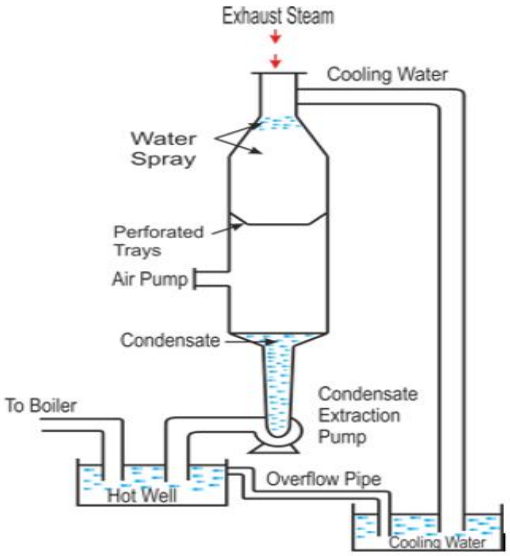


Fig4.10: Jet condenser

(b) Surface condenser

Surface condensers are used in large power plants. The main purpose is to condense the exhausted steam at higher efficiency and convert the steam into impurity-free water which may be utilized in a steam generator or steam boiler. Surface condensers condensate can be used as feed water, less pumping power required and creation of better vacuum at the turbine exhaust.

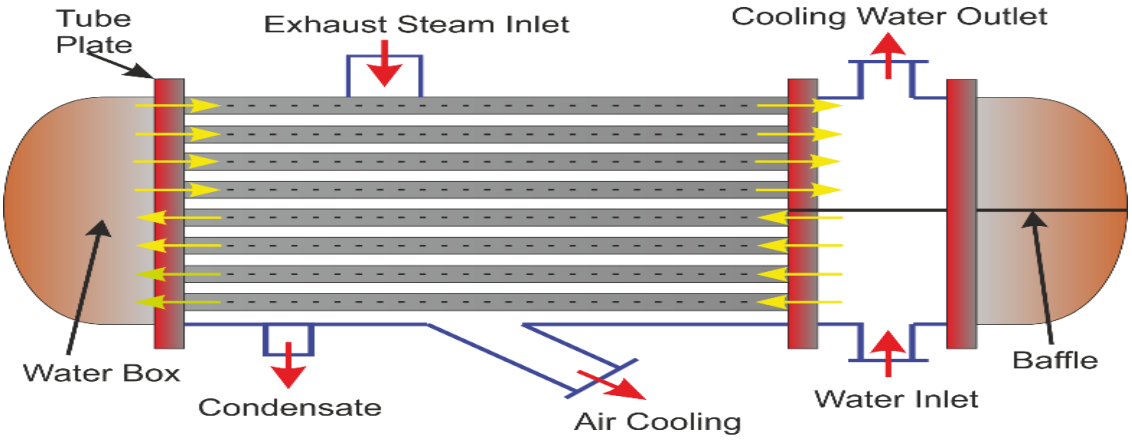


Fig4.11: Surface condenser

3.Prime Mover

The prime mover converts steam energy into mechanical energy. The prime movers are used for generating electricity might be diesel, external-combustion engine, Steam turbines, gas turbines, and water turbine. In case of steam power station, the prime movers is turbine, which is named, steam prime movers. There are two types of turbine.

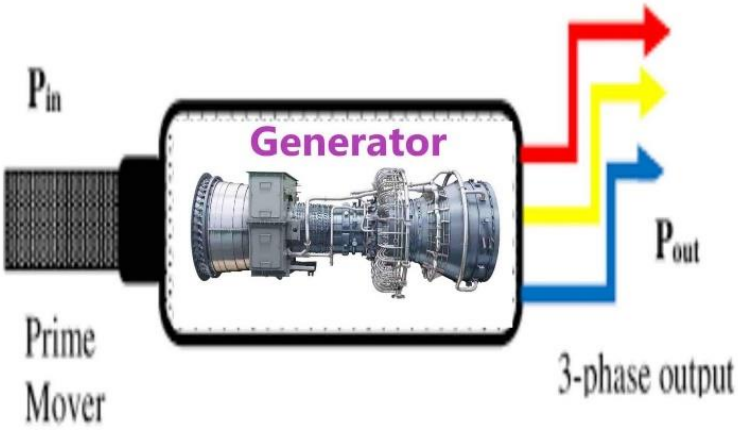


Fig4.12: Prime mover

(a) Impulse turbine

- Impulse turbines are used for high heads
- The blades are symmetrical
- It consists of nozzles and moving blades
- Steam expended completely in the nozzle
- The purpose of turbine is to generate kinetic energy
- Pressure is constant over the moving blades

- Efficiency is low
- Occupies less space per unit power

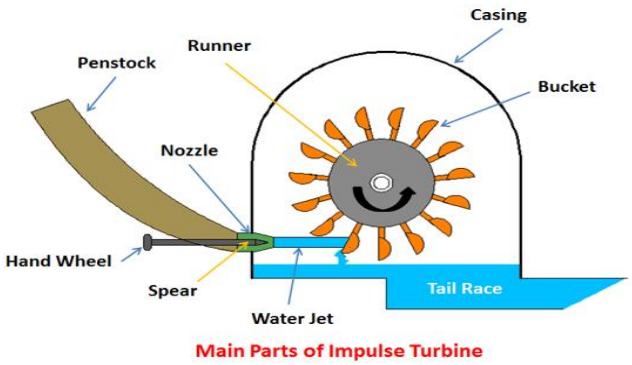


Fig4.13: Impulse turbine

(b) Reactions turbine

- Reaction turbines are used for low heads
- The blades are unsymmetrical
- It is fixed blades which act as nozzles and moving blades
- It's partially expanded in the fixed blades
- Some amount of pressure energy is converted kinetic energy
- Pressure some takes place in utilized to moving blades
- Efficiency is high
- Occupies more space per unit power

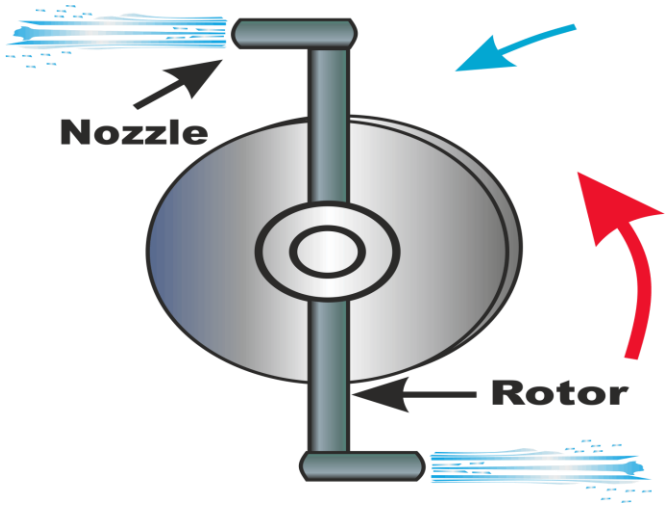


Fig4.14: Reactions turbine

4. Water treatment plant

Provided waters quality inside boiler is very important for simultaneous operation of boilers. So before providing water for boiler system must ensures that the provided water is pure and clean. Water treatment plant basically clean the feed water and purified them. Continuous improvements and changes of this system of maintaining water quality, understanding the corrosion mechanisms, and the development of recent chemicals have resulted during a more economical and efficient water management. Given figure presents a modern water treatment system.

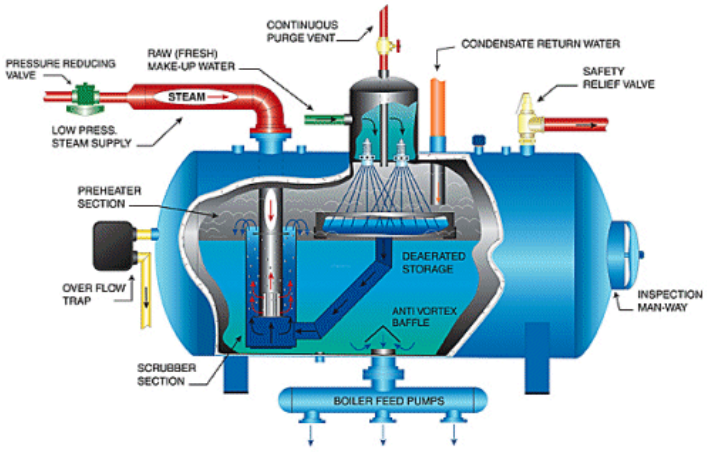


Fig4.15: Water treatment plant

5. Electrical equipment

(a) Alternator

Alternator is a mechanical device which converts mechanical energy into electrical energy. Alternator has large amount rating electricity. At bigger power generating station alternators are used to generate electricity. It's known as synchronous generator.

Fig4.16: Alternator.

(b) Transformer

Transformer is an electrical device consisting coils of wire used to transfer power by means of a changing magnetic flux. There are two types of transformer.

1. Step up
2. Step down

Step up transformers are used to raise the voltage and step-down transformers are used to lower the voltage.

Fig4.17: Transformer

(c) Switch gear

Switch gears are used for controlling, regulating, and switching the electric circuit. Those controlling power system is understood as switchgear. The switches, fuses, breaker, isolator, relays, current and potential transformer, indicating instrument, lightning arresters and control

panels are samples of the switchgear devices. The switchgear device is related to the supply machine. It is placed in both the high and low voltage side of the transformer. It is used for de-energizing the instrumentation, for testing and maintenance, and for clearing faults.

Fig4.18: Switch gear

6. Ash Processing unit

Bottom Ash (Slurry):

After combustion the residue product is ash which direct fall into bottom ash chamber. After that ashes go through a process where a system ensures that no metallic particle left inside the ashes. If there is any kind of metal those are collected by the system. After the process ashes transported to landfill land. Ashes work as very good landfill.

Fly ash:

After combustion flue gas go through the exhaust system. In this time flue gas contains a lot of fly ashes and some other particle. If those ash and particle not controlled by any system, it can harm the environment and cause air pollution. A fly ash control system is install which spray water and clean the flue gases as much as possible after the procedure flue gases are released to the environment.

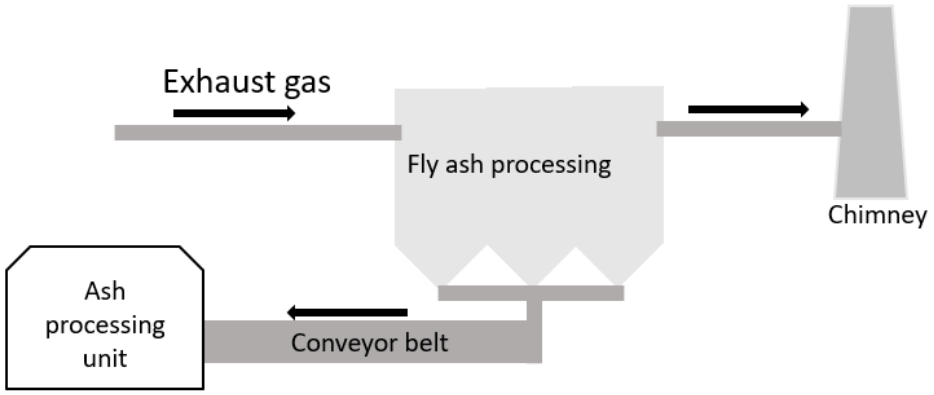


Fig4.19: Schematic diagram of the Ash Processing system

4.2: Fuel mixture injection system (FMIS).

FMIS uses pyrolysis fuel and gases from anaerobic digestion to increase the heat inside the combustion chamber. This system processes the fuel and makes a gaseous mixture of pyrolysis fuel and air. This gaseous mixture pyrolysis fuel is highly burnable which works as an alternative to biogas. In case of a shortage of Burnable waste or gas, this mixture work as an alternative fuel for continuous operation inside the combustion chamber. Fig.5 shows a schematic diagram of the Fuel mixture injection system

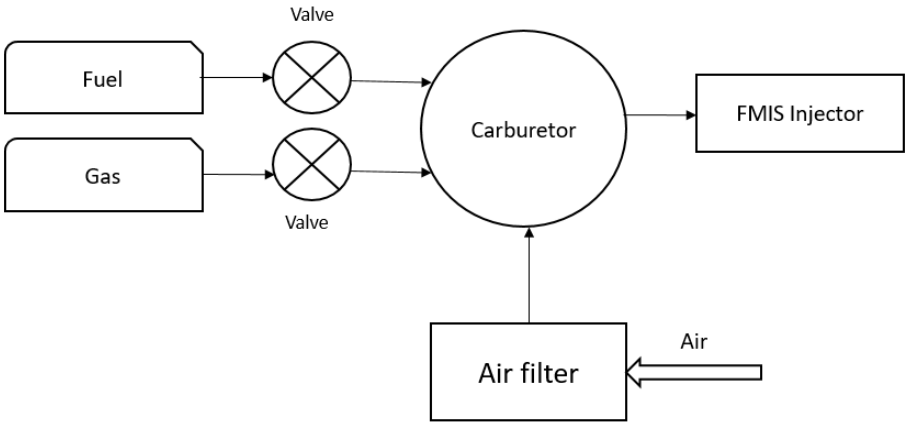


Fig4.20. Schematic diagram of the Fuel mixture injection system

4.2.1 Equipment of FMIS (Fuel mixture injection system)

(a) Air filter

Air filter is a device used for the removal of particular or gaseous (molecular) impurities from the air. It removes dust mold, and pollen from the air.

Fig4.21: Air filter

(b) Carburetor

Carburetor is mechanical device premixing vaporized fuel and air in appropriate proportions and supplying the mixture to an internal combustion Chamber through injector.

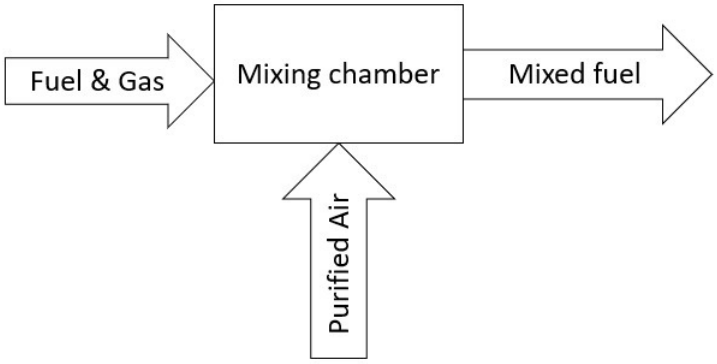


Fig4.22: Schematic diagram Carburetor

(c) Injector

Injector is a mechanical device which inject gaseous mixture of fuel inside the combustion chamber.

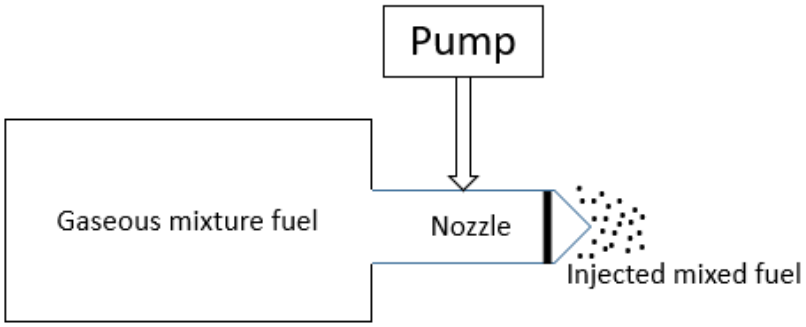


Fig4.23: Injector

CHAPTER 05

Data processing

5.1 Introduction

Nowadays generation of Waste is growing very rapidly. This is not only a problem in Bangladesh but also many other countries are facing this problem. Environment pollution due to waste is now on top chart. It is creating huge ecological problem for living creature. Therefore many countries are searching for the solution. Research on waste problem started more than 100 years ago. In many countries waste is not burden anymore. They are using it as a resource. This thesis focused on a combined solution of waste management system which basically covert the waste into electricity through an environment friendly system. The data here is collected from many journal and research paper. Also, some data are taken from DSCC and DNCC waste management system.

5.2 Growth in generation of MSW

MSW (Municipal solid waste) is increasing day by day. The generation of MSW can be predicted. MSW generation per day,

$\mathbf{(MSW)}\text{gen}=\sum_{j=1}^{365}\sum_{i=1}^{m}(\mathbf{Ci}\times\mathbf{Vi}\times\mathbf{di}\times\mathbf{Tij})$

Here,

M=Number of trucks

C_i=Capacity of truck (m^3/ Truck)

V_i=Loading Volume ratio

d_i=Density of MSW (Tons/m^3)

T_{ij}=Number of Trips per Day

There is another calculation by historical waste generation (2001 to 2015) on the average growth rate of per capita waste generation. It was calculated by [4] projected waste generation in a year,

$$(\text{PWG})=\frac{(PBY+PBY\times AGP)\times(PCWB+PCWB\times AGW)\times 365\times 1}{1000}$$

Here,

PBY=Population on that year

AGP=Annual growth rate of population

PCWB=Per capita waste generation (kg/cap/day)

AGW=Average growth rate in the per capita waste generation

5.3 Heating value of MSW

Waste contains a lot of heating value. But there is many kinds of waste like plastic, wood, food, metal, paper, etc. are mixed together so exact heating value of waste is very tough to calculate. Although heating value of waste can be calculated by using some equation which are given below.

Low heating value,

$\text{LHV}^{1}=\sum_{1}^{m} WA \times HHVA$

Here,

m=Number of elements in MSW

W_A=Weight of the element A

HHV_A=Heating value obtained from bomb calorimeter of the element A. [4]

By Dulong's model,

$\text{LHV}^{2}=81\text{C}+342.5(\text{H}-\frac{O}{8})+22.5\text{S}-6(\text{W}+9\text{H})$

According to Steuer's model,

LHV^3=81(C-$\frac{3}{8}O$) + $57\frac{3}{8}O + 345(H - \frac{O}{16}) + 25S - 6(W + 9H)$

LHV_{MSW}= Average of LHV^1, LHV^2, LHV^3

= $\frac{LHV1 + LHV2 + LHV3}{3}$

5.4 Energy Potential (EP_{MSW}):

Energy Potential from MSW [4],

EP_{MSW}= LHV_{MSW}× W_{MSW}×$\frac{1000}{3.6}$

[Ref: Kumar et al.2010, Ibikunle et al.2018, Gupta (2013), Daura 2016]

W_{msw}= Weight of MSW (tons)

According to Delong's and Steuer's model

EP_{msw}=[81(C-$\frac{3}{8}O$) + $57\frac{3}{8}O + 345(H - \frac{O}{16}) + 25S - 6(W + 9H)$] × W_{MSW}×$\frac{1000}{3.6}$

EP_{MSW}=[81(C-$\frac{3}{8}O$) + $57\frac{3}{8}O + 345\left(H - \frac{O}{16}\right) + 25S - 6(W + 9H)$] ×$W_{MSW}$×277

Here,

C=Weight of carbon Content

H= Weight of Hydrogen Content

S= Weight of Sulphur Content

W= Weight of moisture Content

O= Weight of Oxygen Content

Electrical power potential of MSW,

EPP_{MSW}=277.8×LHV_{MSW}×$\frac{Wmsw}{24}$×η_p

η_p=Efficiency of conversion in power plants.

5.5 Energy generation from Bio Waste

Through Anaerobic digestion can produce up to 133.5 kg of methane from per ton of organic MSW. [8] This amount may change with the quality of organic waste.

Lower heating value (LHV) of Methane=50000 KJ/kg

So that, 133.5×50000=6675000 KJ/kg

Assuming 25% thermal efficiency of electricity generation at the plant, 6675000×0.25=1668750 KJ/Ton.

Which is equivalent to 463.54 Kwh/Ton. [1 KJ=0.000278 KWh]

5.6 Energy generation from Plastic

The amount of output products of 1 kg of plastic waste after pyrolysis.

1 kg of Plastics after pyrolysis	
LPG (gas)	150gm
Petrol	350gm
Diesel	450gm
Carbon char	50gm

Table5.1: Output products after pyrolysis.

800 kg of pyrolysis oil (Petrol & Diesel mixture) can be recovered from one ton of plastic.

1kg of pyrolysis oil= 44000 KJ

So that, total heating value is 44000×800=35200000KJ

Which is equivalent to 9778 KWh [1 KJ=0.000278 KWh]

150kg of gas can be recover from one ton of plastics.

1 kg of pyrolysis gas= 16000KJ So that, total heating value is 16000×150=2400000KJ

Which is equivalent to 667 KWh [1 KJ=0.000278 KWh]

The total energy can be recovered from per ton of plastics,

9778+667=10445 KWh/ton

Assuming 25% thermal efficiency of electricity generation at the plant, 10445×0.25=2611.25KWh/Ton.

So that, this system can generate up to 2611.25 KWh electricity per ton of plastics.

5.7Energy generation in Waste based combined power Plant

Combined power plant uses three type of fuel. Gases from ADS, Pyrolysis fuel from Plastic treatment plant and Burnable waste. Burnable waste (BW) contains wood, paper, textile waste, leather, etc. Table.5.2 shows different type of materials present in burnable waste and their heating values.

Materials	Heating value
Wood	16580 KJ/Kg
Paper	14085 KJ/Kg
Leather	19050 KJ/Kg
Textile	17476 KJ/Kg

Table5.2: Heating value of different types of material from BW

After separating plastics and recyclable waste the average calorific value of burnable waste is 16797 KJ/Kg [4]

So That, The average heating value of burnable waste 16799000 KJ/Ton

Assuming 25% thermal efficiency of electricity generation at the plant, 0.25×1679000=4199250 KJ/Ton

Which is equivalent to 1166.46 KWh/Ton. [1 KJ=0.000278 KWh]

This power plant is combined and both burnable waste and gas are used in the combustion chamber. [4]

So, from 1 ton of organic and 1 ton of burnable waste, the system can generate 463.54 KWh/ton and 1166.48 KWh/ton.

[1 KJ=0.000278 KWh]

So that, after separating recyclable waste this system can generate 1630.02 KWh electricity from 1 ton of organic/bio-waste and 1 ton of burnable waste. [This result will vary with the quality of waste and the amount of different types of waste.]

In case of additional demand when two processes work at the same time the generation of electricity from 1 ton of plastics, 1 ton of bio-waste and, 1 ton of BW can go up to 4241.21 KWh. Here three fuels inject inside the combustion chamber at the same time to generate more heat. Electricity generation in this combined system depends on supply of waste the more supply the more generation of energy.

5.8 Efficiency of waste based combined power plant

1. Thermal Efficiency,

$$\eta_{\text{Thermal}} = \frac{Heat\ equivalent\ of\ mechanical\ energy\ tranmitted\ to\ turbine\ shaft}{Heat\ of\ waste\ \&\ gas\ combustion}$$

2. Overall efficiency,

$$\eta_{\text{overall}} = \frac{Heat\ equivalent\ of\ electrical\ output}{Heat\ of\ combustion\ of\ waste\ \&\ gas}$$

Overall Efficiency = Thermal efficiency × Electrical efficiency

5.9 Power to grid

Power transmitted to the grid,

$$\mathbf{PG = EPP_{MSW} \times \eta g \times \eta t \times \frac{1}{100}\ (MW)}$$

$\boldsymbol{\eta_g}$=Generation Efficiency

$\boldsymbol{\eta_t}$=Transmission Efficiency

CHAPTER 6

Conclusion /Draw back Future work

6.1 Introduction

With the growth of population generation of waste also growing and creating huge threat to environment and eco system. Waste problem is a major reason for extinction of many species. Plastic waste in ocean creating huge threat to the eco system of the ocean. Nowadays micro plastic is found inside fishes and many other animals. So, a proper waste management is very much important for whole world to save the earth from pollution. Many countries like Bangladesh facing this kind of problem as waste management system is costly to install. So, a system which is beneficial also easy to install, easy maintain and also installation cost is not much is needed. So that country which are not developed can install the technology and get rid of from this waste problem curse. This combined system is a system which is very much effective and can convert waste into resources. The installation cost of this combined system is not high as the technology can build locally. Few parts of this system is expensive but it can give a good support in long run. The system is sustainable and effective, the more waste the more generation of electricity and resource.

6.2 Conclusion

Integration of a combined system of pyrolysis, anaerobic digestion of bio waste, and Burnable wastes processing unit in the waste management process can convert every piece of waste into useable resources in form of electricity, fuel, and fertilizer. Without a combined system there was 5-10% unburnt waste left inside the chamber of burning. But here there is no way that unburnt waste is left inside because of FMIS. When the system ran out of gas FMIS inject a mixture of pyrolysis fuel and air which ensure constant heat inside the chamber. While in diesel Sulphur output is 80ppm but in pyrolysis fuel Sulphur output is 0.17ppm. Which is very environment friendly. This combined waste management system causes less CO_2, CO, Carbon

emissions. The implement of FMIS provides a constant generation of heat inside the combustion chamber which ensures the uninterruptable generation of electricity and makes the system more sustainable. The findings of this paper will be helpful for implementers and policymakers to select the perfect way to build a waste-based power plant and a proper waste management system for solid waste.

6.3 Future work

The purpose of this thesis is to provide a futuristic model of waste management system which covert waste into electricity and resources. Another purpose of this system is to save environment from waste. Generation of waste will increase with the growth of population. Urbanization and economic development also a reason for growth in waste generation. The more earning the more tendency of waste generation. Therefore growth in generation of waste will not stop. So, a sustainable waste management system is needed. WTE is one of the best solution as the pollution due to WTE is low. In case of combined waste to energy plant every types of waste are treated is separated treatment system. Therefore this system is more effective and environment friendly.

Effective model of waste management system for waste to energy will help to improve the present waste management system and presents an idea of waste management system. More improvement can be done in this system by adding some modern technology. The main goal of the system is to generate electricity. But moreover this system produce fertilizer also landfill and other recyclable materials. Many countries using this type of landfills and most interesting part is this landfill causes no harm to soil or water. The fertilizer produced by this system is totally neutralized and very good soil conditioner. As the fertilizer is made from totally bio waste there is no harmful chemical inside the fertilizer. Therefore the use of this bio fertilizer will not cause any types of soil pollution or water pollution.

Energy generation of this system depends on supply of waste. The more waste the more generation of energy. Managing waste have a significant impact on environment, human health and usable lands. Disposal of waste in dumping field cause greenhouse effects and formed greenhouse gases like CH_4, CO_2, and other toxic gases. In Dhaka, Bangladesh the production of waste increasing very fast and therefore the presence of greenhouse gases also increasing and making the air unbreathable. Nowadays government of Bangladesh taking steps to figure out the problem. But need more afford and research to solve this problem. The presented system may

help the implementer to get an idea of a proper waste management system. This combined system undoubtedly way better considering conversion of waste to resource as this system work on every types of waste. Although the system take more land but less than dump yard and can manage every types of waste. Moreover by selling electricity and reduction of greenhouse gases combined waste to energy system has been a waste management system that has no competitors except the solar system in the power generation sector. Also extra fuel from pyrolysis plant, ashes as landfill and fertilizer can be sold. Therefore WTE should be introduced in the competitive power generation field in a commercial manner. Through frequent research works of WTE unknown capabilities and possibilities of combined WTE system can achieve. More improvement can be done by researching more in this waste to energy conversion technology.

People who are unaware of such technologies like waste to energy need to be drawn attention so that more enthusiasts along with environmentalists can come forward to build a better future. And people must aware of throwing waste in any places. The more clean and waste free environment the more we can breathe clean air. Discussion among the researchers and the people who are interested to know the possible possibilities and future of combined waste to energy conversion system can surely reduce the gap of ignorance and increase the awareness. After all the main beneficial from this combined waste management system is the general people and future generation.

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