ISBN: 978-93-94570-62-7

4. Conversion of Waste to Energy

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Abstract:

Exponential growth in population, economic growth, and increasing rates of urbanization are the main factors for the generation of Municipal Solid Wastes (MSW). Rates of the generation of waste and its composition are also being affected by urbanization. Developed countries are the major contributors to MSW as a general trend there is a parallel relationship between economic development and waste generation. In high-income countries percentage of plastic and paper has been increased in the overall composition of waste. Waste to energy (WtE) technologies are the treatment of wastes to generate energy in the form of heat, electricity, or transport fuel.

These technologies convert the energy content of different types of wastes into different forms of valuable energy. There are various methodologies included in WtE technologies like thermo-chemical which includes incineration, co-combustion, thermal gasification, etc., and a bio-chemical conversion which includes the production of bioethanol, bio hydrogen, biogas production, and microbial fuel cell generation, and chemical conversions. WtE plants can bridge the gap between the waste recycling problem and power generation in the country.

Keywords:

Municipal Solid Waste, waste to energy, urbanization.

4.1 Introduction:

The unwanted, worthless, defective substance discarded after primary use is known as waste like municipal solid waste, industrial waste, biomedical waste, radioactive waste, etc. (1).

Municipal solid waste is mainly produced by households, industries, and commercial activity it consists of biodegradable, recyclable, inert and other materials. About 1.3 billion tonnes of Municipal Solid Waste (MSW) is being produced annually and this figure is going to increase up to 2.2 billion tonnes up to 2025. Such type of prediction is forcing the human race for the development of alternative waste management technologies (2). Waste to energy (WtE) technologies can be promising solutions for this.

4.2 What is a Waste to Energy?

A new technology that converts Municipal Solid Waste into electricity or heat is known as Waste to Energy (WtE) conversion technology (3). Waste conversion technology involves the following steps:

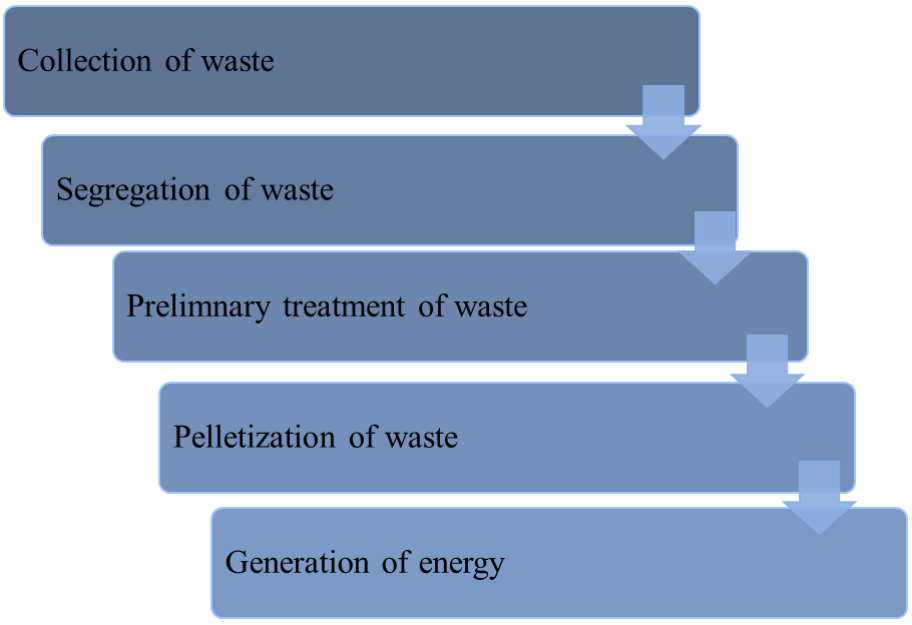

Figure 4.1: Components of WtE Technology

4.2.1 Collection of Waste:

When the solid wastes are being transferred to the end of treatment or landfill from the point of use and disposal. The waste is generally collected from the household door to door, factories, restaurants, etc. by waste collection vehicles.

The waste is then dumped in a waste collection or dumping zone and it has to be optimized. The most significant challenge in WtE is waste collection since local participation and public involvement is dependent upon adequate and reliable collection services (4).

4.2.2 Waste Segregation:

The collected waste consists of different kinds of materials like organic waste, paper, plastic, metal, glass, etc. so all these are separated either manually or with the help of a conveyer belt. This is one of the most crucial steps as it is not suitable to burn all these items as will cause the release of toxic pollutants into the atmosphere.

4.2.3 Preliminary Treatment of Waste:

In landfills, excess emission of methane gas takes place which can be minimized by the process of WtE technology. Most suitable wastes for energy generation are separated and further sorted according to their calorific value, lower pollution content, low moisture content, deodorized etc. The chemical or physical characteristics of biological wastes are also modified (5).

4.2.4 Pelletization of Waste:

Basically this is a method where the waste is generally condensed or its physical form is changed and by removing the inorganic content and moisture its organic content is enriched. Pellets are prepared from the solid wastes by various processes such as segregation, crushing, mixing high and low heat value organic waste material, and finally producing fuel pellets or briquettes from it. The pellets produced have a high calorific value. These pellets are used for energy generation in various areas like cement kilns, coal-fired power plants, industrial steam or heat boilers, pellet stoves, etc. (6).

4.2.5 Energy Generation from Waste:

Depending upon the feed stock and energy generation various methods such as combustion, biological treatment, landfills, etc. are used for WtE.

4.2.6 Conversion of Waste to Energy Technology:

Various technologies are now used for the production of energy from various wastes depending upon the feedstock. Following are some:

4.2.7 Thermal Combustion:

For generating heat and steam thermal combustion is used which is probably the oldest technology where biomass is burned in the presence of oxygen. Through direct firing steam, electricity, and combined heat are produced by biomass combustion.

High steam pressure is produced in the boiler after burning of biomass this steam flows through a series of turbine blades which makes the turbine rotate and then electricity is produced.

The feedstock for direct combustion comes from sugarcane mills, rice mills, and paper mills. Sometimes co-combustion technology is also used where biomass is burned along with fossil fuels such as coal and natural gas. Combined heat and power generation (CHP) can be performed by the use of biomass (7).

In the power plants where electricity is produced, a large amount of heat is also generated which is discharged into the atmosphere whereas in CHP this heat is used in district heating.

Energy from waste (EfW) is another form of direct combustion, where the waste is burned in a controlled manner so that the volume and mass of MSW can be reduced. During this process, gases are produced which contain a mixture of combustible products which then produce heat and which are further converted into steam and then to electrical energy.

4.2.8 Thermal Treatment:

When compared with fossil fuels biomass have certain limitations such as low bulk density, high moisture content, and a low calorific value which does not allow the large-scale burning of the biomass. Hence the raw biomass is reprocessed for energy production which involves the following steps.

Torrefaction: This is basically a thermal pre-treatment process where the physical and chemical composition of raw biomass is altered.

This is a heating process of biomass between 200^0C - 400^0C temperature in the absence of air which results in evaporation of moisture and driving out of low calorific components.

Hemicellulose in the biomass is also decomposed and at the end, a coal-like substance is produced. As a result of torrefaction, high-grade biofuels are produced this can be used as a replacement for coal in electricity production (8).

Gasification: When carbon present in organic waste is converted into a synthetic gas (syngas) which largely comprises carbon monoxide and hydrogen with the help of air or steam at 800^0C-1000^0C the process is known as gasification.

These syngas is burned to produce heat energy. This process takes place through partial oxidation where the involvement of oxygen is very less.

The process of gasification takes place in a gasifier which consists of various zones like drying, pyrolysis, combustion, and reduction. Removal or evaporation of surface water through filtration, evaporation, or both is known as drying. The process involving the charring of biomass is known as pyrolysis. In this process, solid biomass is broken down around 240^0C.

The broken down by-product including the liquid and gas is known as the tar. Further breakdown of this tar into simpler gases is known as cracking. Removal of oxygen from waste products at high temperatures to produce combustible gases is known as reduction.

Pyrolysis: This is a thermochemical process where the organic matter does not combust but the compounds present in it such as cellulose hemicelluloses and lignin decompose into charcoal and combustible gases.

The suitable temperature for this process ranges between 400^0C-600^0C. Three types of products are formed biochar, bio-oil, and syngas depending upon the process and factors such as temperature, pressure, and heating (9).

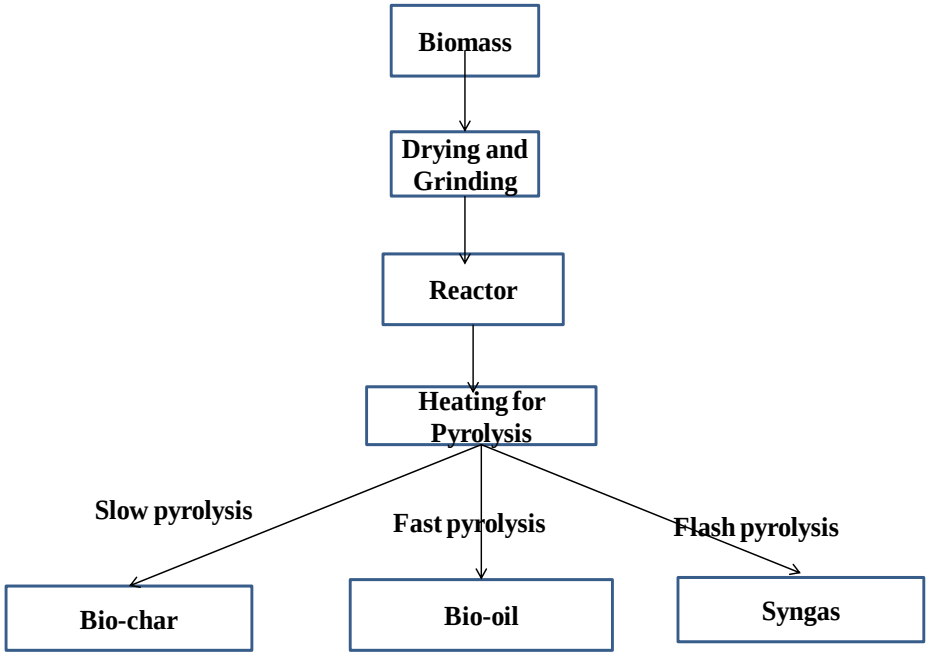

Figure 4.2: Process of Pyrolysis and Formation of Various Products

1. **Biochemical:** Biochemical processes like fermentation and anaerobic digestion are used to derive various forms of energy from biomass. This is an anaerobic process where complex carbohydrates are broken down into simple sugars with the action of microorganisms. Further, these simple sugars are converted into alcohols like bioethanol and gases like bio hydrogen (10). Now a day's bioethanol is blended with petrol. The biogas produced can be separated as bio methane and bio hydrogen and can be used as fuel (11).
2. **Benefits from WtE:** WtE technology is very helpful in the safe disposal of waste. This technology utilizes the waste material and provides a number of useful out puts from it which are summarised in Figure 4.3. These are various energy forms either they directly act as fuel source or as substrate for energy generation (12).

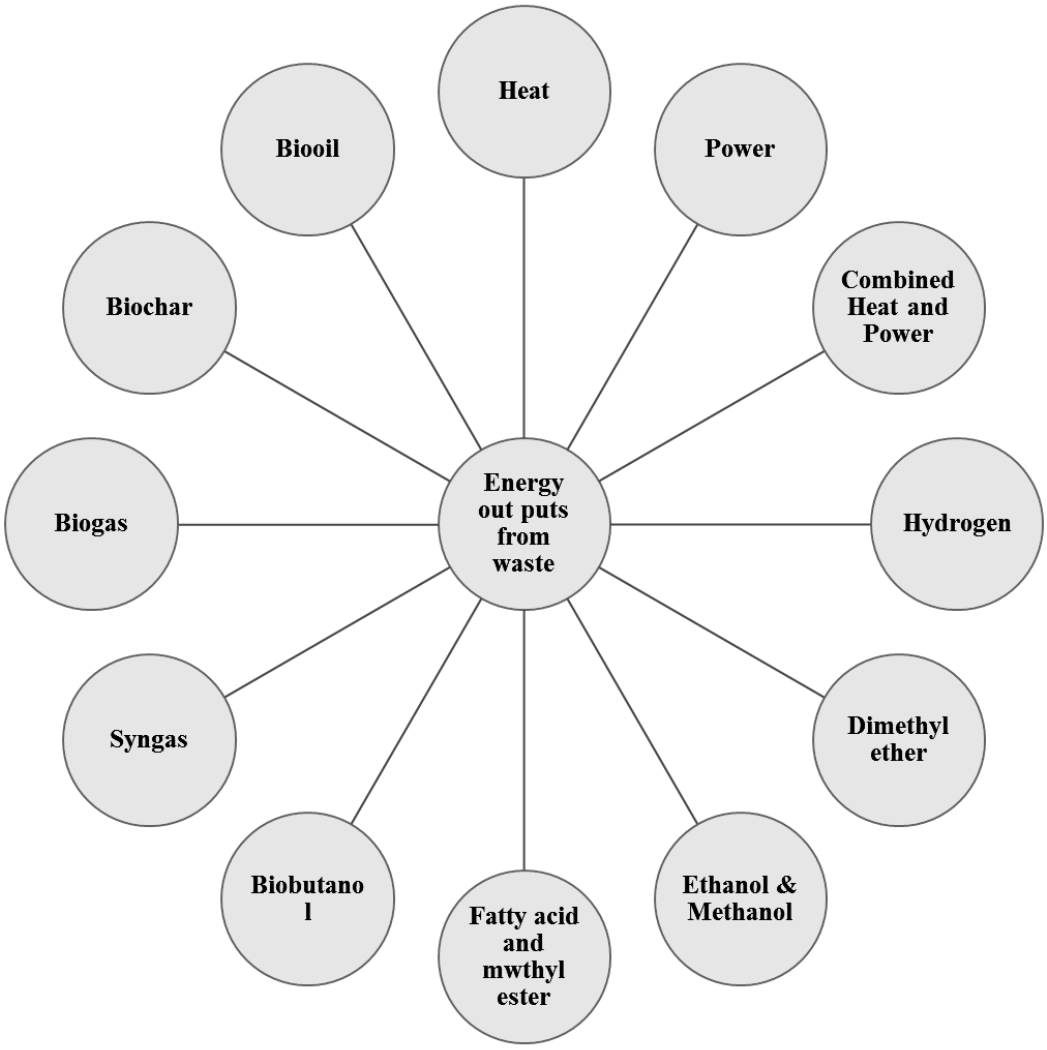

Figure 4.3: Various forms of Energy Sources Derived from Waste

WtE is one of the important aspect of waste management. There is a conceptual designed hierarchy which gives an idea of most and least preferred steps for waste management.

Top priority is given to waste prevention and generation of energy from it followed by reuse, recycle recovery and then disposal of waste.

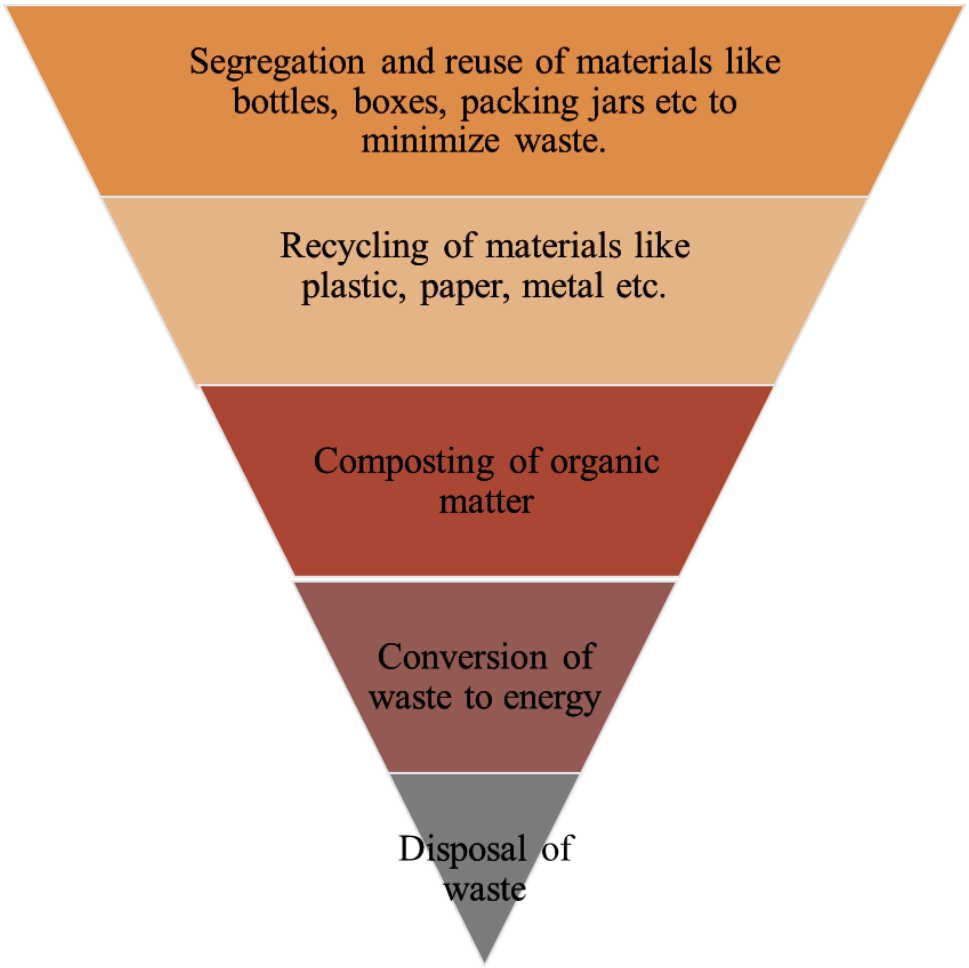

Figure 4.4: Hierarchy of Sustainable Waste Management Showing Most Preferred Process at the Top and Least Preferred Process at the Bottom

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