Production of Energy from Waste Materials

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ABSTRACT

The search for renewable and clean sources of energy is growing rapidly in the modern times. Waste to energy is one of the best renewable source having dual advantages of producing energy along with cleaning of environment from wastes. This paper includes various types of wastes that can be used to generate energy. The techniques used for this conversion and their scope have been discussed. The problems encountered in this process are also pointed out.

Keywords

Waste materials, sewage, pyrolysis, gasification, themo-chemical conversion.

1. INTRODUCTION

The increasing fuel prices and the demands for energy have compelled many countries to look for alternate sources of energy for both economic and environmental reasons. Also the public awareness about sanitation is growing. The common solution of the above two problems is the production of energy from the waste products. The dual pressing needs of waste management and reliable renewable energy source are creating attractive opportunities for investors and project developers in the waste to energy sector.

Every year, about 55 million tonnes of municipal solid waste and 38 billion liters of sewage are generated in the urban areas of India. In addition, large quantities of solid and liquid wastes are generated by industries. Waste generation in India is expected to increase rapidly in the future. As more people migrate to urban areas and as incomes increase, consumption levels are likely to rise, as are rates of waste generation. It is estimated that the amount of waste generated in India will increase at a per capita rate of approximately 1-1.33% annually. This has significant impacts on the amount of land needed for disposal, economic costs of collecting and transporting waste, and the environmental consequences of increased waste generation levels. This increases pressure on the government and urban local bodies to manage waste more efficiently. Due to these reasons, the Indian waste to energy sector is poised to grow at a rapid pace in the years to come [1-2].

2. NEED OF CONVERSION OF WASTE TO ENERGY

The need of the growing energy deficit is making the government central and state governments keen on alternative and renewable energy sources. Waste to energy is one of these. It is garnering increasing attention from both the central and state governments because of the following reasons:

- Most wastes that are generated, find their way into land and water bodies without proper treatment, causing severe water pollution. They also emit greenhouse gases like methane and carbon dioxide, and add to air pollution. The adoption of environment friendly waste to energy technologies will allow treatment and processing of wastes before their disposal. Waste to energy generates clean, reliable energy from a renewable fuel source, thus reducing dependence on fossil fuels, the combustion of which is a major contributor to GHG emissions.
- While the Indian Government's own figures would suggest that the cost of waste to energy is somewhat higher than other renewable sources, it is still an attractive option, as it serves a dual role of waste disposal and energy production.
- The conversion of waste to energy is a profitable business. If the right technology is employed with optimal processes and all components of waste are used to derive value, waste to energy could be a profitable business. When government incentives are factored in, the attractiveness of the business increases further.
- The government of India already provides significant incentives for waste to energy projects, in the form of capital subsidies and feed in tariffs. With concerns on climate change, waste management and sanitation on the increase, the government incentives for this sector is only set to increase in future.
- Success in municipal solid waste management could lead to opportunities in other waste such as sewage waste, industrial waste and hazardous waste. Depending on the technology used for energy recovery, eco-friendly and green co-products such as charcoal, compost, nutrient rich fertilizer or bio-oil can be obtained. These co-product opportunities will enable the enterprise to

expand into these related products, demand for which are increasing all the time.

- These provide opportunities to the people for future. With distributed waste management and waste to energy becoming important priorities, opportunities exist for companies to provide support services like turnkey solutions. In addition, waste to energy opportunities exist not just in India but all over the world. Thus, there could be significant international expansion possibilities for Indian companies, especially expansion into other Asian countries [1-2].

3. TYPES OF WASTES AVAILABLE FOR CONVERSION TO ENERGY

Waste can be broadly classified into the following categories:

A. **Industrial Waste**

The waste from small scale and bigger industrial units, more often toxic and hazardous is called industrial waste. Rapid industrialization has resulted in the generation of huge quantity of wastes, both solid and liquid. Despite requirements for pollution control measures, these wastes are generally dumped on land or discharged into water bodies, without adequate treatment, and thus become a large source of environmental pollution and health hazard. Over the last three decades, many cases of serious and permanent damage to environment by these industries have come to the fore. Industrial wastes could be classified into two types: hazardous industrial waste and non-hazardous industrial waste

Hazardous industrial waste: Hazardous wastes, may cause danger to health or environment, either alone or when in contact with other wastes. About 10 to 15 percent of wastes produced by industries are hazardous. The generation of hazardous wastes is increasing at the rate of 2 to 5 percent per year. Inventorisation of hazardous wastes generating units and quantification of wastes generated in India are being done by the respective State Pollution Control Boards (SPCBs). Hazardous waste in particular includes products that are explosive, flammable, irritant, harmful, toxic, carcinogenic, corrosive, infectious, or toxic to reproduction. There are a large number of hazardous wastes generating units located in India. In India, about 4.43 million tons of hazardous wastes are generated annually, out of which 71,833 tons are incinerable as per the reports of SPCBs. There is a need to explore the possibility of using such wastes by other industries.

Non-hazardous industrial waste: Non-hazardous or ordinary industrial waste is generated by industrial or commercial activities, but is similar to household waste by its nature and composition. It is not toxic, presents no hazard and thus requires no special treatment. It includes ordinary waste produced by companies, shopkeepers and trades people like paper, cardboard, wood, textiles, packaging, etc. Due to its non-hazardous nature, this waste is often sorted and treated in the same facilities as household waste. Non hazardous industrial wastes being diversified in their chemical nature, physical texture and moisture content and calorific values etc demand distinct treatments [3].

B. Urban Waste

The proliferation of urban waste has direct impacts on sanitation in India. With crowded cities and significant poverty, millions of people in Indian cities are directly exposed to the harmful effects of the urban waste. Urban waste mainly includes municipal solid waste, fecal and sewage sludge.

Municipal Solid Waste (MSW) is more commonly known as trash or garbage. MSW includes commercial and residential wastes generated in municipal or notified areas in either solid or semi-solid form. It consists of household waste, wastes from hotels and restaurants, construction and demolition debris, sanitation residue, and waste from streets.

Sewage is defined as untreated municipal liquid waste requiring treatment in a sewage treatment plant. Sewage contains about 99.9% of water, while the remaining content may be organic or inorganic. Sewage sludge is the semi-solid precipitate produced in wastewater treatment plants. Such sludge can also occur in untreated sewage disposed off into lakes and other water bodies. Sewage sludge generation in India is increasing at a faster rate as more and more sewage treatment plants (STP) are being developed. Sewage sludge and effluents from these STPs are frequently disposed off on agricultural lands for irrigation/manure purposes.

Sludge of variable consistency collected from on-site sanitation systems, such as latrines, non-sewered public toilets, septic tanks and aqua privies is denoted as fecal sludge. The fecal sludge comprises varying concentrations of settled solids as well as of other, non-fecal matter [4].

C. Biomass Waste

Biomass is fuel that is developed from organic materials, a renewable and sustainable source of energy used to create electricity or other forms of power. The materials that make up biomass fuels include scrap lumber, forest debris, certain crops, manure and some types of waste residues. With a constant supply of waste from construction and demolition activities, wood not used in papermaking, municipal solid waste, the production of electricity can continue indefinitely. Biomass is a renewable source of fuel to produce energy because waste residues will always exist in terms of scrap wood, mill residuals and forest

resources and the residual biological matter from those crops [5].
Biomass can readily be used in boilers to produce directly heat and steam to generate electricity. This is being done at a small scale at remote locations and in a centralized way in large production units of more than 50 Megawatts. Co-firing with coal is an attractive option with a relatively low need for additional investments.

Gasification is, although the technology exists already for decades, it is still being developed for advanced uses of biomass and waste. The gas which can be produced this way, a syngas, is a well known commodity in the energy generation and chemical process industry. This offers excellent options for high efficiency large scale electricity production and chemicals.

Biofuel currently represents 0.3% of the total diesel and gasoline consumption in the Market. Major oil companies in the EU have formulated their strategies in view of their responsibilities to contribute to a sustainable development, but also advocate a seamless introduction. This means that any replacement of conventional fuels by bio-fuel should not induce major changes in the current supply and distribution infrastructure. For the next decades any bio-fuel should have such properties that they can be blended into the current conventional fuels without major adaptation of the technological infrastructure. This means that carbon based renewable fuels are for the next decades the only option for a substantial replacement of the fuel pool. The major candidates for short term replacement of fuel out of mineral oil like biodiesel (RME), pressed vegetable oils (PVO), and conventional bio-ethanol from starch and sugar crops show manufacturing costs of between 12 and 21 dollar per Gigajoule, which compares with the costs including excise duty and taxation of mineral diesel between 17 and 30 dollar per Gigajoule. In the future Fischer-Tropsch diesel and bio-ethanol from lignocellulosic biomass can offer lower prices than current biodiesel and conventional bioethanol fuels [6].

D. Bio-Medical Waste

Bio-medical waste means any solid and liquid waste including its container and any intermediate product, which is generated during the diagnosis, treatment or immunization of human beings or animals. Biomedical wastes are hazardous because of their infectivity and toxicity. Bio Medical waste consists of Human anatomical waste like tissues, organs and body parts, animal wastes generated during research from veterinary hospitals, microbiology and biotechnology wastes, liquid waste from any of the infected areas and incineration ash and other chemical wastes [7].

4. TECHNOLOGIES FOR PRODUCTION OF ENERGY FROM WASTE

There are number of techniques used to obtain energy from waste biodegradable as well as non-biodegradable through thermal, thermo-chemical, biochemical and electrochemical methods.

A. Thermal Conversion

The process involves thermal degradation of waste under high temperature. In this process, complete oxidation of the waste takes under high temperature. The major technological option under this category is incineration. Incineration serves the dual purpose of reduction of both the toxicity and the volume of the waste, which is an important consideration when the disposal of wastes is finally destined for landfills. Most of the process wastes from chemical unit operations can very well be treated in properly designed incinerators. But incineration has been losing attention these days because of its emission characteristics [3].

B. Thermo-Chemical Conversion

In this process high temperature driven decomposition of organic matter takes place at high temperature which produces heat energy, fuel oil and gas. This method is useful for wastes containing high percentage of organic non-biodegradable matter and low moisture content. The main technological options under this category include Pyrolysis and Gasification. Pyrolysis is a form of treatment that chemically decomposes organic materials by heat in the absence of oxygen. Pyrolysis typically occurs under pressure and at operating temperatures above 430^0C. In practice, it is not possible to achieve a completely oxygen-free atmosphere. Because of the presence of few amount of oxygen in pyrolysis system, a small amount of oxidation occurs. If volatile or semi-volatile materials are present in the waste, thermal desorption will also occur. Organic materials are transformed into gases, small quantities of liquid, and a solid residue containing carbon and ash. The off-gases may also be treated in a secondary thermal oxidation unit. Particular removal equipment is also required. Several types of pyrolysis units are available, including the rotary kiln, rotary hearth furnace, and fluidized bed furnace. These units are similar to incinerators except that they operate at lower temperatures and with less air supply.

A molten salt process may also be used for waste pyrolysis. In molten-salt oxidation (MSO), combustible waste is oxidized in a bath of molten salts (at 500–950^0C). There is no direct flame, and this prevents many of the problems associated with incineration. Shredded solid waste is injected with air under the surface of a molten salt bath. Hot gases rise through the molten salt bath. The salt, being alkaline, scrubs acids from the gases. The heat of the molten salt degrades and melts the waste material. Because the salt bath is liquid, it also removes some particles in the gas. Spent molten salt is tapped from the reactor, cooled, and placed in a landfill. Pyrolysis treats and destroys semi-volatile organic compounds fuels, and pesticides in soil. The process is applicable for the treatment of organics from refinery wastes, coal tar wastes, creosote-contaminated soils, hydrocarbons, and volatile organic compounds [8].

Gasification processes involve the reaction of carbonaceous feedstock with an oxygen-containing reagent, usually oxygen, air, steam or carbon dioxide, generally at temperatures in excess of 800°C. It involves the partial oxidation of a substance which implies that oxygen is added but the amounts are not sufficient to allow the fuel to be completely oxidized and full combustion to occur. The process is largely exothermic but some heat may be required to initialize and sustain the gasification process.

The main product is a syngas, which contains carbon monoxide, hydrogen and methane. Typically, the gas generated from gasification will have a net calorific value of 4-10 MJ/Nm^3.The other main product produced by gasification is a solid residue of non-combustible materials (ash) which contains a relatively low level of carbon. Gasification plants, based on syngas production, are relatively small scale, flexible to different inputs and modular development. Producing syngas to serve multiple end-uses could complicate delivery of the plants but it could provide a higher degree of financial security [9].

The products of these processes producer gas, exhaust gases etc can be used purely as heat energy or further processed chemically, to produce a range of end products. In the future, gasification, pyrolysis and plasma arc technologies might become fierce contenders to traditional thermal combustion with energy recovery, but they are still emerging technologies. Gasification has not yet to be proven to work in India. Pyrolysis and plasma arc suffer a similar setback around most of the world.

India's only pyrolysis plant, in Pune, recently came under scrutiny due to its failure to run at capacity. Studying the reasons for this failure, which are currently unknown, could provide a better picture about the future of emerging technologies [10].

C. Bio-Chemical Conversion

In this process enzymatic decomposition of organic matter takes place by microbial action. It produces methane gas, and alcohol etc. This method is preferred for wastes having high percentage of organic, bio-degradable matter and high level of moisture/ water content, which aids microbial activity. The major technologies used under this category are anaerobic digestion (bio-methanation) and fermentation. Anaerobic digestion is the most frequently used method for waste to energy while fermentation is an emerging technique. Biomethanation has strong potential for the production of energy from organic residues and wastes. Bio-methanation is a process by which organic material is microbiologically converted under anaerobic conditions to biogas. Three main physiological groups of microorganisms are involved: fermenting bacteria, organic acid oxidizing bacteria, and methanogenic archaea. Microorganisms degrade organic matter by biochemical conversions to methane and carbon dioxide. Determination of practical and theoretical methane potential is very important for design for optimal process design, configuration, and effective evaluation of economic feasibility. A wide variety of process applications for biomethanation of wastewaters, slurries, and solid waste have been developed. They utilize different reactor types and process conditions like retention times, loading rates, temperatures, etc. in order to maximize the energy output from the waste and also to decrease retention time and enhance process stability. Biomethanation has strong potential for the production of energy from organic residues and wastes [11].

D. Electro-Chemical Conversion

Electrochemical conversion mainly includes microbial fuel cells (MFC). These systems are developed to trap the energy from wastes. The reduction-oxidation machinery of immobilized microbial cells is catalytically exploited, for the accelerated transfer of electrons from organic wastes. These generate electricity and bio-hydrogen gas. However this methodology needs extensive evaluation studies on bulk scale liquid waste treatments and stands at a nascent level in India as well as worldwide.

5. PROBLEMS FACED BY INDIA TO OBTAIN ENERGY FROM WASTE

The growth of this sector has been affected on account of the following limitations/ constraints:

- Waste-to-Energy is still a new technique in the India & has not developed.
- Most of the proven and commercial technologies in respect of urban wastes are required to be imported from other countries which increase its cost.
- The costs of the projects especially based on biomethanation technology are high as critical equipment required is to be imported.
- In view of low level of compliance of MSW Rules 2000 by the Municipal Corporations/ Urban Local Bodies, segregated municipal solid waste is generally not available at the plant site, which may lead to non-availability of waste-to-energy plants.
- Lack of financial resources with Municipal Corporations and Urban Local Bodies.
- Lack of conducive policy guidelines from State Governments in respect of allotment of land, supply

of garbage and power purchase and evacuation facilities [2].

- Lack of data and awareness impacts every aspect of India's waste management industry. Other than the National Environmental and Engineering Research Institute's (NEERI) survey performed eight years ago about waste composition and generation in 59 cities, there is no other reliable data available. The reliable data about quantity, composition, calorific value and seasonal variations of municipal sewage waste is not available. So municipalities struggle to come up with a structured and a well-moderated response to their own needs. Lack of data decreases the clarity in tender requirements put forth by municipalities and leads to miscalculations by private parties. It was one of the main reasons for the failures of many first generation (1960s to 1990s) and second generation waste management facilities (2000). The failures of many first generation and second generation waste management facilities continue to impact the scope of current projects and the financing and regulatory policy. Due to a lack of awareness about the technology and best practices, municipalities are betrayed for solutions. The salesmen promise zero residue, zero emissions and zero leachate, which is practically not possible. Such problems can be solved by information, training and education.
- A lack of consultants and professional expertise has led to tender documents being developed that are often not clearly scoped. These are just copied from existing tenders from other cities and local requirements are not considered. This is mainly due to the lack of consultants and professionals who have expertise in designing waste management projects. This leads to the stipulation of unreasonable eligibility criteria, one-sided agreements and choosing the wrong partners. Many first generation and second generation Waste management projects failed because of irregularity in payments. Payments from most municipalities are delayed by three to four months. Further to this, the sewage waste management industry in India is growing. People from other sectors are participating in it. They all face similar challenges while developing projects, but do not have mechanisms to achieve consensus on their basic requirements, so that those can be communicated to decision makers [10].

6. CONCLUSION

Waste to energy is emerging technology in India and all over the world to meet demands of energy and removal of waste. The waste products include urban waste, industrial wastes, biomass and biomedical wastes. The techniques for the production of energy from waste are emerging very fast with time. These measures would reduce the quantity of wastes, generate a substantial quantity of energy from them, and greatly reduce pollution of water and air, thereby offering a number of social and economic benefits that cannot easily be quantified.

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