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# A Technical Review of Waste to Energy Technologies Available for Indian Municipal Solid Waste Management

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**ABSTRACT:** India is one of the world's fastest-developing countries. It is witnessing an increase in industrialisation and, as a result, development. Such rapid expansion necessitates the use of energy, which makes India an energy-hungry nation. India currently relies primarily on fossil fuels. Hence there is an urgent need to focus on the development and advancements of other sources of energy, of which waste to energy technologies has shown greater potential. Enhanced Waste Management (EWM) and Enhanced Landfill Mining (ELFM), two unique approaches, aim to put waste landfilling in a sustainable context. The status of technology plays an essential role in choosing the best time to valorize particular landfill waste streams as materials (Waste-to-Product, WtP) or as energy (Waste-to-Energy, WtE). This assessment will assist MSWM policymakers and implementers in gaining a better understanding of the current state, problems, and barriers to successful municipal solid waste management. This study showed that WTE is a possible renewable energy source that can partially meet energy demand while also ensuring effective MSWM.

**KEYWORDS:** RDF, MSW, Waste to energy, Incineration

## I. INTRODUCTION

In developing countries like India waste generation is increasing day by day due to the boom in industrialization, urbanization and population. This also causes environmental issues. India is the second leading nation in the world in terms of population with a nearly 1.2 billion population, and has continued to raise population at the rate of 3-3.5% per annum. The rapid growth of population in India, gives a strong dip on the natural resources[1]. Urban part of India generates approximately 0.136 million tonnes per day or 52 million tonnes per year of municipal solid waste (MSW), increasing nearly 5% annually [CPCB, 2016]. The lifestyle of people in India is changing gradually which is the cause of huge amounts of waste generation. Also, there is almost no segregation of MSW, plastic wastes, commercial wastes, industrial refuse and e-wastes[2]. Thereby we need to have a good and efficient Waste to Energy or Waste to product technologies such that it can cater to mixed type of waste that is generated from Indian households.

## II. RELATED WORK

### WASTE GENERATION IN INDIA

**WASTE QUANTITY:** Even though only 31% of Indian population resides in urban areas, this population of 377 million (Census of India, 2011) generates a gigantic 1,43,449 metric tonnes per day of municipal solid waste, as per the Central Pollution Control Board (CPCB), 2014-15 and these figures increase every day with an increase in population. To further add to the problem, the total number of towns (statutory and census) in the country have also increased from 5,161 in 2001 to 7,936 in 2011, thus increasing the number of municipal waste generation by 2,775 within a decade.[3]

**WASTE COMPOSITION:** The composition of MSW at generation sources and collection points was determined on a wet weight basis and it consists mainly of a large organic fraction (40–60%), ash and fine earth (30–40%), paper (3–6%) and plastic, glass and metals (each less than 1%). The C/ N ratio ranges between 20 and 30, and the lower calorific value ranges between 800 and 1000 kcal/kg.[4]

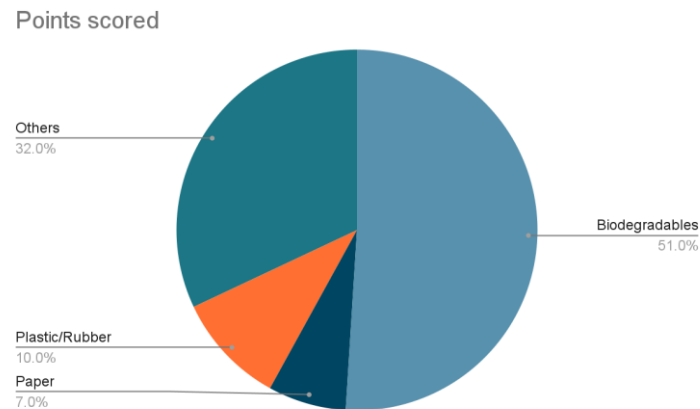


Fig. 1 A pie chart representing the typical composition of MSW in India[5]

### III. METHODOLOGY

#### WASTE TO ENERGY TECHNOLOGIES

In the recent world of advancement there are various options available for potential recovery of energy from the generated waste. It can be majorly classified in 3 broad categories:

1. Thermal conversion
  - i) Incineration
  - ii) Pyrolysis
  - iii) Gasification
  - iv) RDF
2. Biological technologies
  - i) Composting
  - ii) Anaerobic digestion

#### A. Incineration

The incineration of MSW involves combustion of waste leading to volume reduction (90-95%) and recovery of heat to produce steam that in turn produces power through steam turbines (Bhide and Sunderesan 1983). Basically, it is a furnace for burning waste and converts MSW into ash, gaseous and particulate emissions and heat energy. The efficiency of the technology is linked to the waste characteristics and their properties such as moisture content and calorific values. It requires a high temperature of the order of 800-1000o C and sufficient air and mixing of gas streams. The minimum temperature for burning carbonaceous wastes to avoid release of smoke and prevent emissions of dioxin and furans is 850o C. Depending on the nature of wastes and the operating characteristics of combustion reactor, the gaseous products derived from the combustion of MSW may include carbon dioxide (CO<sub>2</sub>), water (H<sub>2</sub>O, flue gas), oxygen (O<sub>2</sub>), nitrogen oxides (NO<sub>x</sub>), sulphur dioxide (SO<sub>2</sub>) and small. Minimum Moisture content should be <45%. Calorific value should be as high as possible; >1500 kcal/kg. Incineration of chlorinated plastic should be avoided as far as possible. The emission standards are prescribed in SWM Rules, 2016. [6]

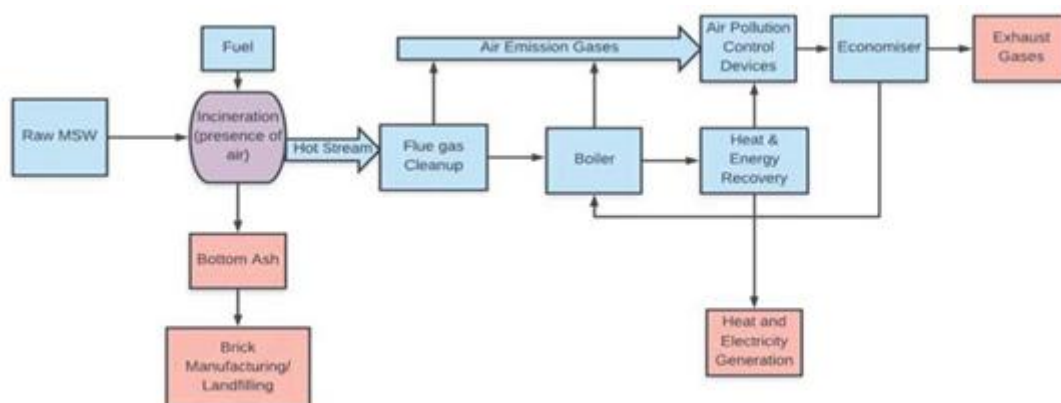


Fig. 2 Incineration process to produce electricity and heat [1]

### B. Plasma Pyrolysis

Plasma pyrolysis or plasma gasification is a waste treatment technology that gasifies matter in an oxygen-starved environment to decompose waste material into its basic molecular structure. The process demands high electrical energy for creating high temperature by an electrical arc gasifier. It does not combust the waste as incinerators do. In a plasma converter, the arc breaks down waste primarily into elemental gas and solid waste (slag). The objective of the process is to generate net electricity, depending upon composition input wastes, and to reduce the volumes of waste being sent to landfill sites. Relatively high voltage, high current electricity is passed between two electrodes, spaced apart, creating an electrical arc where temperatures as high as  $13,871^{\circ}\text{C}$  is reached. The temperature from one meter arc can reach up to  $\sim 4000^{\circ}\text{C}$ . At these temperatures most types of waste are broken into basic elemental components in a gaseous form, and complex molecules are atomized - separated into individual atoms. Depending on the input waste (plastics tend to be high in hydrogen and carbon), gas from the plasma containment can be removed as Syngas, and may be refined into various fuels at a later stage. There has been issues of plasma systems regarding high temperatures requirement and short life of liners which are highly susceptible to both chlorine attack and to local variability in such high temperatures, not likely to last more than a year in service.[6]

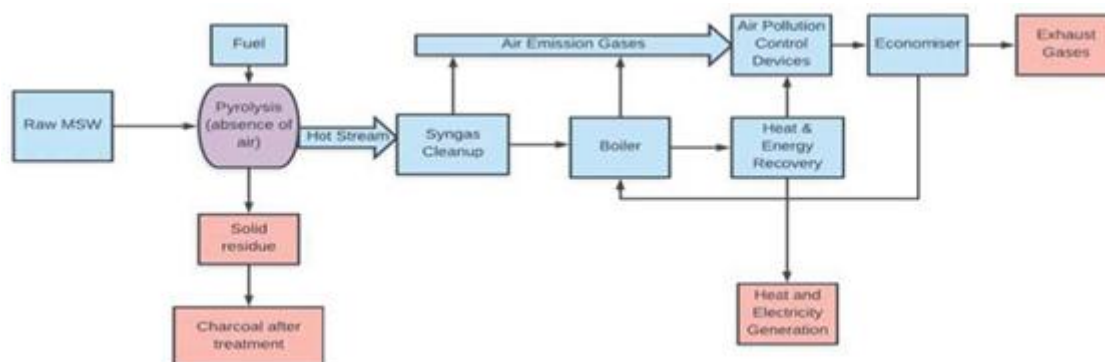


Fig. 3 Pyrolysis process to produce energy and heat[2]

### C. Gasification

Gasification process contains partial combustion of waste to generate energy. This is accomplished by providing high temperature ( $>7000^{\circ}\text{C}$ ) with a limited amount of air (i.e. partial combustion). The final product of the gasification process are char, tar and syngas. Syngas is energy rich and clean through gas turbines or engines to produce energy and heat. This process can reduce about 70% mass and 90% volume of waste [Elwan et al., 2013; Kalyani and Pandey, 2014; Moya et al., 2017]. Limited gasifiers were installed in India, mostly used to burn agro biomaterial. There are two different projects of gasifiers existing in India. First is NERIFIER gasifier installed at Nohar, Hanugarh, Rajasthan by Navreet Energy Research and Information (NERI). It is used to burn agro biomass, sawmill dust and forest dust. Second is TERI gasifier installed at Gaul Pahari Campus, New Delhi by Tata Energy Research Institute (TERI) [Sharholi et al., 2008]. Figure 4 illustrates the gasification process.[2]



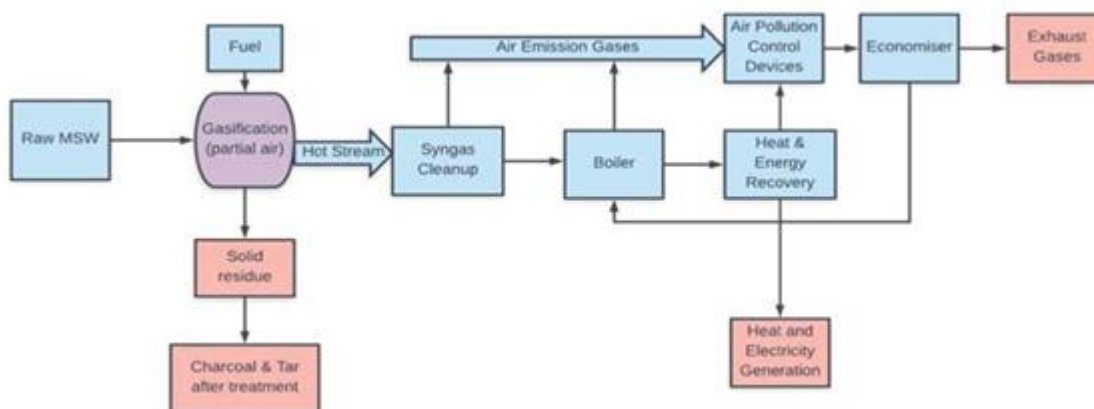


Fig. 4 Gasification process to produce energy and heat[1]

#### D. RDF/ Pelletization

It is basically a processing method for mixed MSW, which can be very effective in preparing an enriched fuel feed for thermal processes like incineration or for use in industrial furnaces. It is a fuel produced by shredding municipal solid waste (MSW) and steam treatment for reducing moisture content. RDF consists largely of organic components of municipal waste such as plastics and biodegradable waste, which are compressed into pellets, bricks, or logs. Non-combustible materials such as glass and metals are removed during the treatment process with an air blow or other mechanical separation processing. The MSW collected for disposal is tested for its moisture content and when the moisture content is more than 35- 40%, it requires drying to produce fuel pellets with reasonable calorific/heating values. The reduction in moisture can be done artificially or by natural sun drying. The sun dried garbage is then uniformly fed into a rotary drying system i.e. Hot Air Generation burning oversize garbage or other fuel to further bring down the moisture level to about 10-12%. RDF is an alternative to WTE and is a potential waste management technology[6]

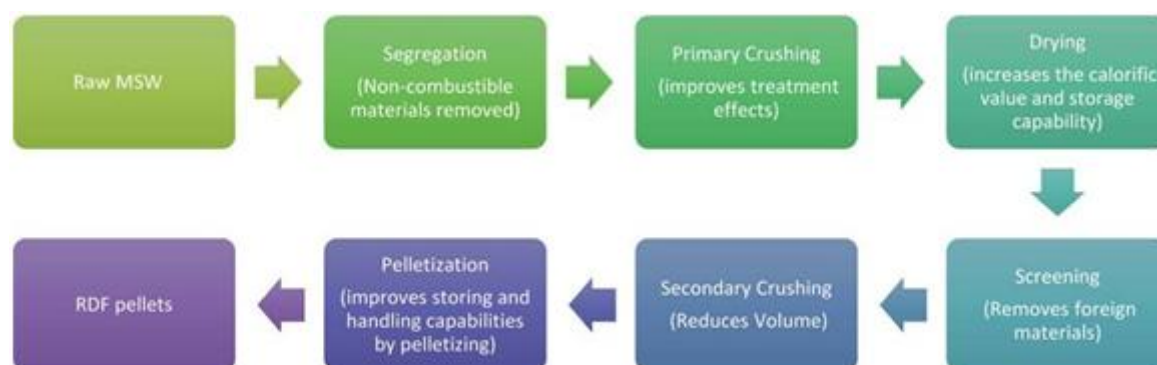


Fig. 5 Refuse derived fuel process [1]

#### E. Anaerobic Digestion Process

**Biomethanation /Bio-waste Derived Fuel** It is a process based on anaerobic digestion of organic matter in which microorganisms break down biodegradable material in the absence of oxygen. The process is widely used to treat wastewater sludge and organic wastes because it provides volume and mass reduction of the input material. It produces methane and carbon dioxide rich biogas suitable for energy production and hence, is a renewable energy source. The nutrient-rich solids left after digestion can be used as a fertilizer. It generally treats Sorted organic fraction only (highly putrescible) for better gas yield. Fibrous organic matter is undesirable as the anaerobic microorganisms do not easily break down woody molecules such as lignin, cellulose, hemicelluloses, etc.. Preferred C/N ratio is 25-30. Moisture content should be >50% which implies on feed, gas production, system type, system efficiency. Area requirement for

bio-methanation is approximately 25 m<sup>2</sup> 4 per tonne of MSW. Extra area required for machinery, gas containing and storage facilities. [6]

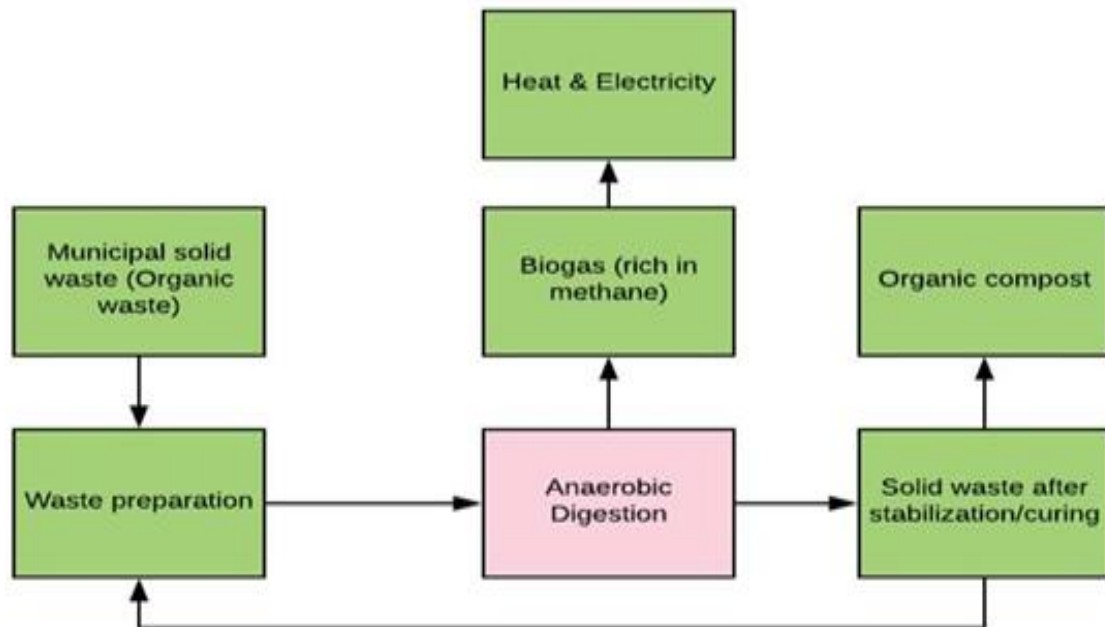


Fig. 6 Anaerobic digestion process[Source: Tan et al., 2014; Joshi and Ahmed, 2016]

### Overview of various waste to energy technologies

Since there are various Waste to energy technologies available and out of which we have to find the suitable technology for the different types of mixed MSW available in municipalities. Out of the various studies we found that the composition of the MSW changes with the municipality. Also the use of this type of technology depends upon the quantity of waste and other factors. Hence we have made the comparison based on the different criteria such as :

- Type of Solid Waste
- Air Pollution
- Volume Reduction of waste
- Contribution to Energy
- Solid waste generation due to rejects
- Adverse Impacts
- Status of Technology used in other countries
- Final Product
- Contribution to Food

Criteria	Waste to energy technology						References
	Incineration	Pyrolysis	Gasification	Refuse derived fuel	Composting	Anaerobic digestion	
<b>Status of technology used</b>	Widely used in developed countries	Mostly used in developed countries	Mostly used in developed countries	Widely used	Widely used	Widely used	[Gupta et al., 2017; Jayaprakash et al., 2018]
<b>Types of solid waste</b>	Unsorted waste	Specific type of recyclable plastic waste	Unsorted waste	Unsorted waste without hazardous and infectious waste	Sorted organic waste, high lignin material is acceptable	Sorted organic waste, animal or human excreta, less suitable for high lignin waste	[Chinwan and Pant, 2014; Jayaprakash et al., 2018]
<b>Final products</b>	Heat	Heat, pyrolysis oil	Heat, char	RDF	Compost/humus product	Compost/humus product, low calorific RDF, heat	[Moya et al., 2017; Gupta et al., 2017]
<b>Adverse impacts</b>	Pollution from air emission toxic gases	High energy consumption, during operation, noise and air pollution	High energy consumption, during operation, noise and air pollution	Uncertain heating value	Odor and insect problem	Problem of leakage of methane gas	[Jain et al., 2014; Jayaprakash et al., 2018]
<b>Air Pollution</b>	High	High	Medium	High	Low	Low	[Planning Commission Report, 2014; CPCB, 2016]
<b>Solid waste generation due to rejects</b>	Low	Low	Low	Low	High	Low	[Planning Commission Report, 2014; CPCB, 2016]
<b>Volume reduction of waste</b>	75-90%	75-90%	75-90%	75-90%	15-30%	45-50%	[Planning Commission Report, 2014; CPCB, 2016]
<b>Contribution to energy</b>	Power generation from heat	Power generation, pyrolysis oil used as raw material	Power generation	Energy from RDF	None	Power generation from biogas	[Moya et al., 2017; CPCB, 2016]
<b>Contribution to food</b>	None	None, high contamination	None	None	Used as compost for cultivation	Used as compost for cultivation	[Planning Commission Report, 2014; Jayaprakash et al., 2018]

Table 1: Overview of various waste to energy technologies[2]

#### IV. CONCLUSION

Waste to energy technologies make it possible to dispose of municipal solid waste in a safe and environmentally beneficial manner. It generates electricity and heat while also resolving the solid waste management issue. According to the findings of the study, waste to energy technologies have been explored in India for a long time but have failed. It's because of a lack of strategic and logistic planning, inept financial financing, insufficient technical attention, and poor resource management. For sustainable waste management systems, there is a need to raise environmental awareness and improve people's attitudes about garbage. Currently, the Indian government and citizens are attempting to adopt a variety of activities in relation to the environment.



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