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Waste to Energy: A Case Study on Morba Village

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Abstract: ***The world today faces a series of problems; prominent among them are rapid increase in population (decrease in free space), energy crises and waste. Worst hit by these problems are developing and underdeveloped countries. Various methods are known to mankind for the generation of energy which is classified as renewable and non renewable methods. The raw material required to generate energy is mostly fossil fuels which are depleting. Hence it is essential to go for alternative ways to generate energy. One way as an alternative source for energy generation is to use waste as a source of energy. This methodology aims at tackling two major problem of present world; namely waste disposable and energy shortage. The waste produced in an area is used to generate electricity to meet the ever growing need of electricity. In this paper a case study done on Morba village (situated in Maharashtra) is presented and the waste to energy potential of the village is found out. The methodology along with its detail is presented and the calculations are done on the basis of various research papers.***

Keywords: WTE- Waste to Energy, MSW- Municipal Solid Waste, GHG- Green House Gases

1. Introduction

Nature is a closed loop system i.e. nothing in nature goes waste. Everything is reused in a natural ecosystem. But the sad truth about manmade systems is that they are not normally closed loop systems and account for generation of the so called non usable material popularly known as "waste". The true fact is that the term waste actually doesn't exist and the so called waste of one system is the required raw material input of another system. Nature does it in a perfect way. The same methodology of the nature can be implemented in order to reduce or eliminate the waste and solve the problem of Energy crisis. As energy is the driving force for development in all countries of the world. The increasing clamour for energy and satisfying it with a combination of conventional and renewable resources is a big challenge. Another concern is that of waste accumulation. The rapid increase in population coupled with changing lifestyle and consumption patterns is expected to result in an exponential increase in waste generation of upto 18 billion tones by year 2020. [3] It is anticipated that population of India would be about 1,823 million by 2051 and about 300 million tons per annum of MSW will be generated that will require around 1,450 km^2 of land to dispose it in a systematic manner. The area required from 2031 to 2050 would be 43,000 hectares for landfills piled in 20 meter height. [4]

Most wastes that are generated find their way into land and water bodies without proper treatment, causing severe water and air pollution. The problems caused by solid and liquid wastes can be significantly mitigated through the adoption of environment-friendly waste to energy technologies that will allow treatment and processing of wastes before their disposal. The environmental benefits of waste to energy, as an alternative to disposing of waste in landfills, are clear and compelling. 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. 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.

The waste management sector faces a problem that it cannot solve on its own. The energy sector, however, is considered to be a perfect match, because of its need to continuously meet a growing energy demand. Waste is now not only an undesired product of society, but a valuable energy resource as well. Energy recovery from waste can solve two problems at once: treating non-recyclable and non-reusable amounts of waste; and generating a significant amount of energy which can be included in the energy production mix in order to satisfy the consumers' needs. [1]

The Garbage or waste is also called as Municipal Solid Waste (MSW) which is a waste consisting of everyday items that are discarded by the public. Following major categories of waste are generally found in MSW of India:

- Biodegradable Waste: Food and kitchen waste, green waste (vegetables, flowers, leaves, fruits) and paper.
- Recyclable Material: Paper, glass, bottles, cans, metals, certain plastics, etc.
- Inert Waste Matter: C&D (Construction & Demolition), dirt, debris.
- Composite waste: Waste clothing, Tetra packs, waste plastics such as toys.
- Domestic Hazardous Waste (also called "household hazardous waste") and toxic waste: Waste medicine, e-waste, paints, chemicals, light bulbs, fluorescent tubes, spray cans, fertilizer and pesticide containers, batteries, and shoe polish.
- MSW in India has approximate 40–60% compostable, 30–50% inert waste and 10% to 30% recyclable. [4]

MSW is generated from several sources like residential, commercial, institutional, etc. The composition of municipal waste varies greatly from country to country and region to region and changes significantly with time. In India the biodegradable portion which mainly includes food and yard waste dominates the bulk of MSW by making up approximately 50% to 60% of the total MSW. Following are some facts about Indian MSW:-

- Solid waste generation in India is about 115,000 tons per day with a yearly increase of about 5% (according CPCB, India)
- Research studies reveal that the per capita generation rate increases with the size of the city and varies between 0.3 to 0.6 kg/day in the metropolitan areas. The estimated annual increase in per capita waste quantity is about 1.33% per year.
- The 11th Five Year Plan of India has envisaged an investment of approximately Rs. 2,000 crores for Solid Waste Management (SWM).

The large amount of Municipal solid waste can be used to generate energy. Several technologies have been developed that make the processing of MSW for energy generation cleaner and more economical than ever before. While older waste incineration plants emitted high levels of pollutants, recent regulatory changes and new technologies have significantly reduced this concern. United States Environmental Protection Agency (EPA) regulations in 1995 and 2000 under the Clean Air Act have succeeded in reducing emissions of dioxins from waste-to-energy facilities by more than 99 percent below 1990 levels. The EPA noted these improvements in 2003, citing waste-to-energy as a power source "with less environmental impact than almost any other source of electricity."[3]

These technologies can be implemented in India in the developing Towns and Villages where the cost of land is not much high as compared to metropolitan cities. This paper presents a case study on Morba Village which is almost a small town and is developing at a faster rate. This village is situated in Mangaon Taluka of Raigad District, Maharashtra, India. The basis for the research done is the census data of the village and the various research articles based on the per day waste generation potential along with the various waste to energy conversion tools. All the possible combinations of methodologies are presented and the analysis for the same is done along with cost implications and the capital as well as payback period.

2. Methodology

In order to utilize the waste as an energy source, its collection is an important aspect. The waste of a village is collected in a dumping ground by different means like waste collection vehicles and door to door garbage pickup facilities. The waste collected in the dumping yard is then transferred to a segregation plant. The Segregation of waste is done either manually or automatically by means of various technologies for waste segregation available in market. Basically, Waste is segregated in three categories: Organic, inorganic, toxic. Major constituents are organic and inorganic waste.

The Organic waste is the source for biogas and fertilizer generation. The biogas plant receives all kinds of organic waste - typically livestock manure and organic industrial waste. The dry solid in livestock manure contains carbon, among other things, and in the process this carbon is transformed into biogas, a compound of methane (CH4) and carbon dioxide (CO2).

The manure and waste are mixed in the plant's receiving tank before being heated to 38-52°C/100-125.6°F and pumped into the digester in which the biogas is produced. The biomass stays in the digester for 2-3 weeks and the fermented slurry can subsequently be used as crop fertilizer. This fertilizer has improved qualities such as less odor inconveniences when spreading the slurry and significant reduction of greenhouse gasses. Figure 1 shows simplified process flow diagram of a typical biogas generation plant. It represents all the major processes involved along with the possible uses of biogas as an alternative fuel source. Whereas figure 2 shows the schematic diagram for the same.

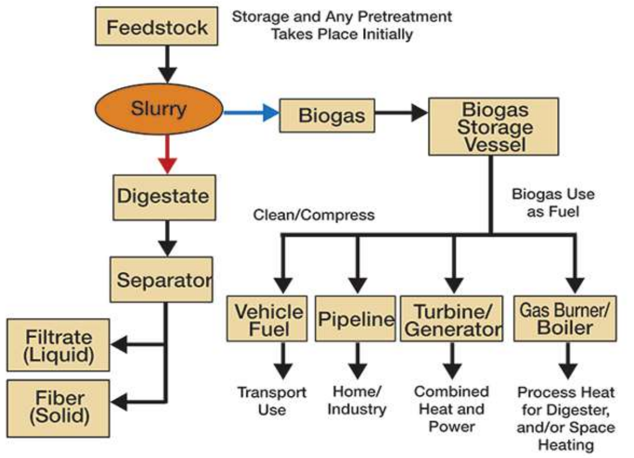

Figure 1: Process cycle of Biogas Plant

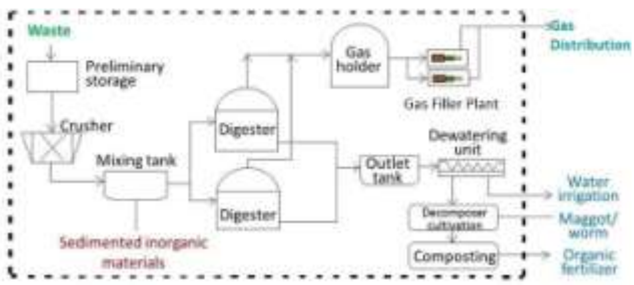

Figure 2: Schematic diagram of Biogas plant

On the other hand, Inorganic waste needs further segregation. The Inorganic waste reaching the Waste to Energy (WTE) plant is composed of different types of dry waste. Waste such as fibre, plastic, paper, glass (non-metallic) and metallic wastes are identified and separated. Non-degradable materials such as glass, ceramics and metals are not easily processed in WTE plant. Metallic substances are separated by magnetic and gravity separation techniques. A sorting and segregation unit will be installed in WTE plant in order to remove unwanted material present in waste. [2]

Through various technologies available we can easily convert almost all the non-metallic waste into heat which helps in steam generation to drive a turbine. On the other hand, the metallic waste (such as copper, aluminum, iron) and glass etc can be sold as scrap as per the market rate of the respective material. The waste collected contains 5% of toxic waste. This kind of waste is to be disposed carefully.

Electricity can be produced from waste through direct combustion, and the released heat during combustion is utilized to produce steam to drive a turbine. This indirect generation has an efficiency level of about 15% to 27%, with modern plants reaching the higher end of the range. The electrical efficiency rate from incineration is usually higher than from gasification due to lower operating temperatures, steam pressure and overall energy required to run the plant. Gasification and pyrolysis processes produce a combustible synthetic gas (syngas) that can either be used to produce electricity through the process presented above, or further refined and upgraded to for direct generation in a gas turbine or engine. [1]

The typical process of the waste to electricity generation plant is as depicted in the figure 3. Initially, the dry waste is put in a shredder which converts the irregular chunks of waste into smaller more uniform pieces which are then feed to the thermal converter and oxidizer where the feed is burnt either by pyrolysis or direct combustion to produce hot flue gases. These gases are then fed to boiler to produce steam which is ultimately used to run the turbine or else in some cases the flue gases can directly be used to run the gas turbine which in turn produces electricity by the use of generators.

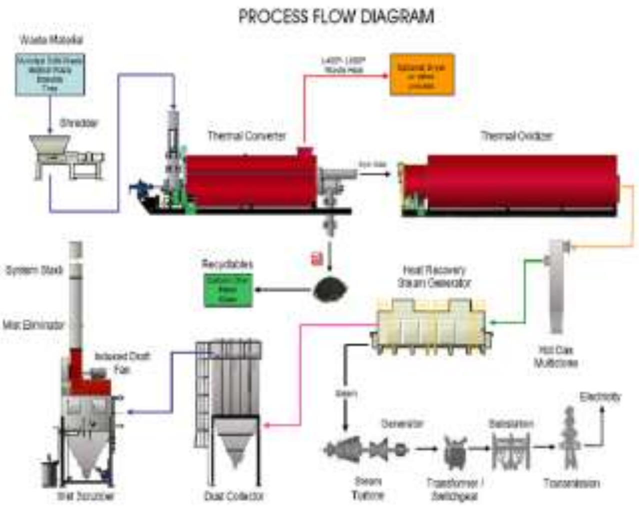

Figure 3: Waste to Electricity Generation Process flow

3. Calculations and Result Analysis

In order to calculate the waste generation of Morba village, it is necessary to know the current population. This information can be obtained from the census data.

Population of Morba according to 2011 census is 6798 [5]. Since, the population data obtained is from 2011 census, so in order to calculate the current population the growth rate data is to be used.

Growth rate per decade of India = 17.64 % [6]

∴ Growth rate per year = 1.764 %

Now, for 2017 i.e. 6 years; Growth rate will be 6 × 1.764
= 10.584 %

∴ Approximate population in year 2017 would be;
6798 × (1 + 0.10584) = 7517.5

Let's assume the population to be 7500 People in 2017

The waste generation of a village depends upon the number of people residing in it. So the total quantity of waste generated by the village can be calculated by referring the value of waste generated per person and the total number of people in the village.

Waste Generation rate in India for a village with population less than 10000 is 0.36 kg/day per person [7].
∴Waste generated by 7500 people = 7500 × 0.36
= 2700 kg/day

As per research conducted by various organizations and mentioned in urban development series knowledge papers; 59 % of total waste in India is organic waste.

Therefore Wet/Organic waste = 2700 × 0.59
= 1593 kg/day

And Dry + Reusable waste = 2700 - 1593
= 1107 kg/day

3.1 Biogas and Fertilizer Calculation:

The Organic Waste thus generated can be used as a fuel to the biogas plant, which in turn can produce Biogas and Fertilizer as an Output by decomposition of this organic waste.

1 ton of waste produces 240 m^3/day [8].

Organic waste has approximate 60% water content and in order to have quality production of biogas 80% water content has to be maintained. So, 20% water is to be added.

∴ 1593 × 1.2 = 1911.6 kg of input slurry

Now, Biogas generated from 1911.6 kg = 1.9116 × 240
= 458.7 m^3/day

1 m^3 = 1000 liter of biogas

∴ Per day 458700 liter of Biogas is generated

The average methane content in biogas produced due to the organic waste is 53% of total gas produced.

Also, as per Calorific value comparison, 1m^3 of Biogas is equal to 0.433kg of Butane.

So, 458.7 m^3 of Biogas = 458.7 × 0.433 = 198.617kg

As One Cylinder of LPG is 14.2 kg of Butane

∴ 165.4kg = 13.9 ~ 14 Cylinders

The current Cost of 1 LPG cylinder is Rs. 718.5 in Mumbai

We have 14 Cylinder Equivalent per day = 718.5 × 14
= Rs.10059

∴Total cost of gas per month = 10059 × 30
= 301770 /month

Considering inconsistency or losses in gas as well as maintenance in generation plant as 15 %

Actual revenue generated per year = 301770 × 12 × 0.85
= 3078054 / year
~ 30.78 Lacs/ year

The above income from biogas plant is only of Biogas produced due to the organic waste. It doesn't consider the amount of fertilizer that can be produced from the residual slurry of the biogas plant. In order to account for the fertilizer production, the calculation of fertilizer produced per day is to be calculated as follows.

As density of Biogas is 1.15kg/m^3 and biogas produced from 1911.6kg of organic slurry is 458.7m^3 per day. Hence, weight of biogas produced from 1911.6kg of organic slurry is 458.7 × 1.15 = 527.505kg
So, 527.505kg of biogas is produced from 1911.6kg of organic slurry and the rest is wet fertilizer.

Wet Fertilizer= 1911.6 – 527.505 = 1384.095kg

As, 80 % water is present in slurry (i.e. 20 % solid is fertilizer)

Therefore, Dry fertilizer = 1384.095 × 0.2 = 276.819kg
and Per month fertilizer generation = 276.819 × 30
= 8304 kg/month

Cost of 1 kg fertilizer Rs.5
Revenue generated = 8304 × 5 = 41520 /month
Revenue generated per year = 41520 × 12
= Rs. 498240

∴Total income from biogas/year = 3078054 + 498240
= 3576294
~ 35.76 Lacs

3.2 Electricity Generation from Dry Waste:

Till now only biogas and organic fertilizer generation from organic waste is considered. There are technologies available which can convert the non usable dry waste like plastic, paper, Fibre, cloth, Wood etc. into electricity.

Dry + Reusable waste = 1107 kg/day

As per research conducted by various organizations and mentioned in urban development series knowledge papers; 36 % of total waste in India is Dry and non-reusable waste.

Therefore, Dry Waste = 2700 × 0.36
= 972/day

The energy content of a fuel is measured in terms of its calorific value (CV), expressed as Joules per kilogram. In the case of coal fuel, a typical value is approximately 30 MJ/kg, while for oil the value is about 40 MJ/kg. These values can be compared with that for MSW of about 10 MJ/kg. In fact the calorific value of MSW has increased about 20% since the early 1970s, because of factors such as the decreasing quantity of ash in the waste from coal fires, and the increasing proportion of dry packing material. Nevertheless, the principal cause of short-term fluctuation in the calorific value (CV) of MSW is variations in its moisture content.
1 kg of dry waste produces 17.6 to 20 MJ/kg[1]

3.6 MJ heat produces 1KWH of Electricity for 100% plant efficiency. But Dry waste to electricity conversion efficiency is 40%. Hence, 3.6MJ/0.4 = 9MJ [9]

So, 9 MJ heat produces 1 KWH of Electricity and 1 kg of dry waste produces 18MJ heat. Hence, 18 MJ of heat i.e. 1kg of waste will produce 2KWH of Electricity.

Now, 972 kg of dry waste would produce = 972 × 2
= 1944 kwh/day
Per month electricity production = 1944 × 30
= 58320 kwh

Assuming Per unit rate of electricity = Rs. 5
Revenue generated/month = 58320 × 5
= Rs. 2, 91,600
Revenue generated/year = 291600 × 12
= Rs. 34, 99,200
~ Rs. 35 Lacs
Cost of operation and maintenance ~ 5 lakhs
Therefore, Revenue Rs. 30 Lacs

3.3 Revenue from Scrap Calculation

Scrap available (Metal + Glass) = 2700 × 0.05
= 135 kg/day
∴ Glass content = 2700 × 0.03 = 81 kg/day
Metal content = 135 – 81 = 54 kg/day

Now applying a thumb rule, out of 54 kg/day scrap
50 % would be iron i.e; 27 kg/day
25 % Aluminium i.e; 13.5 kg/day
25 % Copper i.e; 13.5 kg/day

Rate per kg of [10]
Iron Scrap rate = Rs.20/kg
= 27 × 20 = Rs.540
Aluminium Scrap rate = Rs.136/kg
= 13.5 × 136 = Rs. 1836
Glass scrap rate = Rs.4/kg
= 4 × 81 = Rs. 324
Copper Scrap rate = Rs. 411/kg
= 13.5 × 411 = Rs.5548.5

Total Scrap revenue/day = 540 + 1836 + 324 + 5548.5
= Rs. 8248.5/day

Scrap revenue/year = 8248.5 × 365 = Rs. 3010702.5

Considering Operation and Maintenance cost of Segregation plant as 5 Lacs approx;

Actual Scrap Revenue per Year = 25.10 Lacs

Hence, total profit generated from waste per year
= Revenue from (Biogas + Fertilizer + Electricity + Scrap)
= 35.76 + 30 + 25.10
= 90.86 Lacs
The above calculated profit generation seems quite plausible,

but the cost of installation of these systems is to be taken into account. Also, the payback period calculation is to be performed. In order to do this various sources were found out and the extrapolation on the basis of the data were done.

3.4 Cost of plant (Approximate Data)

3.4.1 Biogas plant installation

Plant Capacity required = 500 m^3/day

Cost of 1 m^3 Biogas Plant = 5294.11 [11]

∴ Cost of 500 m^3 Plant = 5294.11 × 500

= Rs. 2647058

= Rs.26.5 lakhs approx.

3.4.2 Biogas Filling Plant = 34.5 lakhs [12]

3.4.3 Electricity Generation plant:

Plant Capacity required = 2000 kWH

Cost of 1 kWH Electricity Plant = 3600[13]

= 2000 x 3600

=72 Lakhs

3.4.4 Segregation plant = Rs.20 lakhs [14]

Total Installation Cost = 26.5 + 34.5 + 72 + 20

= 153 lakhs

The above is the cost of overall system installation excluding the land cost and extra infrastructure costs. It is assumed in the calculation that the plant would be installed by a government body. The land cost is to be considered in case of privately owned plant. Also the necessary paperwork and legalization expenditure is also excluded.

4. Payback Period Calculation:

Maintenance Cost = 30% * total plant cost

= 35.5 lakhs/year

Payback period = Investment/Cash flow per year

= 153 / (90.86-35.5)

= 2.78 years ~ 3 Years

Hence, total Initial Investment =153 Lakhs = 1 Cr 53 Lakhs

The Payback Period is 3 years.

The same data was presented to the Panchayat of Morba by representing data on the chart as shown below. The Panchayat appreciated the efforts of calculating and gave an assurance to carry forward the idea.

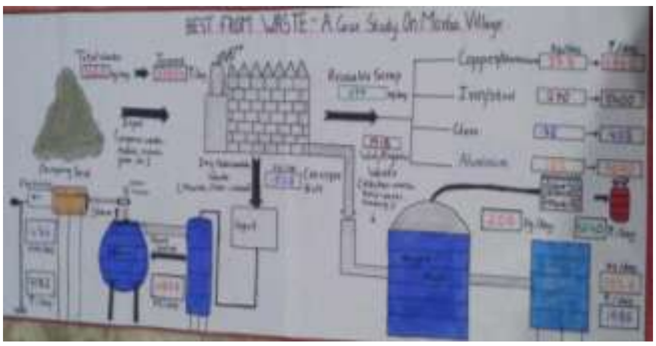

Figure 4: Calculations representation on a chart model

5. Conclusion

This waste to energy methodology helps a country in two ways; it solves the waste disposal/handling problem and helps in energy generation and fertilizer production.

The case study on Morba village effectively supports the above statement. The process of waste collection, waste processing and energy generation is well explained and related calculation is done. The total revenue generated is 90.86 Lacs. Though this methodology holds a very promising future, however the growth of this sector has been affected due to the following limitations/ constraints, Waste-to-energy is still a new concept in our country (India). The initial cost for the set up of biogas plant, segregation machineries etc is high. Most of the technologies (required in different phases of waste to energy generation process) are 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/Urban Local Bodies. Lack of conducive policy guidelines from State Governments in respect of allotment of land, supply of garbage and power purchase / evacuation facilities.

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