Feasibility Study on Solid Waste to Useful Energy

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Abstract - Solid waste management becomes a major challenge in a country with increasing population and simultaneously striving for economic development. Many studies indicate that solid waste generation rate is influenced to a large extent by the level of industrialisation, habits of public and climatic conditions. Presently world’s more than 50% population resides in urban areas. The outmoded methods used there for solid waste management are neither efficient nor environment friendly. Solid waste may become a precious resource by adapting an appropriate waste management method and the rightly controlling the resulting environmental pollution. It may be converted into an effective fuel to act as the urban sustainable energy of tomorrow. Harnessing the useful energy from the solid waste effectively ultimately would contribute in improving the country’s economy. The fast depleting fossil fuels and their ever-increasing demand further reinforce the importance of energy from alternate sources and if this alternate source is solid waste, it will be like striking two birds with an arrow. The present study focuses on the sustainable treatment of solid waste disposal and explores several methods to harness energy from it. The authors have carried out this study in a University Campus.

Keywords – Solid Waste, Energy, Fossil Fuel

1. Introduction
It has been reported [1] that in year 2016, the quantum of about 2.01 billion tonnes solid waste had been generated by different cities across the globe which quantifies to a footprint of 0.74 kg / person / day. Due to day by day increasing population and modernization, it is estimated that waste generation per annum is to be escalated by 70 percent from 2016 level to 3.40 billion tonnes in 2050. The comparison among producers of global waste is shown in Figure 1. The major shift in global waste is moreover due to modernization, changes in habits, luxurious lifestyle, avoiding sustainable solutions etc. in day to day life.
Technology enthrallment in larger cities is one of the major reasons for exponential rise in waste generation. In India, waste generation is comparatively higher (approximately 0.51 – 1.0 kg / person / day) as compared to other developing countries (approximately 0.1 – 0.495 kg / person / day) across the world. The Energy & Resources Institute (T.E.R.I.) predicts that waste generation will surpass 2.6 x 10^7 tons per annum by 2047, which is 5x times of the existing level in India. Larger populated cities (approximately more than one Lakh) are the main suppliers (72.5 %) of cumulative waste produced in the country. Figure 2 epitomizes the waste created in various towns of country with a comparison of generation of waste in different time span. The per capita per day generation of waste in metropolitan cities has shifted from mean value of 0.5 kg to 1.5 kg [1, 2].

The continuous depletion of fossil fuel and increasing energy demand leads to the exploration of sustainable energy resources. On the other hand, the extensive use of fossil fuel is also believed as the
foremost cause for numerous environmental concerns such as air pollution and global warming. That is why the concept of conversion of waste to useful energy is considered to be one of the best alternatives to cope up the rising worldwide requirement for energy usage. Using WTE technologies, non-ecological and non-biodegradable wastes could potentially be utilized for the production of sustainable alternative energy resources like biofuel and biogas. The conversion also helps to preserve or even slash the carbon cycle of the generated waste [6].

The solid waste production rate is absolutely related to the Gross Domestic Product (GDP) of developing countries. Figure 3 critically showing the relationships between GDP of few nations and per capita MSW generation rates. The MSW generation rate is directly allied with the cumulative growth of a nation. Many countries have shown linear correlations between GDP per capita and MSW generation rate per capita.

![Figure 3: MSW generation rate versus GDP of various countries (Waste Atlas, 2016)](image)

If solid waste is harnessed properly it can give a boost to the economy by reducing dependency on fossil fuels. Need of the hour is to focus significantly in the direction to harness more and more energy through waste recycling and waste processing. In fact, the entire philosophy of waste management needs proper and dedicated efforts right from the household / neighbourhood level to cities, states and the nation [3].

1.1 Solid Waste Management

The best method adopted so far is to dispose of all the waste materials. Likewise, more than 90% of cases, elimination is the solution for any waste material. These wastes are thrown either into open dumps or burned into open air [4]. The following methods are normally implemented for disposing the waste:

- **a) Open dump method**
  It has been observed that more than 90% of the waste elimination is done through uncontrolled open dump system. Most of these dumps are completely saturated.
b) Land fill mode
This technique stores waste underground. This can be implemented easily and is inexpensive in nature. Landfill biogas can be used as a by-product for domestic and household applications. On the other hand, it needs a larger area for proper implementation and also it poses serious threats to the society such as air pollution, ground water pollution and soil contamination.

![Figure 4: Waste management Hierarchy [10]](image)

Figure 4: Waste management Hierarchy [10]

c) Composting mode
Composting is an attractive biological solution used to recover organic material from solid waste. It actually converts biodegradable material into organic fertilizers.

d) Recovery and recycling mode
Recyclable materials like paper, glass, textile materials, metals, plastic etc. can be recycled and recovered into usable form.

Figure 4 shows the hierarchical order of waste management. It is clear that most desirable option is prevention and the least desirable option is landfill, while other modalities of waste management can be recovery, recycle and reuse. It has been reported from various research studies that recycling is a preferred option than energy recovery. It has been observed that the countries exercising recycling have high rate of energy recovery from waste. However, the implementation of WTE facilities is becoming a challenge due to protests from localities, especially in developing countries with high density of population [7].

2. Waste to Energy (WTE) Technologies [4, 5]
It is a well-known fact that generation of waste in India is consistently increasing day by day and it’s a high time to reconsider its waste management stratagem. Although the use of fossil fuels as conventional fuel to produce electricity is still an attractive solution which ultimately increasing the consumption, demand and price as well. To provide a sustainable solution, waste can be a use as an attractive alternative fuel as its supply would be relatively impervious round the year.

2.1 Incineration
Incineration is considered as one of the best established technology to harness energy from waste. In this process, the waste is burnt in furnaces and energy is generated with the application of heat (either electrical energy or heat energy). By-products so obtained in this total process are powder ash and
exhaust gas. The ash residue of this process can be chemically treated to confiscate metals for recycling and the left over can be utilized in construction of materials.

2.2 Anaerobic Digestion
Anaerobic digestion is another attractive technology to create energy from waste. In this process, bacteria decompose materials in the absence of air. Owing to this process, a combination of Methane and Carbon di oxide, Biogas is produced which is again a form of Renewable energy and can be used as a fuel. In anaerobic digestion reduced carbon di oxide emissions, possible valorization of ecofriendly waste for soil conditioners and lower odor emissions can be achieved.

2.3 Gasification and Pyrolysis
In gasification process, organic compound such as briquettes, rice husk, and wood of different trees is converted into renewable fuel (Syngas) and a solid char. This conversion is processed at 650°C plus temperature. Syngas has high calorific value and can be applied for generation of power and bio fuel. Char is a combination of carbon and ash. Different gasification technologies practiced all over the world. The reactors used and the operations realized distinguished these reactors.
Pyrolysis is the process of thermal degradation that occurs with limited supply of oxidizing agent in the temperature range of 400°C to 1000°C or even without the supply of any oxidizing agent. Pyrolysis gas, pyrolysis liquid and solid cokes are produced due to this conversion. The potential efficiencies of pyrolysis and gasification are competitive and both techniques can process every kind of municipal waste.

3. Case Study — A University Campus
Area of the University Campus undertaken for the present study spreads over 44 acres. Owing to its large size, it often encounters issues related to waste management. The University is having lush green campus with proper support of technology. The whole campus is having solar photo voltaic (PV) cells roofs, solar parabolic dishes, gasifier, bio gas plant, composting etc. A lot of energy in different forms can be harnessed and processed accordingly. The waste is properly dumped and collected as wet waste and dry waste in different bins across the campus. The waste from hostels is also collected on daily basis and processed to harness useful energy.

3.1 Solid Waste Sources
Solid waste is being collected from everyday items such as tree leaves, papers, furniture, wooden waste, food scraps, bottles, clothing etc. The waste collected so far are either in solid form or in semi-solid form. They can be categorized as bio-degradable waste which embraces kitchen waste, organic waste and paper waste.

Table-1: Waste composition category

| Category         | Description                                                                 |
|------------------|-----------------------------------------------------------------------------|
| Organic matter   | Food waste from Hostel Mess, leaves from trees in Campus                     |
| Paper / Card board| Office waste paper, old newspapers, magazines, waste card boards etc.        |
| Plastic          | Plastic bags, plastic bottles, plastic strings etc. from stores, offices, workshops, labs etc. |
| Glass            | Bottles, glassware, light bulb, ceramics etc.                                |
| Metal            | Iron and Non-Iron metals including knives, metal waste from workshops, cans, wire, fence, bottle cans etc. |
| Wood             | Wooden chips waste from workshop, furniture waste etc                       |
4. Solid Waste Management Methods being adopted
In the present work collection and processing of different waste have been analysed. Details are discussed in the subsequent sub-sections.

4.1 Collection of Dry Leaves
The trees that provide beauty to the campus become problematic due to falling leaves. The dead leaves if not handled timely and properly not only make the surrounding dirty but can also lead to spread of diseases. As the concept of source segregation of waste is not being followed currently, various wastes from within the campus were observed for 10 different days to evaluate the approximate amount of different waste (Figure 5).

![Figure 5: Distribution of different Waste](image)

Dead leaves from the campus are collected and transported to nearby farms via trolleys on a daily basis. These dry leaves are then mixed with cow dung and mixture is then put into various compost pits where it is left for decomposition.

Composting is a process involving decomposition of organic waste into humus (compost) which acts as a natural fertiliser for plants. The composting process needs to make a stack of organic wastes (like dead leaves, leftover food, etc.) and waiting for this material to decompose into humus after some time (a few weeks or months). The process is accelerated in presence of cow dung or earthworms (Figure 6).

![Figure 6: Composting of Dead Leaves](image)
4.2 Leaf Logs or Briquettes
The Logs (Briquettes) consist purely of dried leaves & other waste material like paper, cardboard, etc. These are used to produce renewable energy. Typically, waste is often dumped in landfills and one of the problems with waste material (like wet leaves) is that they give off methane (a 20 times more poisonous gas than carbon dioxide). Briquettes are extremely cheap and are manufactured easily using simple technique providing calorific value up to 27,000 kJ/kg. These briquettes are processed through briquetting machine and further used in Gasifier installed in Community Kitchen (Figure 7). The usage of Gasifier has been brought down the monthly cost of fuel by 20-30%.

4.3 Leftover Food from Hostel Mess
The University has separate Boys’ and Girls’ hostels in the campus. The leftovers from lunch and dinner within the hostel mess inside the campus is collected in a bin / bucket and sent to bio gas digester on daily basis. The waste food was observed for 10 days to evaluate the approximate amount of daily waste (Figure 8).

4.4 Bio gas Plant
The bio gas plant is first of all charged with slurry of about 20 kg of cattle dung, kitchen waste and water. The bacteria present in the cattle dung decompose the organic material into methane and carbon
After a waiting time of about a fortnight, the gas generated due to chemical reaction. Then it would start to be emitted and the gas holder (upper tank) will rise. Once the gas is used the upper tank will again sink down. The feed (kitchen waste) should be meshed properly and mixed with water so that bacteria can act upon it. This is done as bacteria within our body also is fed upon food material that is meshed and having rich water content.

4.4.1 Analysis of Hostel Waste
The following details show the energy produced round the year from hostel food waste (Data collected before COVID-19 situation).

- Average waste produced in a mess per day = 50 kg
- Equivalent amount of Bio-gas produced = 12.5 kg
- Calorific value of biogas = 20.2 MJ/kg
- Total energy produced in a day = 12.5*20.2 = 252.5 MJ
- **Total energy produced round the year** = 252.5 MJ * 210 = 53025 MJ
  (Excluding holidays, breaks and winter season)

This energy is equivalent to 68 LPG cylinders (commercial)
( Assuming CV of LPG cylinder as 41 MJ/Kg and weight as 19 kg)

5. Conclusion
In this paper, the authors have shown that masses of dead leaves from the campus can be converted to leaf logs (briquettes) to harness a large amount of energy. The manufactured briquettes are eco-friendly and also, their properties like calorific value etc. are comparable to the conventional fuel.

In case of leftover hostel mess food, it was observed that the bio digester being used is quite suitable waste disposal system due to its low setup cost and its ability to produce biogas from even small quantity of food waste. It is not only acting as a waste disposal unit and but also converting the waste into useful energy.

6. Future Scope of the Study
It is hoped that the current study will certainly provide a platform for technocrats and researchers to explore more possibilities for converting waste into useful energy. In the present scenario, the challenge of society is to ensure safekeeping of sustainable renewable energy and waste management.
as well. Waste to energy technologies would provide a sustainable renewable solution for the generation of clean energy to elude these challenges.

Green House Gas emissions can be lower down significantly by promoting WTE technologies for solid waste management. WTE technologies have been promoted and used comprehensively in the developed nations for efficient management of MSW. In most of the developing countries, these facilities are stepped down due to improper infrastructure, ineffective pollution control system, and negligence in maintenance. Further, number of economic, technical, political, institutional and social issues may shackle the implementation of these technologies. Therefore, a special attention is needed from all stake holders, especially government, technocrats, businessmen to support the execution of future sustainable energy resources.

7. References

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