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Management of Energy with Utilization of Municipal Solid Wastes and Agricultural Wastes

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This paper is an attempt to solve the dual problem of energy crisis and waste disposal in the rural sector. The need for electrification from small thermal power plants (5 MW to 10 MW) using agricultural and municipal wastes as fuel in place of coal is stressed. This will not only provide some economical solution to the energy problem, but also give considerable relief from pollution. Hence, a proper management of energy from waste for electrification is suggested.

Keywords: Energy, Solid Waste, Agricultural Waste

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1. Introduction

Ever since the dawn of mankind, we have been consuming energy unmindful of the fact that the reserves are finite. The resources have depleted at an alarming rate while over demand has been increasing steadily. The energy crisis is real and crave and answer to this problem is 'Energy Conservation'.

Serious problems which the present world is facing are: a) Energy crisis b) Waste disposal

The problem of environmental pollution is connected with these problems. The world energy demand is increasing at the rate of about 4.5% per year due to increase in population and various development programs aimed at raising the living standard of the people. As the world consumes more energy, greater the amount of waste is being produced. Hence the energy problem and the waste disposal problem are interconnected. In this paper, we are concerned about waste includes municipal solid waste and agricultural waste like rice husk, bagasse, saw dust, biogas, forest waste etc.

2. Energy from Municipal Solid Wastes

Solid waste management deals with the disposal of municipal solid waste (MSW) material for generation of energy in an economical and environmental friendly manner. Waste disposal is one of the major problems being faced by all nations across the globe. The main difficulty for waste disposal is collection and separation of waste material. Major portion of collected waste is dumped in landfill sites. The recyclable contents of waste ranges from about 13% to 20% [20]. A study of U.K. Department of Energy's Technology Support Unit (ETSU) at Harwell revealed that about 60 million tones of coal equivalent of energy- 18% of total energy consumption was thrown away every year as waste, which is made of organic residues of forms, forestry, industry and domestic refuses [2]. According to Technology information forecasting & assessment council (TIFAC) Delhi, Mumbai, and Calcutta would be generating 5000 tones of garbage everyday, in about a decade, and disposal would be difficult. This existing dumping would also create enormous pollution and health hazards.

2.1 Generation of MSW

Per capita waste generation ranges between 0.2 kg and 0.6 kg per day in the Indian cities amounting to about 1.15 lakh Million Tonnes (MT) of waste per day and 42 million MT annually [24].

The waste generation rates in India are lower than the low-income countries in other parts of the world and much lower compared to developed countries. However, lifestyle changes, especially in the larger cities, are leading to the use of more packaging material and per capita waste generation is increasing by about 1.3 per cent per year. With the urban population growing at 2.7 per cent to 3.5 per cent per annum, the yearly increase in the overall quantity of solid waste in the cities will be more than 5 per cent. The Energy and Resources Institute (TERI) has estimated that waste generation will exceed 260 million tones per year by 2047—more than five times the present level. Cities with 1,00,000 plus population contribute 72.5 per cent of the waste generated in the country as compared to other 3955 urban centers that produce only 17.5 per cent of the total waste as shown in Table 1 [25].

Table 1: Waste Generation in Class 1 Cities with Population above 1,00,000

Type of cities	Tonnes/ day	% of total garbage
The 7 mega cities (Mega cities are above 4 million population)	21,100	18.35
The 28 metro cities	19,643	17.08
The 388 class 1 towns (Class 1 cities with population in the 100,000 to 1 million range)	42,635	37.07
Total	83,378	72.50

In addition to MSW, large quantity of waste, in both solid and liquid forms, is generated by the industrial sector like breweries, sugar mills, distilleries, food processing industries, tanneries, and paper and pulp industries. Out of the total pollution contributed by industrial subsectors, 40 to 45% of the total pollutants can be traced to the processing of industrial chemicals and food products and agro based industries together contributes 65-70% of the total industrial waste water in terms of organic load [10, 20]. Table 2 gives an estimate of waste generated in India by various sectors and Industries.

Table 2: Estimated quantity of waste generated in India

Waste	Quantity
Municipal solid waste	27.4 million tones/ year
Municipal liquid waste (121 class I & II cities)	12,145 million liters/day
Distillery	8057 Kilo liters/day
Pressmud	9 million tones/ year
Food & fruit processing waste	4.5 million tones/ year
Willow dust	30,000 tones/year
Dairy industry waste	50-60 million liters/days
Paper and pulp industry waste (300 mills)	1600 m3 waste water /days
Tannery	52500 m3 waste water /days

In addition, the daily per capita sewage generation is about 150 liters. The total sewage generated in India, about 5 billion liters/day in 1947, grew to 30 billion liters/days in 1997. However, the total treatment capacity available is only about 10% of the quantum generated. It is estimated that under the Ganga action plan, 46000 Nm^3 (Normal cubic meter) of biogas can be produced daily from the sewage treatment plants in 21 Indian cities by treating about 339 million liters/ days of municipal waste water. This, with appropriate biogas power plants, will generate total Electrical energy of 99,450 kwh/day [8, 20].

2.2 Fuel Pelletization Plants

As part of pilot project for integrated waste management, the Department of science and technology (DST) and Technology Information, Forecasting and Assessment Council (TIFAC) New Delhi established a prototype fuel pelletization plant at Deonar, Mumbai, in the early 1990s [15,20]. In this process, the garbage was first dried to bring down the high moisture levels. Sand, grit and other incombustible matters were than mechanically separated before the garbage was compacted and converted into pellets. Fuel pellets have several advantages over coal and wood, it is cleaner, free from incombustibles, has lower ash and moisture contents, is of uniform size, cost effective, and eco-friendly [20]. The RDF pellets can be conveniently stored and transported long distances and can be used as a coal substitute at a lower price. It is planed to establish 10MW plant, which convert the city's garbage into fuel pellets [10].

2.3 Biomethanation

Biomethanation is a comparatively well-established technology for disinfections, deodorization, and stabilization of sewage sludge. It leads to bio-gas/power generation in addition to production of compost (residual sludge). This process reduces the environment pollution and proved to be an eco-friendly energy production method [20]. In India, recently a 5 MW power plant based on biomethanation technology was constructed and operationalized at Lucknow but unfortunately it had to be closed down for various reasons, one among them being non-supply of appropriate quality of MSW to the plant. The organic content in the waste supplied to the plant is reported to have been as low as 15 per cent. Biomethanation technology on a small scale is also functioning at Vijayawada and at other places in the country for the treatment of selected organic waste collected from canteens, vegetable markets, etc [26]. A United Nations Development Programme (UNDP), Global Environment Facility (GEF) funded project called Development of High Rate Biomethenation Processes as a Means of Reducing Green House Gases Emission is being implemented by the Ministry of Non-Conventional Energy Sources covering different waste sectors [21].

3. Energy from Agricultural Waste

As vast majority of Indian population lives in villages and agriculture is the main work of the people living in the villages. Thus agricultural waste products is available in huge amount and does not cost any thing to produce it, only collection cost is there, the electricity produced will be of very low cost and most appropriate for domestic purpose and running small scale industries [6]. In India, about 17 million tones of rice husk and about 5 million tons of rice bran are produced annually along with about 52 million tons of clean rice. Farm income can be increased both directly and indirectly if these large quantities of rice husk are utilized in an economically profitable means. Agricultural wastes, like paddy and wheat straw, have significant long term potential due to their abundant availability [18].

3.1 Agro Thermal Power Plants

The Department of Non-Conventional Energy source in collaboration with Punjab has set up a 10 MW agro-thermal power plant based on rice husk at Jalkheri near Patiala. This project envisages de-husking of large quantities of rice and utilization of husk in the first stage to extract furfural and then to

then to fire husk in a fluidized boiler linked with co-generation plant to generate 10 MW of electricity. This plant will have about 5 MW of surplus electricity to be connected to the grid [6]. It has been estimated that sugar industry in India can generate almost 2,000 MW as surplus electricity during crushing season. It has been estimated that sugar plant requiring 4 MW can produce with its bagasse 10 MW of electricity. Hence after meeting factory's requirement, about 6 MW can be surplus to be fed to the grid. Since sugar factories are normally in the rural areas, this surplus electricity could be used for irrigating sugarcane fields or industrialization of rural areas [4]. It has been estimated that power requirement to the extent of 12000 MW can be met with in India by utilization of paddy and wheat straw [2].

Rice and sugarcane is harvested in the month of November. Since the rice straw and bagasse has moisture contents from (4 to 50%), we have to dry them in open air for two to three months. Then some of these wastes can be utilized for generating energy and supplying it to irrigation pumps for irrigating wheat crop in the month of February-March and the remaining part of the waste can be stored, which can be utilized for the irrigation of rice, sugarcane and for other crops in the month of July-August. In addition to the major advantages of the management of rural energy, there are lots of other advantages. The coal generally used in thermal power plant contains 26 to 55% of ash. But in case of agricultural wastes (husk, straw, bagasse) the ash percentage is 1-17 %. [5] Thus the area required to dump this ash is less. Also, ash handling cost is less. So for coal based thermal plants very efficient filters are required to reduce dust pollution, it is almost negligible in case of agricultural wastes [6]. The fuel such as rice husk, bagasse and saw dust can be utilized by using fluidized bed combustion (FBC) in an economically viable and environmentally acceptable manner. More than any other type of combustion system, FBC systems are flexible in their ability to burn a wide range of fuels [5]

3.2 Fluidized Bed Combustion

Fluidized bed energy technology offers several unique characteristics for using biomass in small scale energy conversion operations. A fluidized bed consists of a chamber in which solid particles suspended by high velocity air forced upwards through the particles.

The turbulent mass of solid particles stores heat and rapidly transfer this heat to any fuel introduced into the bed. Before rice husk is burnt in the fluidized bed it is necessary to heat the inert bed of solids to about 500^0 C using an auxiliary heating system. Normally about 2 to 3 hours of time is required for preheating the bed. Initial combustion tests reveled that 30 to 45 minutes were required to reach stable bed operating temp after initiating fuel bed. The units could be shut down for periods of 8-10 hours and can be restarted without preheating of the bed. Until a bed temp of 600 to 650^0 C is reached considerable amount of visible smoke and emissions were observed after Initiating fuel feed [18]. According to Institute of solid waste research and Ecological Balance (INSWAREB), rice husk, is the cheap by-product of paddy milling, has the potential to galvanize the electricity starved rural India with a gross calorific value of 3000 kcal/kg, it is capable of high efficiency combustion, could serve as the fuel for mini power plants of 1 to 2 MW capacity that can be set up in rural areas [20]. The properties of Rice husk are shown in Table 3.

Table 3: Properties of Rice husk

S.No	Parameters	Amount
1.	Moisture	9.59%
2.	Ash	15.089%
3.	Volatile Matters	66.043%
4.	Fixed Carbon	9.178%
5.	Particle size	1.95-2.28 mm
6.	Bulk density	117.6 kg/m3
7.	Gross Calorific value	3459 kcal/kg

4. Waste Management through Combustion

Energy recovered through the combustion of waste was not considered seriously. For the last 20 years, combustion technology has grown to include an added benefit of energy recovery. Combustion facilities have been successful in recovering material from the waste stream that can be recycled and recovering energy from the residual waste to generate electricity. Electricity generated from waste combustion has become so reliable that the power is "base load" for utilities [7]. Waste combustion is similar to recycling in that it can reduce GHGs emissions in two ways. First, combustion diverts MSW from landfills where it would otherwise produce CH_4 as it decomposes.

Second, the electrical energy resulting from waste combustion displaces electricity generated by fossil fuel fired power generators [17].

5. Waste Management through Recycling

Recycling is also the best strategy to reduce solid waste. Recycling involves the segregation, collection, storage and removal of recyclable or combustible materials. In addition to reducing waste and the associated disposal costs, recycling collection can generate substantial revenue for organizations. Although recycling metal, glass, plastic, paper and other waste expends energy and is therefore less effective than reuse; the process of recycling allows the materials within those products to be reused. The costs and returns of recycling programs depend on local resources and market demand for specific materials. By investigating local market conditions, organizations can develop a recycling program that is economically beneficial. The environmental benefits of recycling include saving energy and preventing pollution associated with the extraction and processing of raw materials, reducing the need for land filling and incineration, and conserving natural resources [23].

6. Waste Management through Landfills

In 1974, 108 million metric tons of MSW and combustion ash were land filled in the United States. In 1997, approximately 129 million metric tons of MSW and combustion ash were land filled, representing 56% of the MSW generated. Modern landfills avoided the release of 44 MMTCE of GHG emissions annually [13]. Landfills with gas collection systems reduce the release of GHG emissions associated with the decomposition of waste. Energy can be recovered from the utilization of CH4 in landfill gases [12]. The key factors in determining GHG emissions produced from landfills are the amount of waste managed, level of gas collection and control, effectiveness and timing of the control, and level and type of energy recovery [17]. Figure 1, illustrates the process of decomposition undergone by organic materials in a landfill. The organic materials that contribute to biogas production are primarily cellulose materials and food waste.

The materials are invaded by aerobic bacteria and fungus, which begin the decomposition initially, process, producing carbon dioxide and water. After these organisms deplete the oxygen in the buried wastes, anaerobic bacteria begin to dominate. The first groups of anaerobic bacteria are those that are also tolerant of aerobic conditions. This group of bacteria hydrolyzes the cellulose materials, breaking them down into simple sugars that are more easily decomposed by other bacteria. Other bacteria in this group of oxygen-tolerant anaerobic bacteria decompose the sugars and other organic materials, forming acids and carbon dioxide. Finally, the methanogenic bacteria, which cannot tolerate oxygen, become dominant and the methane production reaches a peak in a given area of the landfill. This process can take up to 2 years before the methane production reaches its peak. It then slowly declines over time as the feed materials are used up [22].

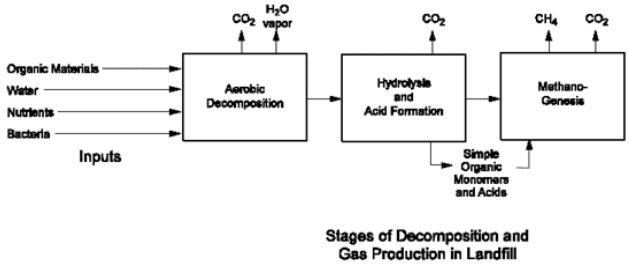


Figure 1: Process of Decomposition

The advantage of landfilling is that, it is the least cost option for waste disposal and has the potential for the recovery of landfill gas as a source of energy, with net environmental gains if organic wastes are landfilled. Major limitation of this method is the costly transportation of MSW to far away landfill sites.

7. Greenhouse Gases (GHGS)

A study was conducted using a life-cycle methodology to track changes in GHG emissions during the past 25 years from the management of MSW in the United States. In 1974, MSW management consisted of limited recycling, combustion without energy recovery, and landfilling without gas collection or control. About 8% of waste was recycled as commingled material and 21% of waste was combusted (without energy recovery) and remaining 71% of waste was landfilled without landfill gas control. During the next 25 years, recycling steadily increased from 8% in 1974 to 10% in 1980, 16% in 1990, and 27% by 1997.

By 1980, waste combustion without energy recovery declined and was replaced by waste-to-energy plants. Data indicate that by 1997, 17% of the MSW generated in the United States was used to produce electricity at 102 waste-to-energy facilities nationwide. Also in 1997, 56% of the waste that was landfilled was going to approximately 1200 sites with liners, leachate collection and control. Some of these sites, primarily the larger ones, also have landfill gas control. With the time and technology change, it is moved towards increased recycling, combustion (with energy recovery) and land filling (with gas recovery, control utilization). The benefit of material recycling and energy recovery is to reduce potential GHG emission despite an almost 2-fold increase in waste generation [11,14,17]. GHG emissions from MSW management were estimated to be 36 million metric tons carbon equivalents (MMTCE) in 1974 and 8 MMTCE in 1997. If MSW were being managed today as it was in 1974, GHG emissions would be approximately 60 MMTCE. GHG emissions were calculated for the years 1974, 1980, 1990, and 1997. Figure 2 illustrates the changes to waste management for each of these years.

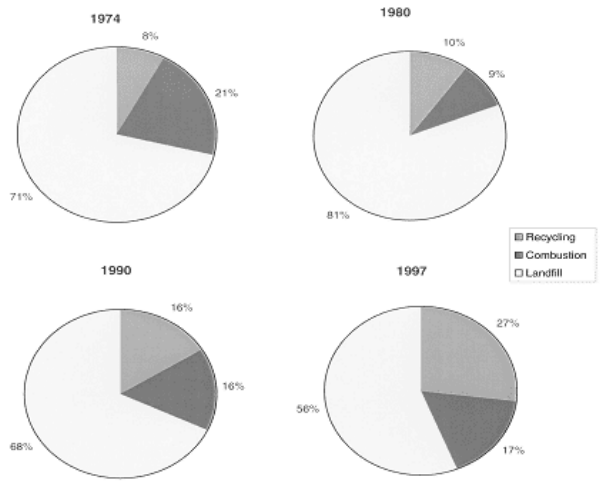


Figure 2: Changes in the management of waste in the United States from 1974 to 1997

8.Conclusion

This paper has presented management of energy from MSW and agricultural waste by converting this energy into electrical energy with the help of small thermal plants which may be utilized to provide electricity for irrigation pumps in rural area, for small scale industries, for recycling and for producing gases fuels. In this way, the waste can utilize as renewable sources of energy.

The additional advantage is economics in production, reduction in pollution and avoiding land filling is also obtained in this process of energy management. However, there is an urgent need of some mechanism for collection, separation and transportation of waste. So that proper quality and quantity of the waste generated may be sufficient to be utilized for production of power or for some other useful purpose as explained in this paper.

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