Research Journal of Agricultural Sciences 9 (1): 48-50, 2016
ISSN: 1308-3945, E-ISSN: 1308-027X, www.nobel.gen.tr

Biogas Production Potential of Solid Wastes: A Research Experience

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Received: January 08, 2016
Accepted: February 24, 2016

Abstract

Energy demands are increasing with ever-increasing world population. Such increasing demands resulted in a rapid increase in number of renewable energy facilities. Current energy requirements are mostly met with fossil fuels all over the world. However, fossil fuels have significant hazardous impacts on environment and make several countries dependent to foreign countries. Thus, renewable energy sources are quite significant for environment and country economies. Biogas is one of the most popular renewable energy resources. In this study, performance of an electricity generation facility from solid wastes in Tokat province was assessed. Experiments were performed under controlled conditions between July and December. The daily amount of incoming solid waste to the biogas production facility (kg), electricity generation (MW) and methane gas production were determined. In addition, temperature and relative humidity were also examined. The daily solid waste entered to the process was between 4494 - 7239 kg. With this solid waste, minimum methane production was 43,33 m3 and the maximum methane production was 54,91 m3 corresponding to minimum 1,58 MW and maximum 5,85 MW electricity production in one day.

Keywords: Renewable Energy, Biogas, Solid Waste

INTRODUCTION

Energy demands are every-increasing to improve the life quality of people worldwide. Besides, rapid increases in pollution also increase energy consumption. Fossil fuels are the most common energy source, but these sources are not able to meet current demands. Therefore, more efficient studies should be carried out on renewable energy sources and technologies both to increase the productions and to widespread the use of these renewable sources [1]. Energy consumption is among the most significant factors indicating the development levels of the countries [2]. Recent increases in energy prices in Turkey and foreign-dependency in energy market increased the interest in renewable energy sources.

Negative impacts of fossil fuels on environment have reached to considerable levels. Especially carbon emissions are way over renewable energy sources. Biomass energy is one of the most important renewable energy sources. Biomass is the only energy with carbon renewable [3].

Biogas is one of the most significant energy sources to be produced and used in Turkey. Biogas is a gas produced through anaerobic fermentation of organic wastes. This is an autogenous process in solid waste storage facilities. Domestic, agricultural and industrial organic wastes are used in biogas production of solid waste storage facilities [4]. Biogas is composed of 65% methane (CH_4), 35% carbon dioxide (CO_2) and slight amounts of moisture [5, 6, 7].

Biogas was first started to be used in Germany and France. In Germany, biogas production activities are planned to be implemented in 43000 large facilities by the year 2020. In biogas production, Germany is followed respectively by Italy, France, the Netherlands, Czech Republic, Spain and Austria [8, 9].

Wastes with various origins are used in biogas production activities and these waste sources are provided in detail below:

Livestock wastes: Manure of cow, horse, sheep and pig-like livestock, slaughter house wastes, the wastes created during the processing of livestock products.

Plant wastes: Cereal, straw and hay wastes, maize wastes, sugar beet leaves, hazelnut husks, weeds, the wastes created during the processing of plant products.

Organic domestic and industrial wastes: Sewage and bottom sludge, paper and food industry wastes, other domestic and industrial wastewaters with high dissolved organic matter concentrations. These kinds of wastes are used in large biogas production facilities constructed by local administrations (municipalities) and large industrial corporations [10].

Waste repositories or sanitary landfills have commonly been used for the storage of urban and industrial solid wastes for years. Organic wastes constitute large portion of domestic wastes and disposal of these wastes initially applied in these repositories [11]. Regular storage, repository or landfills store solid wastes in designated site or inactive mine sites and bury these wastes regularly. In Turkey, daily about 65000 tons of domestic and industrial solid wastes are stored regularly and landfill-gas with 40-60% methane is produced through anaerobic fermentation [12,13].

Landfill method for regular storage of solid wastes is also a significant methane production method [14,13] (Figure 1). Instead of inefficient burning and use of organic wastes as organic fertilizer, they should be gathered in landfills and used for biogas production. Feasibility studies have already been carried out by some local administrations and municipalities for biogas production from solid wastes or repositories. In places with sufficient space for regular storage of solid wastes, landfill method may control and minimize the hazards created on environment and allow controlled decomposition of solid wastes. Landfill is the easiest and the most economic method for disposal of domestic and industrial wastes [15].

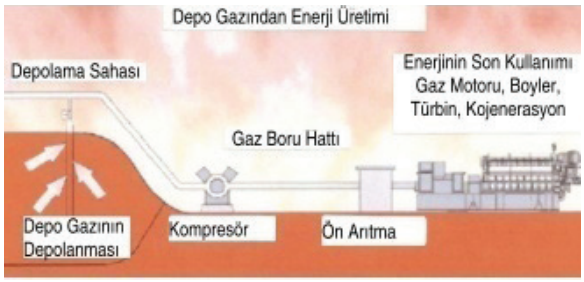

Figure 1. Energy generation system from landfill gas [16]

Biogas has a wide range of use including heating, electricity generation, direct engine fuel and agricultural use of by-products. In Germany, leading biogas producer, 2300 MW electricity was generated in 5800 facility in 2010 [17]. In Turkey, 85% of biogas potential comes from livestock waste (manure) and 15% comes from municipal landfill sites [18,19]. In this study, performance of an electrical energy production facility from solid wastes in Erbaa town of Tokat province was assessed.

MATERIAL and METHOD

In this study, biogas production of electrical energy generation facility in Erbaa town of Tokat province from the domestic wastes during 6 months of production period (between July and December 2015) were investigated and facility performance was assessed (Figure 2).

Figure 2. General view of the facility

The facility is constructed over 6 hectares land area. Daily solid waste intake of the facility varies between 4494 - 7239 kg. Average daily solid waste intake during the six months of research period is 5505 kg. Solid waste composition should be known for biogas production. Characteristics of solid wastes were determined daily before the initiation of biogas production.

During the biogas production processes, methane (CH_4), oxygen (O_2) and carbon dioxide (CO_2) measurements were performed daily at certain intervals. Measurements were performed with Geotech-brand gas measurement device (Figure 3). Instantaneous temperature and relative humidity measurements were also performed throughout the experiments. These measurements were performed with Clima air-brand temperature and humidity meter.

Figure 3. Gas meter

RESULTS and DISCUSSION

Ambient temperature and humidity are two significant factors effecting biogas production quantities. Therefore, ambient conditions were continuously measured and recorded during the production processes. Measured temperature and relative humidity values are provided in Table 1.

Table 1. Monthly average temperature and relative humidity values

	Temperature (C°)	Humidity (%)
JULY	31,67	76,67
AUGUST	29,25	77,00
SEPTEMBER	26,50	79,31
OCTOBER	19,00	78,26
NOVEMBER	13,00	66,83
DECEMBER	3,25	68,21

As it was seen in Table 1, temperature difference between summer and winter months were quite high as expected, but significant changes were not observed in relative humidity values.

Periodical methane (CH_4), oxygen (O_2) and carbon dioxide (CO_2) measurements were performed throughout the experimental period. Average measured values are provided in Table 2.

Table 2. Monthly average gas production values (m3/day)*

	Metane (CH_4)	Oksijen (O_2)	Carbondioxide (CO_2)
JULY	44,11b	1,55 a	35,48 b
AUGUST	44,73 b	1,51 a	34,36 b
SEPTEMBER	45,13 b	1,48 a	35,38 b
OCTOBER	44,33 b	1,49 a	36,45 b
NOVEMBER	45,13 b	1,48 a	35,38 b
DECEMBER	52,15 a	0,22 b	39,69a

*Statistically different at a α: 0.05

As it was seen Table 2, gas production values (methane, oxygen and carbon dioxide) were significantly different at 5% level only in December. Besides several other factors, abrupt decrease in temperature in December (as it can be seen in Table 1) might have resulted in this difference. However, the amount of solid waste incoming to the facility should also be taken into consideration. Therefore, electrical energy generation values are provided in Figure 4 based on

incoming solid waste quantities. Daily average values were considered in this graph. Every four values in "x" axis correspond to weeks of that month and values are provided for 24 weeks covering the months between July-December.

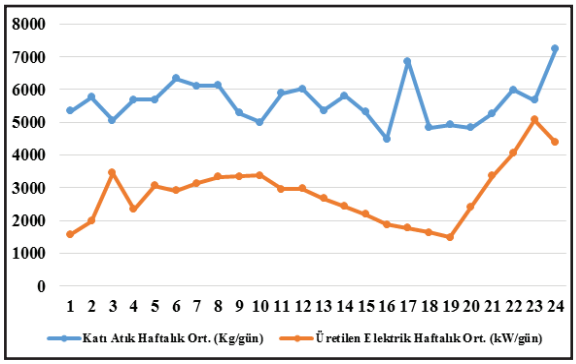

Figure 4. Daily incoming solid waste and electrical energy productions

As it can be seen from the graph, daily average values continuously changed. There was an inverse relationship between the change in incoming wastes and change in electrical energy generation. Contrary to expectations, such a case was because of the quantity of organic waste for biogas production rather than incoming solid waste. Especially the light weight of organic materials than the solid materials might have resulted in this inverse relationship. Therefore, the increase in solid waste quantities in kilograms might have resulted from the increase in ratios of glass and other metals in solid wastes.

CONCLUSION

As to conclude, this autogenous energy source is lost in several towns and provinces of Turkey. Considering the yield losses in already established solid waste repositories, daily about 2.9 MW electricity is produced from solid wastes in Turkey. Such a value-added produced from a settlement with 65000 population should be incorporated into country economy [20].

Biogas production facilities from solid wastes have significant positive effects on environment. Negative impacts on environment can significantly be reduced through controlled storage and methane production with fermentation of solid wastes. However, sending domestic and industrial wastes to biogas facilities without pre-separation makes the electricity production processes difficult and reduces the performance and yields of these facilities. Therefore, awareness should be raised within the society for the separation of recyclable wastes.

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