Tarım Makinaları Bilimi Dergisi (Journal of Agricultural Machinery Science)
2012, 8 (3), 271-277

Economic and Environmental Impacts of Biogas

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Received (Geliş Tarihi): 07.04.2011 Accepted (Kabul Tarihi): 17.05.2011

Abstract: Renewable energy resources have been drawing attention in many countries in recent years. One of them is biogas that is particularly important in rural areas. Developed and developing countries and some international organizations headed towards to biogas and other renewable energy sources because of many reasons, such as "Renewable", "Economic", "Environmental Pollution", "Global Warming", " Greenhouse Effect ", and "Public Health" etc. It is expected that fossil-based energy resources will run out after a short period. Nowadays, efficient of existing resources has not been considered as possible. These have forced to use more efficient and more widespread of renewable energy sources. In biogas systems, all kinds of organic waste have been processed and produced electrical energy in biogas production plants. In addition to the production of biogas electricity, formation of environment and air pollution caused by waste is also reduced to the minimum. Remaining waste of biogas is called bio-fertilizer. It is very efficient plant fertilizer, which is used in sustainable agriculture. Electricity generation from Biogas has been increasing rapidly in recent years. Generated electricity is given to the public power network. Besides, heat that occurred during this process is used to warm the facilities, which are located close to plants, such as greenhouses and housing.
Key words: Biogas, renewable energy, economy and environment.

INTRODUCTION

As it is well known, technology has been advancing day by day and population has been increasing continuously, but energy resources has been remained insufficient for this increase. We should start to use wastes that find within nature for generating electricity nowadays when we are involved in the search for new energy sources. Also, we can get rid of those wastes. This recycling process is called biogas. In recent years, biogas systems have been drawing attention especially in rural areas. Developed and developing countries and some international organizations headed towards to biogas and other renewable energy sources because of many reasons, such as "Renewable", "Economic", "Environmental Pollution", "Global Warming", "Greenhouse Effect ", and "Public Health" etc. Studies in several centers have been conducted on this technology, which has low-cost and does not produce waste, for the purpose of protecting - controlling the environment, and promoting to search resources that will replace to the fertilizer in several centers (Altun, 2005).

Biogas has been consisted of anaerobic fermentation of organic matter by certain microorganisms. In anaerobic fermentation, organic wastes of domestic, agricultural and food industry have been used in biogas reactors. Biogas can be used directly for heating and electricity production, and it can be used for a vehicle fuel or in natural gas system after CO_2 is separated and pressurized. Biogas is considered as a source of renewable energy due to continuous production of waste. If biogas replaces some fossil resources, the greenhouse gas emissions will be able to reduced (Yılmaz, 2009).

According to estimates from the Energy Market Regulatory Board, Turkey's electricity demand will increase by up to 60% in 2015. The Turkish Ministry of Energy and Natural Resources has decided to tend renewable energy sources for reducing the transfer of resources from abroad and due to commitments that are given by the signing of the Kyoto Protocol (Ulusan, 2009). Although various institutions under the Ministry of Energy currently apply according to Renewable Energy Resources Act that was made in 2005, New Renewable Energy Resources Act that is No. 6094 was legislated in December 29, 2010. The purpose of this new law is to promote the use of renewable energy sources for electricity production, gaining of these resources into the economy as reliable, economical, and quality manner, increasing of the diversity of sources, cutting of greenhouse gas emissions, assessment of wastes, environmental protection and developing of the manufacturing sector that is required realization of these objectives.

The total value of Renewable Energy Sources, the amount of renewable energy sources, which is given to electrical power distribution system by each organization under Renewable Energy Sources Support Mechanism and list prices in the Renewable Energy Resources, are multiplied according to Central Bank of Turkey current foreign exchange buying rate as the Turkish lira, is calculated.

This law entered into force on May 18, 2005. The prices in Table 1 attached to this law will be applied during ten years for all production license holders under Renewable Energy Resources Support Mechanism that entered or will enter to business from May 18, 2005 to December 31, 2015. However, security of supply in line with other developments, especially after the commissioning date of December 31, 2015 Renewable Energy Resources certified manufacturing facilities, which will be implemented under this Act for the quantity, price, and with the sources in Table 1, prices for a maximum period, determined by the Council of Ministers (Anonym, 2010).

BIOGAS POTENTIAL IN TURKEY

To determine the potential of animal waste, number of animals of Turkey Statistical Institute was taken as a reference in 2009 (3.6 tons per year for cattle, 0.7 tons per year for small animals, 0.022 tons per year for poultry) and calculations were made according to those data. The amount of biogas per ton of waste is considered 33 m^3 for cattle waste, 58 m^3 for small animals, and 78 m^3 for poultry (Kaya and et al., 2009). According to estimation, the amount of animal waste that can be used in Turkey is approximately 63 million tons and it is equal to 2.5 million tons anthracite (Table 2).

Large amounts of waste organic matter that released especially in rural areas are important for the evaluation of biogas and organic fertilizer production.

When energy statistics of Turkey are examined, animal and plantal wastes are to meet 9% of total energy production and 4% the total energy consumption. Animal manure is generally used for heating and cooking in rural areas of Turkey. The use of animal manure in agricultural production is more economical than using for heating and cooking. Animal manure has superior properties compared to artificial fertilizers. It provides plant nutrients to soil and improves soil structure (Anonymous, 2011a).

BIOGAS UTILIZATION AREAS

Most of the biogas is usually consumed in the region where it was produced. In addition, the biogas demand has varied throughout the year. Demand balance of biogas is blocked if biogas connects to natural gas system.

Table 1. The prices which will be applied for types of facilities are based on the Source of Renewable Energy.

(It is the command of the Law No. 6094 dated December 29, 2010.)	
Production Facility Type based on the Source of Renewable Energy	**Prices are to be applied (US Dollar cent/kWh)**
Hydroelectric plant	7.3
Wind power generation facility	7.3
Geothermal energy production plant	10.5
Biomass facilities (including landfill gas)	13.3
Solar energy plant	13.3

Biogas can be used both direct combustion and lighting which converted into electrical energy. When biogas uses in lighting, it has been benefited the lamps that work directly with liquefied petroleum gases. To increase of lighting the flame, mantle and glass lantern is used in this system. Glass lantern stabilizes the light and it provides more flame with giving back the heat which is thrown out. Biogas is especially used in the medium-and large-scale plants, electricity generators. From biogas to electrical energy conversion efficiency is between 22-40%.

Components of biogas are Methane (CH_4), 40% - 80%, Carbon dioxide (CO_2), 20% - 50%, Hydrogen Sulphur (H_2S) 0.0005% - 0.0002%, Ammonia (NH_3) 0.0005% - 0.0001%, Nitrogen (N_2), 0% - 3%, Hydrogen (H_2) is 0% - 5%. Heating value of biogas is 5100 kcal / m^3 (Anonymous, 2011b).

It is required that remove biogas form the CO2 particles, water vapor and hydrogen sulphur before connected to natural gas system. Heat production is the way of the most intensive and common using form of biogas. When it needs to use in boilers that was developed for natural gas, it can easily be used small changes without pre-treatment. Most biogas reactor is heated and the gas, produced 10% and 30% of large-scale plants, is used for this purpose in the small-scale facilities (Yilmaz, 2009).

Using of Biogas in Heating

Flammability of biogas is originated form its composition which contain methane (CH4. Complete combustion of biogas takes place when it is mixed with the air about 1:7 ratio. Biogas can be used in thermosiphons as well as ovens, stoves, operated by gas fuels, for heating. Biogas can easily used in stoves, operated with liquefied petroleum gas (Anonymous, 2011c).

Using of Biogas for Lighting

Biogas can be used both directly in combustion and it is used in the lighting by converted into electrical energy. It is utilized the lamps, operated by liquefied petroleum gases when biogas is used directly in the lighting (Anonymous, 2011c).

Using of Biogas in Engines

Biogas can be used directly in the gasoline-powered engines without need to add any additive and it be used with purification of methane gas which contains. It is required to mix with a specific amount (18-20%) of diesel oil in the case of biogas is used in the diesel engines (Anonymous, 2011c).

Biogas is used in 3.8 million vehicles in the whole world, and it is reported that it did not make any troubles in 10.000 cars and buses, operated by biogas. In recent years, European car manufacturers have carried out to project for producing the natural gas vehicles. European Union has tried to improve around 21% its energy production, obtained from renewable sources in 2010. Sweden has intended to increase 8% of biogas using for transportation in 2020 (Yilmaz, 2009).

Stages of Conversion from Biogas to Natural Gas

Biogas is converted to natural gas with a specific process. This process is can be outlined summarized as follows:

- This procedure is applied for the vehicles, designed to use of the natural gas obtained from biogas.
- The waterscrubber and PSA technology are the most common used technology for upgrading to biogas.

Table 2. Expected amount of biogas and its coal equivalent for potential of animal waste produced in Turkey, 2009 (TUIK, 2009)

Animal Species	Number of animals (unit)	Amount of muck Fertilizer (ton per year)	Biogas Amount (m^3 per year)	Anthracite equivalent (ton per year)
Cattle	10813174	38927426	1284605058	1156144.552
Sheep and Goat	26879802	18815861	1091319938	982187.9442
Chicken-Turkey-Goose- Duck	234082206	5149808	401685024	361516.5216
Total	**271775182**	**62893095**	**2777610020**	**2499849.018**

There are two main steps in these technologies:

1. To remove CO_2 from gas: minor contaminants, such as sulfur compounds are lost before removal of CO_2.

2. Water dew point must be set before or after upgrading the biogas. Along with all these using ways, biogas production began to increase around the world. However, biogas is used for combined heat and power plants much more than the others. In recent years, although 500,000 gas-operated (gas-fueled vehicles) have been sold in Europe, fossil gas mainly has been used in those vehicles. However, the biogas is used for transportation vehicles in some countries. There are about fifty biogas service stations in Sweden (Anonymous, 2011c).

BIOGAS ECONOMY

Biogas economy is a highly complex, and it is hard to compare with other energy production systems. Unlike other energy-producing systems, the anaerobic fermentation systems aim to find solutions to many things out of energy requirement (Yilmaz, 2009).

Project designing, initial investment and business costs can be stated as mainly factors that make up the biogas system. Electricity, sale of organic fertilizer which is released, and using for heating purposes of using of waste heat that obtained from cogeneration system, can be stated of expected revenue in the biogas systems.

Initial Investment Cost

Site preparation of biogas plant, soil excavation and filling, construction, mechanical and instrumentation design work can be considered as cost items. In addition, technical, legal, and planning permissions, financial activities, and connections for sale of produced electricity can be shown as the project development expenses.

Business Expenses

Business costs of a biogas plant vary depending on the capacity of facility, design criteria and local circumstances. Business expenses generally consist of the following components.

- Staff costs
- Insurance
- Transportation costs
- Maintenance costs

Business Income

Produced electricity, released heat and the sale of organic fertilizer are the most important sources of income that expected from biogas system. In addition, the liquid manure which is used in the agricultural areas, and obtained from procedure can be sold to generate income (Kumar et al., 2009). The amount of biogas per ton of waste is considered 33 m^3 for cattle waste, 58 m^3 for small animals, and 78 m^3 for poultry. Energy value of 1 m^3 of biogas is 17-25 MJ/m^3. 150-300 liters per person per day is considered sufficient biogas per farm. 4248 liters of biogas is required for a family, which consists of four people, and it can be obtained from three cows. 30-40 liters biogas requires for boiling per liter water, and 0.5 kg rice needs 120-140 liters biogas for cooking. In addition, a lamp consumes 120-150 liters biogas per day (Kasap, 2005).

Cost of Electricity Generation from Biogas

First, special buildings should be constructed for generating electricity from biogas. These facilities vary depending on amount of electricity that desires to produce and location. The average facility cost is around € 3,000 for each kW/h. As an example, a facility, 500 kW/h capacity, costs around € 1.5 million (Ulusan, 2009). Comparison with other fuels in terms of calorific value of biogas is given in Table 3.

According to a study which is conducted in India, almost 0.12 ha forest is saved by means of a biogas plant which produces 2.8 m^3 biogas. 28 ha forest will be saved by means of 240 m^3 fermentation tank which works with 200 cattle every year (Kasap, 2005).

Income of Obtained from produced Electricity

According to former law of renewable energy, government had been paying €5.5 cents per kW/h electricity. This amount was not enough to invest for biogas in Turkey. Therefore, electricity production of biogas was not spread except of a few projects.

However, according to new law (No. 6094) which put into effect on December 29, 2010, Ministry of Energy and Natural Resources will pay $13.3 cents per kW/h for electricity that is generated from biogas. The government also has guaranteed to buy for 10 years. The following calculations based on these prices, and it is setup for 500 kW/h facility.

Table 3. Comparison of biogas with other fuels (Kasap, 2005)

TYPE OF ENERGY	HEATING VALUE	HEATING EFFICIENCY (%)	SPECIFIC FUEL REQUIREMENT	1 m3 BIOGAS EQUVALENT
Biogas	5100 kcal/m^3	82	0.15 m^3/BGh	1 m^3
City Gas	4000 kcal/m^3	82	0.19 m^3/BGh	1.27 m^3
Diesel Fuel	8700 kcal/lt	82	0.089 lt/BGh	0.60 lt
Gasoline	7350 kcal/lt	82	0.105 lt/BGh	0.70 lt
Coke	7000 kcal/kg	60	0.15 kg/BGh	1 kg
Electricity	860 kcal/kwh	95	0.77 kwh/BGh	5.1 kw/h
LPG	11000 kcal/kg			0.46 kg
Wood	3100 kcal/kg			3.47 kg
Natural Gas				0.62 m^3
Wood charcoal				1.46 kg
Dried cow dung				12.3 kg

$13.3-cents / kWh
500 kW/h X 8.000 h = 4.000.000 kWh (annual electricity production)
4.000.000 KW X $ 13.3 cents/KW = $532.000 (annual turnover)
$532.000/12 = $44.333.33 (monthly turnover)

Income of Obtaining from Sale of Organic Fertilizer

500 kW/h facility runs with 62.500m^3 cattle manure per year. 20.000 tons organic fertilizer can be obtained from processing that manure. Efficiency of bio-fertilizer increases by 20%. While farm fertilizer contains 4 kg N, 2 kg P_2O_5 and 4 kg K_2O per ton, bio-fertilizer which is formed as a result of fermentation, contains 5.6 kg N, 3.7 kg P_2O_5 and 5.6 kg K_2O per ton (Kasap, 2005).

The market value of similar organic fertilizer varies around from 500 to 650 TL (Turkish Liras) ranges. Accordingly: 20.000 ton X $500 TL/ t = 10.000.000 TL (annual potential turnover)

Evaluation of the heat released during the production of electricity

Heat is released as well as electric power and organic fertilizer during the process of biogas. This heat can be used for heating in the greenhouse and residential places, which are close to facility. This is also a source, which can be evaluated as a marketable value (Ulusan, 2009).

CONTRIBUTIONS OF BIOGAS FOR ENVIRONMENTAL CLEANLINESS

When different energy resources are evaluated in terms of environmental impacts, they cause to emissions from waste treatment process if there is no an anaerobic fermentation. This situation should be taken into consideration for comparisons.

With the use of biogas instead of fossil resources, emissions of CO_2 and other greenhouse gases is declined. Lesser fossil fuel is consumed during the production of biogas (using of diesel for transporting the waste). As a result, greenhouse gas emission decreases 75% with the using of biogas in houses and cars.

CH_4 is an important component of biogas. It is a greenhouse gas and 1 kg CH_4 equals to 20 kg of CO_2 when it is analyzed in terms of climate change. Reducing the loss of CH_4 from biogas systems will decrease to the greenhouse gas emissions.

Anaerobic fermentation is a good alternative when emissions take into account that causes eutrophication and acidification. For example, leakage of nitrogen from sugar beet can be reduced if it is treated with anaerobic fermentation. If wastes are not collected in the winter months, they are decomposed, and nitrogen becomes free and it causes eutrophication (Yilmaz, 2009).

If organic materials are not used in the production of biogas, they become harmful and pathogenic. In addition, the direct use of these materials leads to nitrate pollution of soil and groundwater. Pig wastes contain heavy metals such as copper and zinc and cause to pollution. This waste leads to the formation of flies and odors, too. Biogas systems providea massive reduction of environmental pollution that occurs due to those wastes. Organic solids which are found in the feeding material is reduced approximately 50% with biogas systems. This rate can be risen up to 80-to 90% in some systems (Eryasar, 2007).

Greenhouse gas emission, released agricultural activities, is approximately 20-35% of total emission. Methane emissions from ruminant animals are originated from digestive system (80%), whereas methane emissions from pork and chicken are originated due to waste decomposition (70%). Biogas systems have two important effects in terms of greenhouse gas effect. First of all, biogas reduces methane emissions that occur during storage of animal waste and they are 21 times more effective than CO_2. Secondly, conversion of biogas reduces CO_2 emissions that will be caused by fossil fuels. Decreasing of 1 kg methane emission equals to 25 kg CO_2. Methane is not only absorbing infrared radiation, but also it causes the production of greenhouse gases such as ozone and water vapor with the photochemical reactions of CO_2. Life of methane molecules is approximately 10 years in the atmosphere. Therefore, controlling of methane emission yield could soon (Eryasar, 2007).

Analysis shows that if biogas is used for the purpose of heating instead of fossil fuels, emissions of greenhouse gas decrease around 75-90%. If it is used instead of Combined Heat and Power (BIG), emissions of greenhouse gas decrease around 60-90%. If it is used instead of gasoline and diesel for vehicles, emissions of greenhouse gas decrease around 50-85%. On the other hand, the biogas systems may be 50-500% higher than bio energy in terms of greenhouse gas emissions.

Anaerobic fermentation and biogas production have some potential environmental advantages depending on the type of waste material, fuel and waste management systems. Anaerobic fermentation usually may be useful in the following circumstances.

- Biogas replaces fossil fuels in case liquid animal waste, waste materials like sugar beet leaves and its head parts normally are not used as raw material for energy;

- Taking into account indirect environmental impacts, for example, (a) reducing of the methane and ammonia emissions during storage of animal waste, (b) decreasing of the leakage of nitrogen which contains waste products with rich nitrogen content and emission of ammonium, and (c) reducing of ammonia emission and composting organic matter;

- It is lead to decrease the potential greenhouse gas emissions and photochemical oxidation reaction, eutrophication, acidification and emissions of particulate matter in case of biogas to replace fossil fuels (Yilmaz, 2009).

Potential Effects of Biogas systems can be grouped under six categories (Eryasar, 2007):

1- Energy-Related Effects: Thanks to the production of renewable energy replaces the commercial and non-commercial fuels. It provides financial benefits for commercial fuels. Energy transmission losses are reduced with energy production. Anaerobic fermentation, especially compared to the thermal cycles, the yield does not fall due to excess humidity is an important advantage. According to those achieved by other methods of conversion obtained from the gas has a lower component. This purification of the gas before using it would result in a relatively simple and economical.

2- Fertilizer-Related Effects: Waste of anaerobic fermentation is called organic fertilizer. Elements make up about 70% of solid matter of the material used in feeding, and their amount and structure remain unchanged after fermentation.

Nitrogen which is found in the fermented manure is mainly ammonium form. Ammonium form is more suitable for the development of plants. Studies which were conducted in China, reported that fermented animal waste increases agricultural productivity around 10-30% more than not fermented.

Thus, using of commercial fertilizer is reduced. Especially, weed seeds, found in the animal wastes lost germinating property during the anaerobic fermentation. Another advantage is that allow for organic agriculture.

3- Health-Related Effects: People who live in rural areas are caused by using of wood and plantal wastes directly combustion systems without chimney for variety of respiratory diseases. Using of biogas eliminates these problems. In addition, flies which live on waste and diseases threaten the health of people living in this area. During anaerobic fermentation waste is disposed of most of the pathogens and parasites. Pathogen removal is around 90%. Thus, reduction occurs in health care expenses. Animal producers are kept under pressure by local residents because of odor which has annoying feature. Source of odor usually are nitrogen and sulfur compounds and varies according to process and waste. In one study, odor removal is 94% in the anaerobic fixed film reactor which cattle fertilizer held for three days, whereas open storage of the waste increases the odor 77% in three days.

4- Development-Related Effects: Biogas systems provide the development of rural living standards. In addition, knowledge and income of local installation and construction workers increases. Migration from rural to urban is reduced. Social pressure, caused by waste and environmental problems, is decreased on farmers. It prevents deforestation with replacing the non-commercial fuels and there are also some non-financial benefits such as reducing the time for collecting firewood and plantal waste. This time reduction reaches about 3 hours when it is removed from the day the time required for feeding the reactor like providing water supply and fertilizer-water mixture for biogas system.

5- Economic Effects: Biogas systems, established in regions causes an increase of savings and income. It decreases that affected by general economic fluctuations by means of the local energy and fertilizer production. It reduces dependence for energy and foreign fertilizer on macro-level. Fermented waste more easily is transported and needs smaller vehicles.

6- Emission Effects: Methane which has an effect 23 times more greenhouse gas than CO_2 and N_2O (nitrous oxide) emissions which has an effect 310 times more effective than CO_2 and ammonia emissions occurs mainly during storage of animal waste. In addition, more synthetic nitrogen fertilization creates N_2O. With fully not proven, fermented fertilizer causes less N_2O emissions than raw manure. It reduces the emission when it is used instead of synthetic fertilizers. Synthetic fertilizer creates 0.0297 ton N_2O emissions per ton. Ammonia emissions which create health, environmental, and odor problem, are decreased by the anaerobic processes. In addition, the direct use of these wastes leads to nitrate pollution in the soil and groundwater. Pig waste contains more heavy metals such as copper and zinc and it causes pollution. These wastes lead to the formation of flies and odors. Biogas systems profoundly reduce environmental pollution. Biogas systems eliminate approximately 50% of organic solids. This rate is 80-to 90% higher in some systems. Wastes, which prepare the environment for growth of various microbes and pests, will be evaluated and eliminated by mean of biogas systems.

CONCLUSION

As a result, biogas can be an alternative for closure of our country's energy deficit, keeping the national capital in the country, and preventing the emission of greenhouse gases into the atmosphere. It should be seen fertilizer as a source of energy, not a waste. Biogas, which is produced by the decomposition of animal and vegetable waste, is possible to use as a source of domestic, clean and alternative energy instead of natural gas or LPG gas for all needs by storing. Biogas for villages and farms and natural gas for our cities will be became future source of energy after a certain period of time.

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