Avrupa Bilim ve Teknoloji Dergisi
Sayı 17, S. 1307-1312, Aralık 2019

Araştırma Makalesi

www.ejosat.com ISSN:2148-2683

European Journal of Science and Technology
No. 17, pp. 1307-1312, December 2019

Research Article

Samsun İlinin Hayvan Gübrelerinden Üretilebilecek Elektrik Enerji Potansiyeli

Hilmi Zenk[1*]

[1] Giresun Üniversitesi, Mühendislik Fakültesi, Elektrik-Elektronik Mühendisliği Bölümü, Giresun, Türkiye, (ORCID: 0000-0002-1653-8580)

(İlk Geliş Tarihi 9 Aralık 2019 ve Kabul Tarihi 31 Aralık 2019)

(**DOI:** 10.31590/ejosat.661910)

ATIF/REFERENCE: Zenk, H., (2019). Samsun İlinin Hayvan Gübrelerinden Üretilebilecek Elektrik Enerji Potansiyeli. *Avrupa Bilim ve Teknoloji Dergisi*, (17), 1307-1312.

Öz

Biyogaz hayvansal atıklardan anaerobik fermantasyon yöntemiyle elde edilebilen bir gaz karışımıdır. İçerisinde bulunduğu % 55-70 CH_4 gazı sayesinde yanma özelliğine sahiptir. Atıkların bertarafı ve tekrar tekrar üretilebilmesi açısından yenilenebilir enerji statüsündedir. Bu çalışmada Samsun ilinin hayvan gübresinden üretilebilecek biyogaz ve elektrik enerji potansiyeli hesaplanmıştır. Samsun ili hayvan yetiştiriciği açısından Türkiye'de 11. sıradadır. Başlıca besi hayvanları sığır, manda, koyun ve keçidir. Bu çalışmada hayvan olarak büyükbaş (sığır ve manda) ve küçükbaş (koyun ve keçi) kullanılmıştır. Hayvan sayılardan elde edilen bulgulara göre büyükbaş hayvanlardan yıllık toplam 24,934,272.00 m^3 biyogaz ve küçükbaş hayvanlardan yıllık toplam 13,722,840.00 m3 biyogaz potansiyeli belirlendi. Bu değerlerin karşılık geldiği yıllık elektrik enerji potansiyeli 92,777.00 MWh değerinde bulundu. Bu enerji değeri 2018 yılı için Samsun elektrik enerji tüketiminin % 10.66 'sına karşılık gelir. Aynı zamanda Samsun şehrinin bu hayvansal atıkların metan gazı potansiyeli 2,312,951.00 ton CO_2 gaz emisyonunu azaltmaktadır.

Anahtar Kelimeler: Biyogaz, Metan, Elektrik enerjisi üretimi.

The Electric Energy Potential of Samsun City from Animal Manure

Abstract

Biogas is a gas mixture that can be obtained from animal wastes by anaerobic digestion method. It has burning property thanks to the 55-70% CH_4 gas it contains. It is in the status of renewable energy in terms of ensuring the disposal of wastes and reproducing them. In this study, the biogas and electrical energy potential of the animal manure of Samsun province were calculated. Samsun 11th ranks in terms of animal husbandry in Turkey. The main fattening animals are cattle, buffalo, sheep and goats. In this study, bovine (cattle and buffalo) and ovine (sheep and goat) were used as animals. According to the findings obtained from the animal numbers, total annual biogas from bovine animals was found to be 24,934,272.00 m^3 and total annual from cattle was biogas potential 13,722,840.00 m^3. The annual electrical energy potential corresponding to these values was found to be 92,777.00 MWh. This energy value corresponds to 10.66% of Samsun electricity energy consumption for 2018. At the same time, methane gas potential of these animal wastes of Samsun city reduces 2,312,951.00 tons of CO_2 gas emissions.

Keywords: Biogas, Methane, Electric energy production.

[*] Sorumlu Yazar: Giresun Üniversitesi, Mühendislik Fakültesi, Elektrik-Elektronik Bölümü, Giresun, Türkiye, ORCID: 0000-0002-1653-8580, hilmi.zenk@giresun.edu.tr

1. Introduction

Our country is among the developing countries as in many other countries. One of the basic needs to reach the level of developed countries is to generate our own energy. However, the increasing energy deficit in our country adversely affects the development of the country. Most of the world's energy needs are supplied from natural energy-based fuels and fossil fuels (Ardıç, 2003). However, these fuels are about to run out because they are limited in nature. Since the world's energy demand increases by 5% on average every year and the vast majority of the energy resources used are natural energy resources, the world countries are in search of new energy resources (Akbulut, 2002).

Our country has a great potential in terms of renewable energy sources. Biogas is one of these energies that has a great potential in our country (Kobya, 1992). Our country's energy needs are rapidly increasing due to rapid economic and industrial development. The energy consumed by our country between 2000 and 2015 is 5 times more than the energy consumed between 2000 and 2010 (Avcioğlu ve Türker, 2012). This proves that energy consumption is gradually increasing. Therefore, our country should turn to different energy sources. This is an alternative source of biogas to different energy sources. Because, our country has a very convenient and rich source for biogas production.

Biogas; It is an odorless, colorless and flammable gas mixture which can be produced from anaerobic environment from organic wastes of human, animal and plant origin (Metcalf and Eddy, 1972). Biogas is not a pure gas. Contains 55-70% methane (CH_4), 30-40% carbon dioxide (CO_2), 1-5% hydrogen sulfide (H_2S) and trace amounts of oxygen (O_2), carbon monoxide (CO), nitrogen (N_2), hydrogen (H_2) gases. The thermal value of the biogas is 4700-6000 kcal/m^3 (Şenol, 2019). Biogas is a good fuel type due to its clean energy and thermal properties. Biogas is generally used in lighting, electricity generation, heating, internal combustion engines etc. In fact, biogas engines can be used without any changes in air gas engines. It is similar to natural gas in terms of its properties and components. The electrical energy value of 1 m^3 of biogas is approximately 4.70 kWh (Şenol et al., 2017).

Biogas production for the installation of biogas plants varies according to the intended purpose. Biogas plants also vary according to their capacity. Those with 6-12 m^3 capacity are called family type, those with 50-150 m^3 capacity are called farm type and those with 100-200 m^3 capacity are called village type biogas plant. However, countries such as Germany, Denmark, Sweden and the United States are using industrial biogas plants with a higher capacity of 1,000-10,000 m^3 (Şenol et al., 2018). Biogas production is now widely used in urban wastewater treatment plants and is increasingly used to eliminate organic wastes such as agricultural wastes, animal industry wastes (Haak et al., 2016). During biogas production; many components such as C/N ratio, mixing speed, pH, temperature, loading ratio, toxic substances and residence time in the reactor are effective. The values of these components vary according to the structure of the plant (Çağlayan and Koçer, 2014).

Biogas can be produced from many organic materials as well as from kitchen waste. One of the biggest problems of our country is the lack of recycling of the garbage formed in the Black Sea Region. Therefore, the garbage is dumped into the sea due to lack of storage area. Thus, animal, plant and human health is becoming a very dangerous situation. Thanks to this energy, renewable energy will be obtained and wastes will be evaluated and energy will be obtained. During the production of a new product or a substance, a by-product or a waste material is produced. However, waste produced during biogas production is an organic fertilizer. Another advantage of biogas production is the recovery of the by-product from biogas production as organic fertilizer (Şenol, 2018b). The obtained fertilizer can be applied directly to the field or allowed to dry. One of the major advantages of this fertilizer is the destruction of a large proportion of pathogenic microorganisms during fermentation. This process makes the organic fertilizer to be used approximately 10% more efficient (Bilgili et al., 2011) Biogas can be used as a result of small changes on the lighting, heating, and electricity generation without the need for a special device (Yüksel, 2011). When biogas is mixed with the air at 1/7 ratio, complete combustion occurs (Bilgin, 2010). At the same time, biogas can be used for heating directly in furnaces and ovens, and can work with biogas in water heaters and water heaters. In order for biogas to burn in LPG furnace and water heaters, nozzle diameter should be increased by 2.5-3 times (Afacan, 2008). According to Alçiçek and Demiruluş (1994), the amount of biogas needed for cooking is 0.3 m^3 per person per day. The amount of heat supplied by 1 m^3 of biogas equals 0.62 liters of kerosene, 1.46 kg of charcoal, 3.48 kg of wood, 0.43 kg of butane gas, 12.4 kg of dung, 1.18 m^3 of gas, 1 liter of alcohol, 0.8 liter of gasoline (Afacan, 2008).

Figure 1 shows a standard farm biogas plant. Turkey's biogas potential, in 2017, which corresponds to 12 percent of the 292 billion kWh of electricity consumption. The total electricity generated by the Keban, Karakaya and Atatürk hydroelectric power plants on the Euphrates in 2016 is 16 billion 798 million kWh. Our annual biogas potential is more than twice the electricity generated by these three dams (Şenol and Zenk, 2019).

In biogas research; daily biogas production depending on fermentation type, type of organic matter, fermentation temperature and concentration and type of organic matter per 1 m^3 fermenter volume; It ranges from 0.3 m^3 to 1.2 m^3. It can be assumed that an average of 0.54 m^3 of biogas can be produced per 1 m^3 of fermenter volume from bovine manure containing 9% dry matter at a fermentation temperature of 36 °C. Considering this value, a biogas plant with a capacity of 25 m^3 will be able to produce 13.5 m^3 per daily, 405 m^3 per month and 4860 m^3 per year biogas. These values can be converted to money by multiplying the sales value of natural gas (Üçgül and Akgül, 2010).

The aim of this study is to determine the annual biogas potential of bovine and ovine livestock wastes registered in Samsun province. Then the theoretical electrical energy of these wastes was determined. In this way, the savings in electrical energy needs of Samsun were calculated.

Figure 1. Farm type biogas plant

2. Materials and Methods

2.1. Method of Generating Electricity With Biogas and Waste

Energy can be generated from biomass and wastes using many different technologies, either indirectly or via internally storable internal methods. These technologies can be examined in two groups as biological and thermal methods. Biological methods include: thermochemical methods subdivided including fermentation and incineration, gasification and pyrolysis. Approximately 90% of the energy generated from wastes is incinerated worldwide. Direct combustion is a commonly used method for converting waste into energy. Today, many power plants using waste have direct incineration systems. In such plants, the efficiency of the plant increases as the steam temperature and pressure increase (Tezçakar and Can, 2010)

Heat and electricity generation methods using solid biomass and wastes are divided into two groups; Production based on combustion and gasification techniques. Production based on combustion: Chemical in combustion process the energy of converting fuel to heat is transferred to heat, the secondary liquid in the heat exchanger and heat exchanger expands, generating mechanical energy in the turbine or similar system. Production based on gasification: it is reacted at high temperature with a controlled amount of oxygen and/or steam without combustion, and a fuel called syngas is produced (Spliethoff, 2011).

2.2. Biogas Potential of Animal Wastes

Cattle and buffalo manure and sheep and goat manure were used in the study of electrical energy potential of animal wastes. According to statistical institutions in Turkey (TUIK), in the province of Samsun, the number of animal belonging to 2018 are given in Table 1 (TUIK, 2019). In 2018, there are a total of 377,792 bovine animals in the province of Samsun, 98,801 of which are culture, 191,510 of which are hybrid and 65,980 of which are domestic. There are a total of 228,714 small ruminants including 204,639 sheep and 24,075 goats.

Table 1. Number of Ovine and Bovine

Animal type	**Number of animals (number)**
Cattle (culture)	98,801
Cattle (hybrid)	191,510
Cattle (domestic)	65,980
Buffalo	21,520
Total number of bovine	377,792
Sheep	204,639
Goat	24,075
Total number of ovine	228,714
Total number of animals	666,506

In the calculation of the amount of waste, 10-20 kg/day (wet) waste yield for cattle is 5% and 6% of body weight. Likewise, 4-5% body weight per day for sheep and goat can be considered waste (Kaygusuz, 2002). The values given in Table 3 are used to determine the amount of waste that can be obtained from animals. Body weight was taken as 400 kg for cattle and 50 kg for small ruminants.

Daily wet waste as a percentage of body weight was selected as 5% for cattle and 4% for cattle. According to these values, wet amounts in daily amounts are considered as 20 kg for cattle/day and 2 kg/day for small heads. The wet waste amounts of cattle, ovine and poultry are calculated separately, and then these values are determined for the total amount of animal waste for the supplement. In biogas production, TK must have 8-13% feed. If this ratio is much higher, gas output is prevented (Al-Azzam, 2003). Solid ratios are around 5-25% of cattle manure and 30% of sheep manure. If excess water is used during the collection of animal wastes, it can fall to TS up to 2-5%. This makes the system less efficient during heating water due to its high energy consumption (Başçetinçelik, 2007). The amount of waste in animal waste varies according to the size and size of the animal feeding regime as well as climatic conditions. In addition, the amount of waste obtained varies according to the breeding type. If animals are kept tied only at night, the resulting waste should be calculated as 50% of the total waste (Entürk, 2004). The duration of the animals in the stable is 65% for dairy cattle, 25% for beef and 99% for poultry (Acaroglu, 2007). According to these calculations, waste production rate of bovine and ovine is 7.3 and 0.73 tons/year, respectively. Based on these values; 66 m^3/year biogas from one ton of bovine and 60 m^3/year biogas from one ton of ovine manure. The methane composition in the biogas was assumed to be 60% (Avcioğlu and Türker, 2012).

The total biogas potential of bovines was calculated according to the Eq. 1.

$$BBP = \sum NB_i \; x \; BBY \qquad (1)$$

Where BBP is bovine biogas potential (m^3/ton.year); NB is number of bovine; BBY is bovine biogas yield (66 m^3/ton.year)

The total biogas potential of ovines was calculated according to the Eq. 2.

$$\mathrm{OBP} = \sum \mathrm{NO_i} \; \mathrm{x} \; \mathrm{OBY} \qquad (2)$$

Where OBP is ovine biogas potential (m^3/ton.year); NO is number of ovine; OBY is ovine biogas yield (60 m^3/ton.year)

According to (Ozer, 2017) 10 kWh is assumed to equal 1 m^3 CH_4. The potential to generate electricity from biogas was calculated according to Eq. (3).

$$e_{biogas} = E_{biogas} \; x \; \eta \qquad (3)$$

Where e_{biogas} is amount of electricity generated (kWh/year); E is biogas unconverted raw energy in biogas (kWh/year) and electricity of biogas; η is the amount may vary depending on the power. In one study, the value of e value was equal to 40%. In this study, this value was determined to be 0,4.

3. Findings and Discussion

Table 2 shows the weight range of bovine and ovine manure, amount of waste produced per day, total solid (TS) and volatile solid (VS) values.

Table 2. Biogas potential by type of animal and waste properties (Avcioğlu and Türker, 2012).

Type of animal	**Weight (kg)**	**Wet waste amount (kg)**		**TS%**	**VS%**
		% of weight	kg/day		
Bovine(cattle and buffalo)	135-800	5-6	10-20	5-25	75-85
Ovine (ship and goat)	30-75	4-5	2	30	20

Table 3 shows the biogas potential, methane potential and electrical energy potential of Samsun city based on the amount of bovine and ovine. According to the data obtained from TUIK, there are a total of 606,506 animals, including 377,792 bovine and 228,506 ovine in Samsun. The total annual waste amount of these animals is 2,924,842.00 tons. Similarly, biogas and methane potential of these wastes were found to be 38,657,112.00 and 23,194,267.00 m^3/year, respectively. Total electric energy potential of bovine and ovine fertilizers in Samsun province was found to be 92,777.00 MWh. In 2018, the electricity consumption in Samsun was 870,189.77 MWh. The electric energy potential of bovine and ovine manure meets 10.66% of the city's electricity need. The calculations do not include the installation cost of the biogas plant and the worker expenses at the plant.

Table 3. Annual energy potential of animal manure

Type of animal	Number of animals	Amount of waste (t/year)	Biogas potential (m^3/year)	Methane potential (m^3/year)	Electric energy potential (MWh/year)
Bovine(cattle and buffalo)	377,792.00	2,757,881.00	24,934,272.00	14,960,563.00	59,842.00
Ovine (ship and goat)	228,714.00	166,961.00	13,722,840.00	8,233,704.00	32,935.00
Total	606,506.00	2,924,842.00	38,657,112.00	23,194,267.00	92,777.00

Figure 2 shows the electrical energy potentials according to animal species. The highest electrical energy potential was calculated as 56,436 MWh/year from cattle. The lowest electrical energy potential was found to be 3,406 MWh/year for buffalo. The annual electric energy potentials of sheep and goats were 29,060 and 3,875 MWh/year.

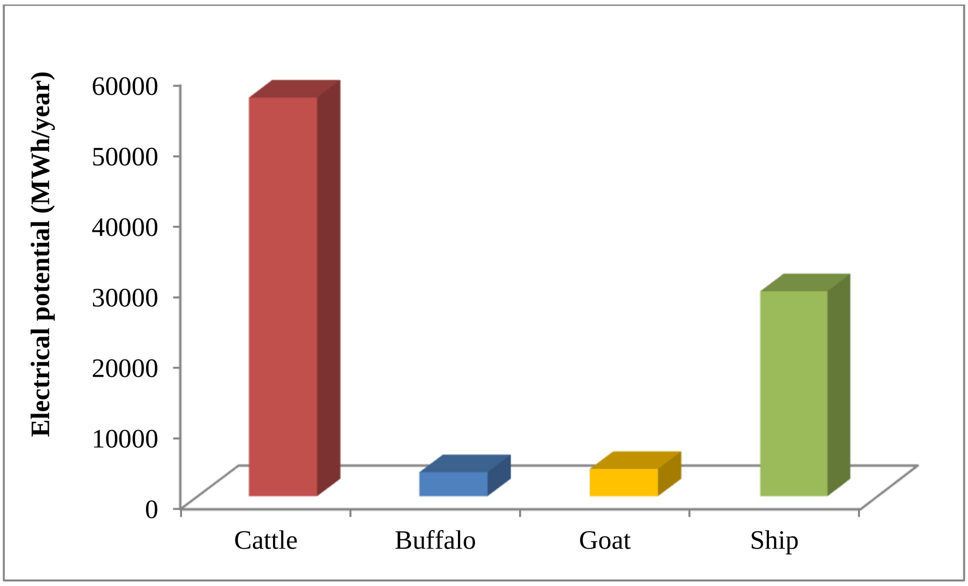

Figure 2. Electric energy potential according to animal species in Samsun

In a study, in 2009 the energy value of animal wastes in Samsun province was found to be 838,175 GJ/year. But poultry manure was also included in this study. This energy value was equal to 232,826 MWh. While the energy potential in 2009 was 232,826 MWh, the potential in 2018 corresponded to 333,997 GJ. The number of animals increases with each passing day as the human population increases and therefore the potential of electric energy increases. Increased animal fertilizers are harmful to nature. The environment is polluting. Therefore, the biological transformation of waste has an environmental approach in addition to providing tremendous energy. 0.107 dollars of electricity energy worth in Turkey for 1 kWh in 2018 (Şenol, 2019). Starting from this value, the energy income that can be obtained from organic wastes of Samsun is 9,927,139 dollars/year. In one study, biogas potential of Ardahan city from animal wastes was determined and 322.6 GW organic waste energy value was determined annually (Ozer, 2017). This corresponds to the CO_2 emission of this energy value 2,312,951 ton. If the findings calculated for Samsun are proportional to these findings; total CO_2 emission rate in Samsun province will fall to 2,394,685 tons of CO_2. Turkey until 2030, greenhouse gas (GHG) emissions reduction targets of up to 21% (Anonymous, 2015). All activities aimed at reducing greenhouse gas emissions will contribute to this aim. The biogas energy potential, Turkey to reduce CO_2 emissions and will have a good chance to use renewable energy to achieve their aims. In addition, this study can contribute to the goal of increasing renewable energy sources around the world.

When the installed power capacity corresponding to the biogas potentials is compared with the current installed power value, it has been found to be an important potential. Effectively use all the energy resources in Turkey is very important. Obtaining these resources in a renewable and sustainable way is an important factor in reducing material dependence on foreign resources. Biogas-based electricity generation provides an additional advantage as it allows for waste disposal. The planning of electrical power generation systems is based on the principle of knowing the potential values of existing primary sources to meet the estimated load demand and ensure high reliability. Compared to fossil fuel sources, biomass energy is a clean and sustainable energy source with less air emission value, less waste in the environment and reduced dependence on foreign sources (Ozcan et al., 2015).

Combustion of biogas provides hot water and air in cooking stoves. Heat and energy from combustion biogas can also be used in lighting production. The energy produced in biogas plants is generally used directly for city electricity. The main output material obtained from biogas is plant organic fertilizer. These treated fermented fertilizers are free of plant pathogens. Anaerobic fermentation is used to generate and use renewable energy from animal wastes and fermented fertilizer biogas. This will reduce the amount of environmentally hazardous waste and reduce waste management costs (Avcioğlu and Türker, 2012).

4. Conclusions

In this study, biogas potential which can be produced from cattle and ovine fertilizers has an important potential for Samsun. The annual biogas potential of cattle and small cattle manure was 38,657,112.00 m^3. This value corresponds to 92,777.00 MWh of electricity energy annually. In Turkey to reduce the high dependence on foreign energy, Turkey's rich indigenous and renewable energy sources should be used and biomass energy promises to reduce this dependence. Policy makers should define specific targets for biomass for electrical mass systems and provide investors with incentive opportunities.

Considering the climatic conditions and production facilities; low investment costs, high efficiency and easy installation, operation and maintenance for the design of biogas systems will enable the development of biogas technology in Turkey and Samsun.

References

Acaroğlu, M. (2007). Alternatif Enerji Kaynakları, Nobel Yayınları, Genişletilmiş 2. Baskı, Ankara.

Afacan, H., & Kasap, A. (2009). Küçük ölçekli sürekli beslemeli bir biyogaz tesisinin çalışma şartlarının belirlenmesi. Tarım Makinaları Bilimi Dergisi, 5(2), 235-240.

Akbulut, A. (2002). Güneş Enerjili Isı Kontrollü ve Faz Değiştiren Elemanlı Biyogaz Tesisinin Tasarımı, (Master dissertation, Tezi Fırat Üniversitesi, Fen Bilimleri Enstitüsü) Elazığ.

Al-Azzam, S. M. (2003). Biogas a source of energy. Amman: National Energy Research Centre.

Anonymous. Animal Statistics, TUİK, 2018.

Ardıç, İ.(2003).Termal, Kimyasal ve Termokimyasal Önişlemlerin Tavuk Gübresinden Biyogaz Üretim Verimine Etkilerinin Araştırılması, (Master dissertation, Mersin Üniversitesi Fen Bilimleri Enstitüsü) Mersin.

Avcioğlu, A. O., & Türker, U. (2012). Status and potential of biogas energy from animal wastes in Turkey. Renewable and Sustainable Energy Reviews, 16(3), 1557-1561.

Özer, B. (2017). Biogas energy opportunity of Ardahan city of Turkey. Energy, 139, 1144-1152.

Şenol, H., & Zenk. H. (2019). Biogas Production and Current Purification Methods. 2nd International Conference on Agriculture, Technology, Engineering and Sciences (ICATES 2019), Lviv, Ukraine.

Başçetinçelik, A., Öztürk, H., & Karaca, C. (2007). Türkiye'de tarımsal biyokütleden enerji üretimi olanakları. IV. Yeni ve Yenilenebilir Enerji Kaynakları Sempozyumu, Kayseri.

Bilgili, A.V., Yaldız O., Bilgili, A. (2011). Kompost Tesisi Kurulması Amacına Yönelik Fizibilite Çalışması Projesi Kapsamında Hazırlanan Kompost ve Biyogaz Tesisi Fizibilite Raporu, T.C. Karacadağ Kalkınma Ajansı, Harran Üniversitesi, Şanlıurfa.

Bilgin, N. (2010). Biyogaz nedir? Tarım ve Köyişleri Bakanlığı Köy Hizmetleri Genel Müdürlüğü, Ankara Araştırma Enstitüsü.

Çağlayan, G., & Koçer, N. (2014). Muş İlinde Hayvan Potansiyelinin Değerlendirilerek Biyogaz Üretiminin Araştırılması. Muş Alparslan Üniversitesi, Fen Bilimleri Dergisi, 2(1), 215-220.

Entürk, E. (2004). Tavuk çiftliklerinden kaynaklanan gübre atıklarının incelenmesi ve uygun arıtma sisteminin önerilmesi.

Spliethoff, H. (2010). Power generation from solid fuels. Springer Science & Business Media.

Haak, L., Roy, R., & Pagilla, K. (2016). Toxicity and biogas production potential of refinery waste sludge for anaerobic digestion. Chemosphere, 144, 1170-1176.

Kaygusuz, K. (2002). Renewable and sustainable energy use in Turkey: a review. Renewable and sustainable energy reviews, 6(4), 339-366.

Kobya, M. (1992). Sığır Gübresinden Biyogaz Üretimi ve Erzurum Koşulları İçin Bir Biyogaz Tesisi Tasarımı, (Master dissertation, Atatürk Üniversitesi. Fen Bilimleri Enstitüsü, Çevre Mühendisliği Anabilim Dalı, Yüksek lisans Tezi, 68s)Erzurum.

Tezçakar, M., & Can, O. (2010). Thermal disposal technologies in obtaining energy from wastes. In 2nd Waste Technologies Symposium and Exhibition, Istanbul.

Metcalf, L., Eddy, H. P., & Tchobanoglous, G. (1972). Wastewater engineering: treatment, disposal, and reuse (Vol. 4). NewYork: McGraw-Hill.

Ozcan, M., Öztürk, S., & Oguz, Y. (2015). Potential evaluation of biomass-based energy sources for Turkey. Engineering Science and Technology, an International Journal, 18(2), 178-184.

Republic of Turkey, Intended Nationally Determined Contribution (INDC), The INDC of Turkey, 2015.

Şenol, H. (2018). Investigation of Biogas Production at Different Temperatures from Organic Wastes. TURAN-SAM, 10(40), 118-122.

Şenol, H. (2019). Biogas potential of hazelnut shells and hazelnut wastes in Giresun City. Biotechnology Reports, 24, e00361.

Şenol, H., Elibol, E. A., Açikel, Ü., & Şenol, M. (2017). Biyogaz Üretimi İçin Ankara'nın Başlıca Organik Atık Kaynakları. Bitlis Eren Üniversitesi Fen Bilimleri Dergisi, 6(2), 15-28.

Üçgül, İ., & Akgül, G. (2010). Biyokütle Teknolojisi. SDÜ Yekarum e-Dergi, 1(1).

Yüksel, T. (2011). Biyogaz, Güneş ve Toprak Enerjisi Kaynaklı Sera Isıtmasının Araştırılması (Doctoral dissertation, Doktora Tezi, Fırat Üniversitesi Fen Bilimleri Enstitüsü, Makine Eğitimi Anabilim Dalı) Elazığ.