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Burdur'da Biyogaz Potansiyeli, CO_2 Emisyonu ve Hayvan Atıklarından Elektrik Enerjisi Eşdeğeri

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ÖZET

Pratik anlamda yenilenebilir enerji kaynaklarından faydalanmanın en uygun yollarından birisi olan biyogaz üretimi ile yeşil enerjiye ulaşıldığı gibi geri dönüşümde sağlanarak çevreye fayda sağlanabilir. Biyogaz, yenilenebilir enerji kaynaklarının en umut verici kaynaklarından biridir ve coğrafi konumu nedeniyle Türkiye'de önemli bir potansiyele sahiptir. Bu çalışmada Burdur için farklı hayvan türlerine ve sayılarına bağlı olarak 2019 yılı için atık, biyogaz üretimi ve elektrik enerjisi eşdeğeri hesaplanmıştır. Hesaplama sonucunda Burdur için yıllık ortalama hayvansal atık içeren biyogaz üretimi 79249.97 m^3-CH_4/yıl ve enerji değeri 2853 GJ/yıl olarak bulunmuştur. Ayrıca bu çalışmada biyogaz kullanılması halinde elektrik enerjisi üretiminin 277.37 MWhe/yıl olduğu ve bu sayede yılda yaklaşık 160.877 ton CO_2 emisyonunun önlenebileceği belirtilmiştir.

Anahtar Kelimeler: *Biyokütle, Biyogaz, Yenilenebilir enerji, Metan, Karbondioksit emisyonu*

Biogas Potential, CO_2 Emission and Electrical Energy Equivalent from Animal Waste in Burdur, Turkey

ABSTRACT

Biogas production, which is one of the most convenient ways of benefiting from renewable energy sources in practical terms, can reach green energy as well as providing benefits to the environment by recycling. Biogas is one of the most promising source of renewable energy sources and has an important potential in Turkey due to its geographical location. In this study, waste, biogas production and electrical energy equivalent were calculated for Burdur for 2019 depending on different animal species and numbers. As a result of the calculation, it was found that the annual average biogas production with animal waste for Burdur was 79249.97 m^3-CH_4/year and the energy value was 2853 GJ/year. In addition, in this study, it was stated that if biogas is used, the electrical energy production is 277.37 MWhe/year and thus approximately 160.877 tons of CO_2 emission per year can be prevented.

Keywords: *Biomass, Biogas, Renewable energy, Methane, Carbondioxide emission*

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1. INTRODUCTION

Parallel to the increase in the world population and the development of the industry increases the energy demand. Energy prices are rising because the current energy supply is not sufficient for this demand. All over the world, there is an increasing tendency to use renewable energy sources instead of fossil fuels for fundamental reasons such as climate change. As a result of the decrease in energy resources and the search for new resources, biogas production from organic wastes is considered as an alternative source (Taleghani and Kia, 2005; Mao vd., 2015). The use of organic wastes in biogas production constitutes an effective waste management step in both waste disposal and energy generation from wastes (Kumaş vd., 2019). As in many countries, the energy requirements are met from fossil sources in Turkey. The frequent use of fossil fuels, especially in recent years, causes damage to the ozone layer, acid rain and increase in global warming. Due to such environmental problems, the use of renewable energy resources will provide both economic and environmental benefits by reducing external dependency (Bilgili, 2020).

Agriculture and livestock activities in Turkey has a high economic potential. In terms of environmental health and waste method, evaluation of animal wastes is very important in energy and agricultural production. The survey conducted for Turkey; It is estimated that the amount of energy that can be obtained from biomass wastes will be 8.6 million TEP and the amount of biogas that can be obtained by digesting these wastes in an oxygen-free environment will be around 1.5 to 2 million TEP. Approximately 3216 GWh of electricity was produced in 2018 from the established biomass-based power generation facilities, which currently have a production capacity of 811 MW(Yağlı and Koç, 2019).

Biogas enables the production of energy and organic fertilizers from organic waste materials. Although biogas is a precaution against global climate change, it is gaining importance day by day in terms of generating heat and electricity, being able to use it as fuel, and increasing productivity in agricultural production as a soil improver (Tınmaz Köse, 2017). Although there are many studies in the literature on biogas, the material frequently used is animal waste and plant waste.

Avcıoğlu and Türker gave the waste potential map of different animal species in their study. In the study, the biogas potential of different animal species was determined using various criteria depending on the number of animals in 2009 (Avcıoğlu and Türker, 2012). Afazeli et al. stated that Iran's biogas production potential from slaughterhouse wastes was 54 million m^3 for 2011(Afazeli vd., 2014). Noorollahi et al. calculated the biogas potential that can be obtained from the manure of livestock for Iran. It has been concluded that Iran's Sistan-Baluchestan and Ilam regions should be priority biogas production regions due to their high gas consumption and huge biogas production potential(Noorollahi vd., 2015).

Bilgen et al., Yelmen et al. They offer a perspective for potential and biomass technologies in Turkey (Bilgen vd., 2015; Yelmen and Çakır, 2016). Abdeshahian et al. conducted research on the biogas potential that can be obtained from livestock manure in Malaysia. It has been calculated that 4589.49 million-m^3/year of biogas can be produced annually from livestock manure in Malaysian farms. It has been stated that the amount of electrical energy produced from animal wastes was 8.27x109 kWh / year in 2012(Abdeshahian vd., 2016). Saka and Yilmaz found that Turkey's plant waste in recent years was 142.4 Mton/year and its biomass potential was about 668 PJ/year(Saka and Yilmaz, 2017). Scarlat et al. calculated that between 13,866 and 19,482 biogas production plants could be installed in the European region, and as a result, electricity generation between 6144 MWe and 7145 MWe was possible(Scarlat

vd., 2018).Yağlı and Koç have determined the amount of power that can be obtained by the production of biogas for Adana, Turkey and the use of this biogas produced. As a result of calculations for all animal species, they stated that the average annual biogas production in Adana province is 88.367,417 m^3-CH_4/year, and in the case of using this biogas, electrical energy production is 309,286 MWhe/year(Yağlı and Koç, 2019). Kumaş et al. generally examined the biogas studies in Turkey and the world. In the study, biogas power plants, uses of generated energy and conversion to other types of energy were investigated(Kumaş vd., 2019). Akyürek and Coşkun investigated the animal-derived biogas potential, energy value, greenhouse gas emissions and organic fertilizer production capacity of the Aegean region, Turkey. It has been stated that the Aegean region has an annual biogas potential of 528 million m^3, corresponding to the energy production capacity of 2.64 TWh, and CO_2 emissions can be reduced by about 4.6 million tons per year if biogas is used (Akyürek and Coşkun, 2019). Görgülü studied biogas potential from animal and agricultural wastes using TUIK data for Burdur in 2018. In the study, Burdur energy potential from animal waste was found to be 447733.2 GJ (10693.92 TEP) (Görgülü,2019). Bilgili calculated the total biomass potential of Adana of plant and animal origin as approximately 23.56 PJ for 2019. He stated that this potential could meet 34% of the province's energy demand (Bilgili, 2020). In this study, the biogas production potential and the amount of power that can be produced for Burdur, Turkey were examined. As part of the study, the number of different animal species found throughout the province for 2019 was determined and annual amounts of fertilizer were calculated. The electrical energy potential that can be produced was calculated by taking into account the fertilizer content and biogas production potential obtained from each animal.

2. MATERIALS AND METHOD

Burdur is one of the important agricultural and animal husbandry cities of Turkey. At least two-thirds of its population are engaged in agriculture and animal husbandry. In general, successful activities in the field of bovine livestock are carried out in the province, 98 % of the cultural breed of animals and a conscious group of producers who manage them are located. Holstein, Brown Swiss and Simmental breeds constitute 1.5 % of Turkey's cattle presence (Anonim, 2020). Cattle manure is used worldwide in biogas production. One of the most important reasons for this is that the amount of fertilizer compared to other animals is excessive. The ratio of solids in the dung of meat cattle is higher than that of dairy cattle. Because dairy cattle have a high content of water and fiber in their manure, and the fiber is resistant to high levels of decay, a lower proportion of methane gas is obtained (Marañón vd., 2012). Biogas production is more efficient as a result of mixing small ruminant manure with cattle manure (Cestonaro vd., 2015). Poultry manure contains more bioparticable organic matter than other animal manure. This, in turn, shows that poultry manure is an important source of biogas (Yağlı and Koç, 2019). Animal species data obtained from TUIK - 2019 was used to determine Burdur's biogas energy potential. According to TUIK 2019 data, there are 865992 animals in Burdur. The number of animals in Burdur province is given in Table1 (TUİK,2019).

Table 1. Animal Numbers

District	Culture and Hybrid Meat Cattle	Culture and Hybrid Dairy Cattle	Domestic Cattle	Calf	Sheep	Goat	Horse Mule Donkey	Chicken	Turkey	Goose	Duck
Altınyayla	305	1674	14	757	6569	6639	100	6100	210	100	100
Ağlasun	585	4545	15	1855	8471	16175	152	5312	20	20	50
Bucak	4247	20240	41	10472	18464	36432	55	66650	8040	0	0
Gölhisar	1895	11607	0	4998	11859	9969	103	3000	0	0	0
Karamanlı	1037	9556	8	3499	27879	4629	42	6500	50	60	30
Kemer	1011	5626	6	3857	13810	2210	28	700	30	28	20
Center	4933	52387	5	15675	51400	40086	280	87000	15000	65	50
Tefenni	1054	6445	51	2150	28000	8617	17	29930	172	105	59
Yeşilova	3372	13945	13	8535	27401	26556	83	5102	315	210	105
Çavdır	970	9020	10	3250	20397	30421	15	1500	15	10	10
Çeltikçi	964	4840	7	1689	4523	9548	51	1080	50	48	0
TOTAL	**20373**	**139885**	**170**	**56737**	**218773**	**191282**	**926**	**212874**	**23902**	**646**	**424**

The study is considered acceptable daily waste quantity and characteristics of the livestock sector in Turkey. Daily fertilizer quantities depending on the type of animal age fertilizer formation per unit animal (kg/day-animal), solids ratio (SR), volatile solids ratio in wet (WM) and solid manure (SM), and methane production are given in Table 2. In the Table 2, Nm^3 is a common unit used in industry to refer to gas emissions or exchange. It stands for normal cubic meter. "Normal" is always dependant on the individual circumstances of each gas, pressure, and use. In practice, only a certain part of the manure can be collected. The collectability of the fertilizers is proportional to the duration of the animals indoors and the collection possibilities of the waste produced. Depending on the animal species, the accepted values in calculating the technical biogas potential and the duration of the animals in the closed environment are also given in Table 2 (Ayhan, 2015; Yağlı and Koç, 2019).

Table 2. Quantity and properties of fertilizer accepted for biogas process by animal type

Animal type	Average Daily Manure Production per Animal (kg/day-animal)	Solid Substance Ratio (SR)(%)	Volatile Solid Content in Wet Manure (WM)(%)	Volatile Solid Content in Solid Manure (SM)(%)	Collectible Useful Manure Ratio (C)(%)	Methane Production (Nm^3 CH4/kg-WM)
Dairy Cattle	43.00	13.95	17.27	83.36	100	0.18
Meat Cattle	29.00	14.66	12.41	84.65	100	0.33
Domestic Cattle	29.00	14.66	17.27	84.65	50	0.33
Calf	2.48	8.39	3.71	44.23	100	0.33
Sheep	2.40	27.50	23.00	83.63	13	0.30
Goat	2.05	31.71	23.17	73.06	13	0.30
Horse-Donkey-Mule	20.40	29.41	19.61	66.67	29	0.30
Chicken	0.13	25.88	20.00	77.27	99	0.35
Turkey	0.38	25.53	19.36	75.83	68	0.35
Goose	0.33	28.18	17.27	61.28	68	0.35
Duck	0.33	28.18	17.27	61.28	68	0.35

The following equations are used for the theoretical calculation of the biogas potential (Yağlı and Koç, 2019).

$$TAM = MA * N * 365 \quad (1)$$

TAM is the total amount of manure (kg / year) that can be produced by animals in a year, MA is the amount of manure (kg / year-animal) one animal can produce in a year, and N is the number of animals.

$$TAAW = TAM * C \quad (2)$$

TAAW is the total amount of annual collectable wet manure (kg/year) and C is the rate of collectible manure that can be collected (%).

$$ASR = TAAW * SR \quad (3)$$

ASR is the total amount of solids in the annual collectable manure (kg / year), and SR is the solid matter ratio (%) in the wet manure.

$$AWS = ASR * WM \quad (4)$$

AWS is the annual total volatile solids amount (kg /year) in wet manure and WM volatile solids content in solid matter (%).

$$MET = AWS * MO \quad (5)$$

MET is the total annual amount of methane that can be obtained from the collectible manure (m^3CH_4 /year), MO is the amount of methane produced from 1 kg WM.

While calculating the energy amount of the annual total biogas produced, the energy value of biogas with 60% methane content was accepted as 22.7 MJ / Nm^3 and consequently the energy value (H) of methane gas was 36 MJ / Nm^3.

$$Q = MET * H \quad (6)$$

Q is the energy equivalent of methane to be produced in a year (MJ /year), the amount of electrical energy that will be obtained as a result of generating electricity (E) in a CHP engine can be calculated by equation (7).

$$E = MET * \eta e * W \quad (7)$$

E is the annual electricity production of the CHP engine (MWhe / year), ηe is the electrical efficiency of the CHP engine (35%) and W is the energy value (10 kWh/m^3) of methane gas. It is thought that 1 kWh of electricity saving corresponds to approximately 0.58 kg of CO_2 emission (Yağlı and Koç, 2019).

3. RESULTS AND DISCUSSION

According to 2019 data, there are 865992 animals in different animal species in the center and districts of Burdur. While there is the highest number of dairy cattle in bovine type, this is followed by meat cattle and domestic cattle, respectively. Sheep is the most common type of small ruminant animal. Chicken has the highest number of poultry.

The district with the highest number of animals in total animal numbers is Center. The district with the lowest number of animals is Altınyayla. When the total number of animals is evaluated, 25.08% is cattle, 47.35% is small ruminant and 27.46% is poultry and the remaining part is equine animals.

Depending on the number of animals, the amount of manure was calculated using Tables 1 and 2 on district basis, and the annual amount of, solid matter and volatile solid amount are given in Table 3. According to Table 3, the amount of useful manure that can be collected according to different animal species is 2208806.6 tons/year. The total amount of solid matter is 322341.4 tons / year, and the total amount of volatile solids is 266594.66 tons/year.

Table 3. Collectable manure amounts and important parameterssolution

District	*Animal numbers*	*Collectible Useful Manure (tons/year)*	*Solid Content Amount (KM)(tons /year)*	*Volatile Solid Content in Solid Manure (tons/year)*
Altınyayla	22568	35149,03	5761,30	4675,81
Ağlasun	37200	80046,91	12427,87	10086,93
Bucak	164641	338932,23	49450,97	40707,94
Gölhisar	43431	175883,39	24845,99	20643,73
Karamanlı	53290	149202,54	22037,65	18403,46
Kemer	27326	92976,56	13485,65	11246,71
Center	266881	729509,90	101615,88	84537,07
Tefenni	76600	119814,91	18922,97	15689,00
Yeşilova	85637	253210,40	38074,77	31377,86
Çavdır	65618	154566,24	24025,02	19600,37
Çeltikçi	22800	79514,51	11693,33	9625,79
Total	**865992**	**2208806,60**	**322341,40**	**266594,66**

A total of 79249.97 m^3 of methane can be obtained from animal wastes throughout the province of Burdur (Figure1). Most of the methane gas consists of animals in Center and Bucak district. The districts that contribute the least to obtaining methane gas are Altınyayla and Çeltikçi districts where the number of animals is low. Theoretically calculations, the total energy value of methane gas that can be produced as a result of biogas production from collectable useful animal manure for 2019 was found to be 2853 GJ / year and 68.14 TEP / year.

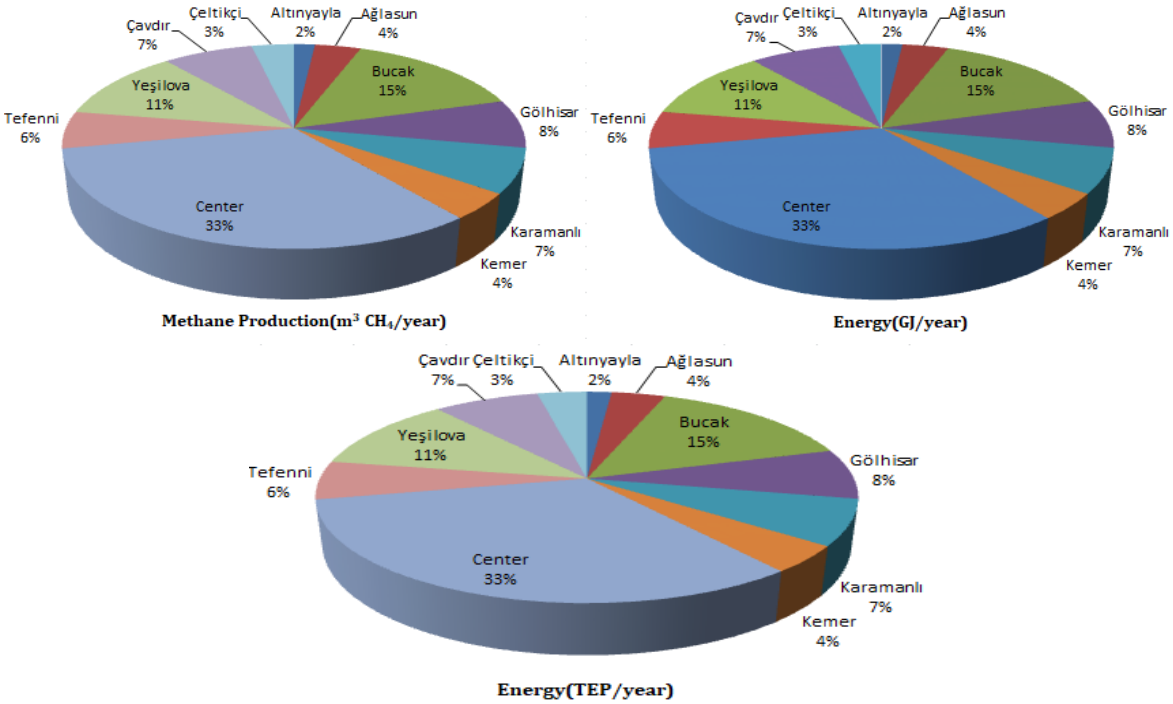

Figure1. The amount of methane and energy equivalent

The amount of electrical energy that can be produced on the basis of the district of Burdur is given in Figure2. According to Figure2, it is seen that when methane gas is used in a CHP engine with 35% electricity efficiency, an annual electricity generation of 277.37 MWhe can be realized. In the distribution of electricity generation by districts, the highest electricity generation was in Center, Bucak and Yeşilova, respectively. The districts with the least production are Altınyayla and Çeltikçi districts. Considering that 0.58 kg of CO_2 emission can be prevented by saving 1 kWh of electricity, approximately 160.88 tons of CO_2 emission can be prevented if biogas is obtained from animal waste.

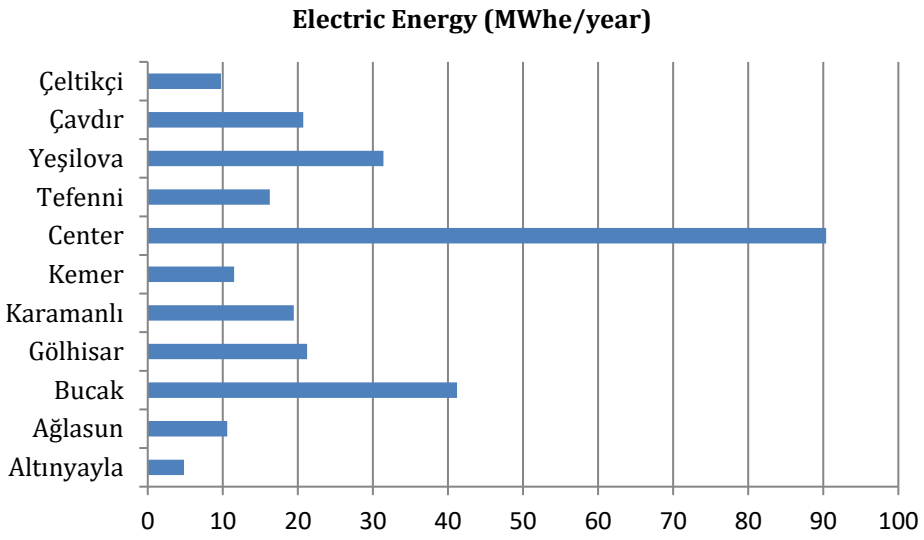

Figure2. The amount of electrical energy

4. CONCLUSION

Biogas is an energy source with different characteristics compared to other alternative energy sources. It has an important place among renewable energy sources due to its potential, social and economic benefits. It is obtained as a result of fermentation of animal wastes in rural areas under airless conditions. Expanding biogas production will not only reduce dependency on foreign sources in energy but also ensure environmental awareness by reducing CO_2 emission.

In this study, methane production amounts and energy potentials were calculated in the case of using animal wastes in biogas production by using TÜİK 2019 animal numbers data on the district basis of Burdur.

There are a total of 865992 animals of different animal species in Burdur. When the distribution of these animal species is examined, it consists of 25.08% cattles, 47.35% small ruminants and 27.46% poultry and the remaining part is equine animals. It is calculated that the total waste from these animal species is 2208806,60 tons / year.

The amount of waste is consists of 1853595 tons / year (cattle), 334772 tons / year (small ruminant), 6895 tons / year (equine animals) and and 13545 tons / year (poultry).

The amount of methane to be obtained from animal wastes in Burdur is 79249,97 m^3 / year, the energy equivalent of this gas is 2853/ year and 68,14 TEP / year in terms of another unit.

On district basis, Center is the district that contributes the most to electrical energy generation from animal waste. The energy production rates of Center, Bucak and Yeşilova districts are 32.58%, 14.85% and 11.31%, respectively. In addition, considering that 0.58 kg of CO_2 emission can be prevented by saving 1 kWh of electricity, it is predicted that 160.877 tons of CO_2 emission per year can be prevented if biogas is produced from animal waste.

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