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Electric Energy Potential that can be Produced Using Cattle Manure in the Isparta Region

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Abstract

Today, in order to meet the increasing energy needs, sustainable and renewable energy production methods are needed in addition to the existing energy sources. Especially taking into consideration the husbandry potential of our country, biogas and energy production through the use of animal waste have emerged as an efficient alternative of production. In this study, the amount of electrical energy that can be produced using cattle manure in the Isparta region was calculated. The husbandry data used in these calculations were obtained from the database of the Turkish Statistical Institute. The potential amount of manure that can be obtained from all of the cattle in the Isparta region was determined as 1,117,002.08 tons. The amount of existing potential manure that can be collected and used for electricity generation was determined as 558,501.03 tons. The amount of biogas to be obtained as a result of the use of animal manure in biogas plants was determined as 12,815,682.93 m^3. The amount of electrical energy that can be produced by using the obtained biogas was calculated as 60,233.71 MW. This electrical energy, obtained as a result of the calculations, will be able to meet 6.00% of the electricity needs of Isparta Province annually.

Keywords: Cattle, Isparta, Biogas, Manure, Electrical energy

Introduction

Biogas is a gas mixture obtained by biomethanization processes in the presence of different microorganisms in an oxygen-free environment of organic substances by anaerobic degradation. Biogas contains methane (CH_4), carbon dioxide (CO_2), nitrogen (N_2), hydrogen sulfide (H_2S), ammonia (NH_3), hydrogen (H_2), Carbon Monoxide (CO) (Anonim, 2014). Because of this property, biogas is a flammable gas mixture consisting of many organic wastes such as Forest Products, domestic and industrial wastes, agricultural wastes and animal manure and is defined as converted energy (Senol et al., 2017; Yetis et al., 2019).

Reliable and cheap energy sources are the most important element of the renewable environment. The probability of experiencing energy crises in the world is great. One of the most important energy sources of our country which is a country of Agriculture and animal husbandry is biogas. The revealing of this potential and the correct assessment of resources is of great importance to the national economy (Aslan et al., 2016; Atilgan et al., 2021).

Failure to evaluate animal wastes, which have high energy production potential, is a significant loss for our national energy resources. Construction and dissemination of biogas plants in accordance with regional conditions and production capacity will prevent environmental pollution and It will develop producers in terms of socioeconomic and cultural aspects in rural (Dagtekin et al., 2019).

Countries require a great deal of energy to maintain their basic activities. In the last 30 years, the increasing energy demand has also increased the need for different and new

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energy production sources (Dalpaz et al., 2020).

Used for electricity and heat generation, biogas is a practical way to efficiently recycle animal and vegetable waste. Animal and plant waste has significant potential for energy production due to its low costs (Ardebili, 2020).

The positive effect of converting animal and plant waste for energy production should not be ignored. Biogas plants in developed countries are used effectively and efficiently, and these facilities recover investment costs in a short period of time (Tolay et al., 2008).

The renewable and continuous production of biogas depends on various factors, namely economic, environmental, and social ones. Due to the use of waste, biogas production has a positive effect in terms of both reducing both foreign-source dependency, and energy and carbon dioxide emissions. Furthermore, the elimination of organic wastes that harm human health and cause environmental problems by converting them into energy further increases the importance of biogas technology (Yagli and Koc, 2019).

Energy production through the utilization of animal and plant waste is considered one of the best methods used for the development of energy production in many developed and developing countries (Khalil, 2019).

Biogas has an important place among renewable and continuous energy sources in many countries around the world. While production is widely conducted in family-type biogas plants in countries such as China and India on the Asian continent, industrial production is widespread in countries such as Finland, Germany, and Austria, due to the plenitude of cooperatives, and animal waste is generally used in these biogas plants (Salihoglu et al., 2019).

It is known that there are about 50 million biogas plants in the world. Approximately 43 million of the existing facilities are located in China, whereas 4.5 million are in India, but these facilities are primitive, have old technology, and are used for heating and cooking purposes. In the United States, approximately 1 billion kWh of electricity is produced annually from 265 biogas plants used for the utilization of agricultural waste (Ar, 2018).

In the European Union (EU) countries, since the early 2000s, the amount of energy produced using sustainable and renewable sources has continued to increase (Sturmer et al., 2021).

Energy production using biogas is expected to play an important role in the energy policy of the EU in the future (Meyer et al., 2018).

When the EU countries were analyzed in terms of the number of biogas production facilities, Germany ranked first with 10,971 biogas plants. Italy, which ranked second, has 1655 biogas plants, while France, which ranked third, has 742 biogas plants. Turkey ranked sixteenth with its 100 existing biogas plants. It is possible to say that Turkey lags behind many developed or developing countries when compared to continental European countries, according to the current number of biogas plants (Figure 1).

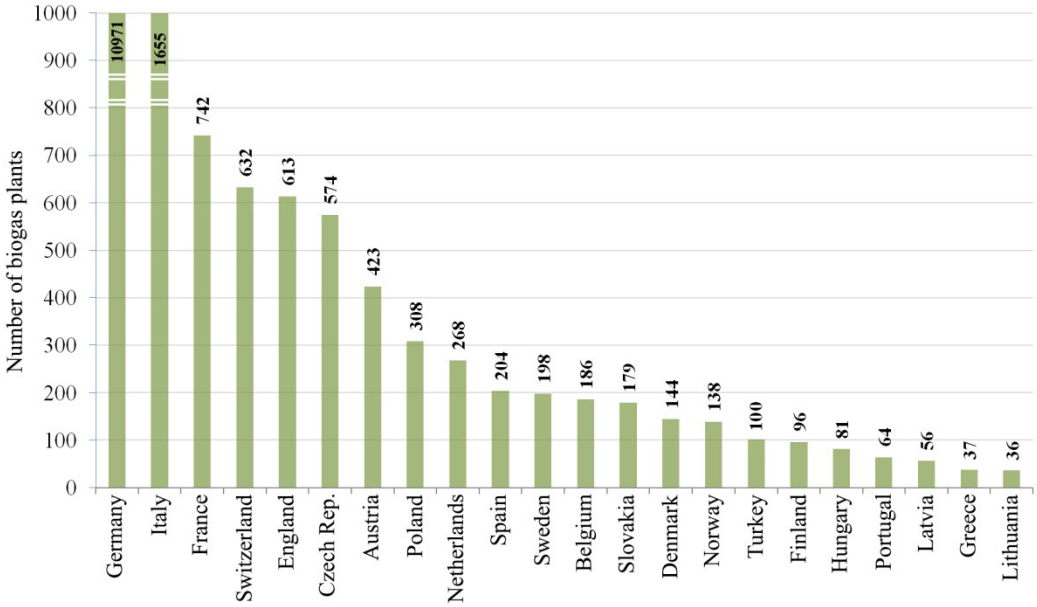

Figure 1. Number of biogas plants in countries on the European Continent (Anonim, 2018; EBA, 2018)

Biogas and biomass power plants operating in our country are examined, it is seen that the Marmara region ranks first in terms of the number of facilities and installed power. The total number of facilities in the Marmara region is 28 and the total installed capacity of these facilities is 197.89 MWe. In addition, the Marmara region alone accounts for 37.28% of Turkey's total installed capacity. The second-ranked Central Anatolia region has 20 facilities, and the total installed power of these facilities is 113.82 MWe. The Central Anatolia region accounts for 21.44% of Turkey's total installed capacity. The Mediterranean Region where Isparta is also included, ranked third in terms of the number of facilities and installed power. The number of facilities in the Mediterranean Region is 19, and the total installed power of these facilities is 78.18 MWe. The installed capacity of the existing facilities in the Mediterranean region to 14.73% of the total installed capacity (Table 1).

Table 1. Biogas and biomass power plants in Turkey by region (Anonim, 2018)

Regions	Number of biogas plants	Installed power (MWe)	Ratio (%)
Marmara	28	197.89	37.28
Central Anatolia	20	113.82	21.44
Mediterranean	19	78.18	14.73
Black Sea	10	57.55	10.84
Aegean	13	44.45	8.37
Eastern Anatolia	6	24.51	4.62
Southeast Anatolia	4	14.38	2.71
Total	100	530.78	100.00

Mediterranean region is one of Turkey's seven geographical regions. It stretches along the Mediterranean Sea coast in the south of Anatolia. The Aegean region is located in the west and northwest of the Mediterranean region. To the North is the Central Anatolia region and to the East is the Southeastern Anatolia region. It borders Syria in the Southeast. The provinces located in the Mediterranean region are Adana, Antalya, Burdur, Hatay, Kahramanmaraş, Mersin, Isparta and Osmaniye (Figure 2).

When the provinces in the Mediterranean region is evaluated according to the number of bovine animals it has, Adana province ranks first with the 248,527 cattle. Adana province has 18.47% of the total animal number of the Mediterranean Region. Burdur province, which ranks second, has 212,727 cattle and its share in the total cattle is 15.81%. Kahramanmaraş, which is in the third place, has 206,836 cattle and its ratio in the region is 15.37%. Isparta province ranks fifth after Antalya in the care of bovine animals in the Mediterranean region. The presence of cattle in the province of Isparta is 145,820 which corresponds to 10.84% of the total presence of cattle in the Mediterranean region (Table 2 and Figure 3).

Figure 2. Mediterranean Region and provinces (HGM, 2021)

According to Turkey's energy production and consumption scenarios, a rapid increase in both production and consumption amounts is expected over the next decade. Our main energy resources are lignite, hydroelectric and biomass energies. In addition to that about 3/4 of the energy used is imported (Aybek et al., 2015). It has become a requirement to use sustainable and renewable energy sources effectively to solve this problem. However, the use of animal waste as manure without any processing causes environmental pollution and also decreases productivity in agriculture. Taking into account the energy needs in Turkey and the environmental problems caused by animal waste, biogas plants should be established to solve these two problems effectively (Tuncez, 2018).

Bovine farming is one of the agricultural activities that contribute greatly to the city economy in the province of Isparta. The most accurate evaluation of the manure obtained with cattle breeding appears as a problem that needs to be solved. The use of manure obtained for this purpose as organic fertilizer for use in agricultural activities or use in energy production by converting it to biogas are the most appropriate alternatives. Evaluation of animal manure as biogas contains two solutions, both in terms of its evaluation in energy production and in terms of allowing the remaining organic fertilizer to be used in crop production at the end of this production.

Table 2. Bovine presence of Mediterranean Region provinces (TUIK, 2019)

Provinces	Number of bovine animal (piece)	Ratio (%)
Adana	248,527	18.47
Burdur	212,727	15.81
Kahramanmaraş	206,836	15.37
Antalya	188,579	14.01
Isparta	145,820	10.84
Hatay	140,246	10.42
Mersin	125,100	9.30
Osmaniye	77,737	5.78
Total	1,345,572	100.00

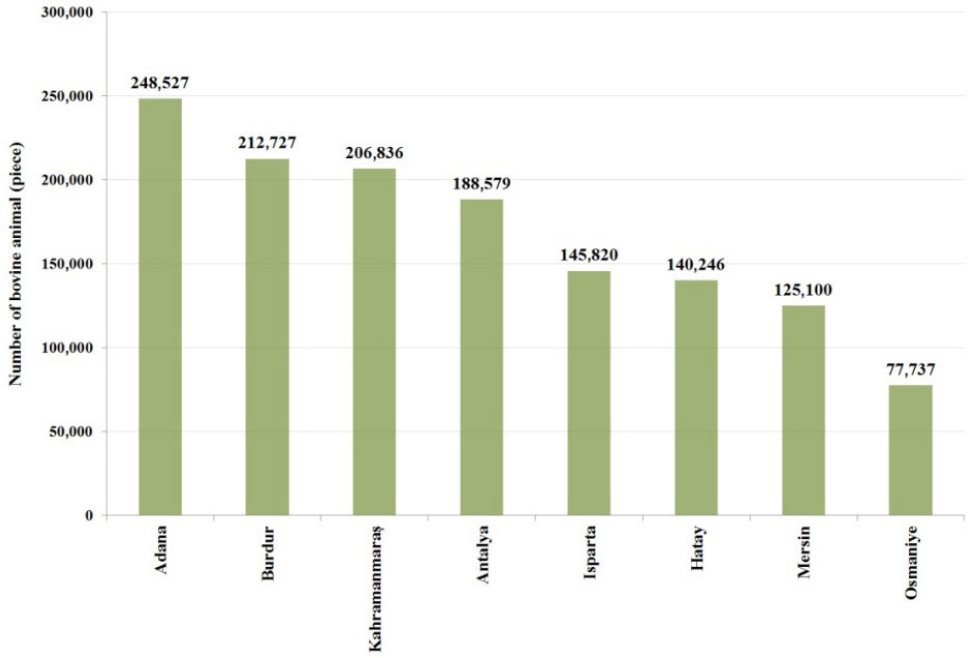

Figure 3. Presence of bovine in the Mediterranean Region provinces (TUIK, 2019)

In this study, the amount of biogas and electrical energy that can be obtained from the manure of cattle in Isparta was determined. The contribution of this amount of electrical energy that can be obtained to the electricity consumption of Isparta province has been questioned. The use of electrical energy which will be obtained from the waste of cattle use in agricultural production is also important in terms of reducing energy usage costs on agricultural activities.

Materials and Methods

Isparta Province is located at 30°20′ and 31°33′ E, and 37°18′ and 38°30′ N. Its surface area is 8933 km^2 and its altitude is 1050 m. Located in the Region of Lakes in the Mediterranean Region, Isparta Province is under the influence of a cold-semi continental climate (DIE, 1999). The research area is shown in Figure 4.

The material of the study comprised the presence of cattle in Isparta Province. The entire bovine animals was covered by the research on the basis of the full counting. Data on the existing bovine animals in Isparta Province were obtained from the Turkish Statistical Institute (TURKSTAT) database. The cattle farming data obtained were sorted and evaluated according to the age groups of the animals. Dairy cattle bred for the purpose of milk production comprised calves between 0 and 12 months of age, heifers between 12 and 24 months of age, and cows (milking) +24 months of age. Beef cattle bred for meat production comprised calves between 0 and 12 months of age, and heifers between 12 and 24 months of age. In Turkey, bull breeding is not preferred due to the use of artificial insemination methods in dairy cattle breeding. For this reason, the presence of bulls was excluded from the scope of the study. Data on the presence of cattle in Isparta Province and its districts are given in Table 3 and Figure 5.

Figure 4. Isparta Province and its districts (Anonim, 2021a)

Table 3. Presence of cattle in Isparta Province and its districts (TUIK, 2019)

Districts	Dairy cattle			Beef cattle		Number of cattle (piece)	Ratio (%)
	Calf (<12 month)	Heifer (12-24 month)	Cow (+24 month)	Calf (<12 month)	Heifer (12-24 month)		
Yalvaç	3,810	4,078	15,683	4,096	3,531	31,198	21.39
Şarkikaraağaç	5,531	5,812	9,929	5,735	2,325	29,332	20.12
Merkez	2,421	2,730	8,900	2,230	2,775	19,056	13.07
Eğirdir	2,163	2,762	6,893	1,732	1,169	14,719	10.09
Sütçüler	1,628	1,406	4,866	1,562	934	10,396	7.13
Keçiborlu	1,166	1,266	3,569	1,779	1,348	9,128	6.26
Aksu	1,123	1,826	2,870	885	1,249	7,953	5.45
Gelendost	1,145	711	3,096	1,216	367	6,535	4.48
Atabey	837	1,051	2,337	859	891	5,975	4.10
Gönen	935	650	2,240	795	373	4,993	3.42
Senirkent	508	515	2,100	520	261	3,904	2.68
Yenişarbademli	211	352	653	165	124	1,505	1.03
Uluborlu	137	116	514	137	222	1,126	0.77
Total	21,615	23,275	63,650	21,711	15,569	145,820	100.00

In dairy cattle, calves <12 months of age had an average live weight of 150 kg in Turkey and the daily amount of manure produced was 8.62 kg. The average live weight of heifers between 12 and 24 months of age was 350 kg, and the daily amount of manure produced was 20.41 kg. The average live weight of cows >24 months of age was around 450 kg, and the daily amount of manure produced was 28.12 kg. In beef cattle, calves <12 months of age had an average live weight of 200 kg in Turkey and the daily amount of manure produced was 11.79 kg. The average live weight of heifers between 12 and 24 months of age was 350 kg, and the daily amount of manure produced was 22.68 kg. (Anonymous, 2006; Anonymous, 2016; MWPS, 2004) (Table 4)

The ratio at which these manure values obtained Turkey can be collected and used as biogas was 50% (Aybek et al., 2015; Ekinci et al.,2010; Kulcu, 2002) (Table 4).

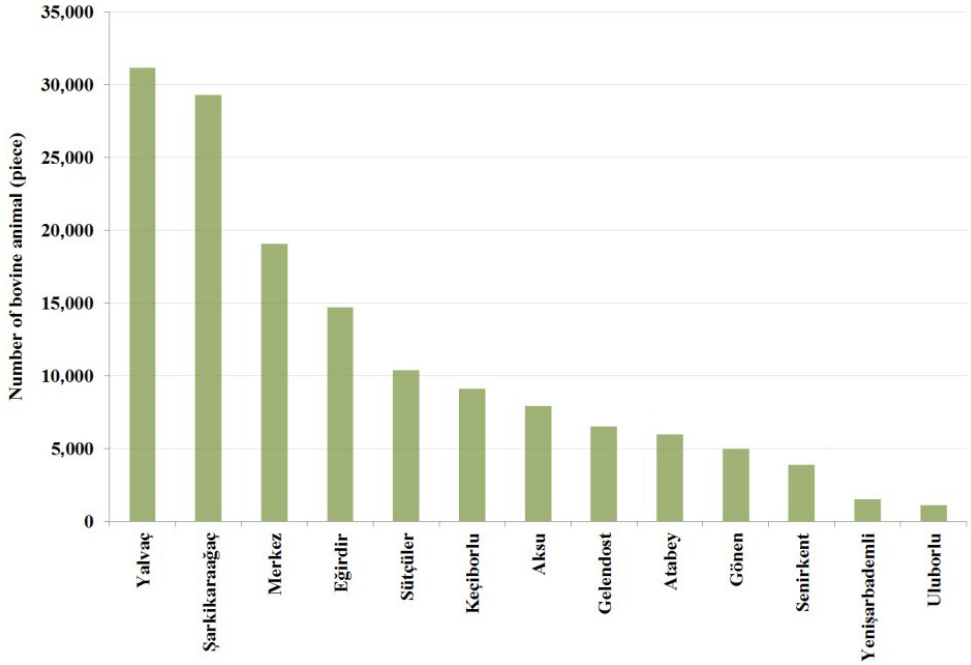

Figure 5. Presence of bovine animals in Isparta Province districts (TUIK, 2019)

Table 4. Daily amount of manure produced by the cattle

Dairy and beef cattle		Age group (month)	Average live weight (kg)	Manure production (kg day^{-1})	The ratio of collectable animal manure (%)
Dairy cattle	Calf	<12	150	8.62	50
	Heifer	12-24	350	20.41	50
	Cow	>24	450	28.12	50
Beef cattle	Calf	<12	200	11.79	50
	Heifer	12-24	350	22.68	50

When the biogas yields of the manure to be obtained from the various cattle were evaluated, the organic dry matter ratio of dairy cattle manure was 85%, and the biogas production efficiency per ton was determined as 20.2 m^3. The organic dry matter ratio of the manure obtained from beef cattle was 85%, and the biogas yield was 34.0 m^3 per ton (Table 5).

It was found that 1 m^3 of biogas obtained using animal and plant wastes is equal to 0.25 m^3 of propane gas. Moreover, 1 m^3 of biogas corresponded to 0.66 liter of diesel, 0.75 liter of gasoline, and 4.70 kWh of electrical energy. Similarly, it was determined that 1 m^3 of biogas corresponded to 4700–5700 kcal heat energy (Table 6).

Table 5. Biogas production quantities according to the various animal groups (Anonim, 2021b)

Animals groups	Organic dry matter ratio (%)	Biogas production efficiency (m^3 ton^{-1})	Methane (CH_4) (%)
Dairy cattle manure	85.0	20.2	55.0
Beef cattle manure	85.0	34.0	55.0
Horse manure	75.0	63.0	55.0
Chicken manure	75.0	100.0	65.0
Sheep manure	80.0	108.0	55.0

Table 6. Energy equivalents of 1 m^3 of biogas (Bugutekin, 2007; Celikkaya, 2016)

Energy equivalents	Units of measurement	Equivalent amount of energy
Propane	m^3	0.25
Diesel	liter	0.66
Gasoline	liter	0.75
Electricity	kWh	4.70
Heat energy	Kcal	4700-5700

Results and Discussion

When the amount of manure produced by dairy cattle in Isparta Province and its districts were evaluated, the amount of manure to be obtained from calves in the Yalvaç district was calculated as 11,987.40 tons. The total amount of manure to be obtained from heifers was found to be 30,379.67 tons, whereas the amount of manure to be obtained from cows was 160,967.18 tons, and the total amount of manure in Yalvaç was 203,334.25 tons. Barely 101,667.13 tons of this manure can be collected and will be used for biogas production.

The amount of manure to be obtained from calves in dairy cattle enterprises in the Şarkikaraağaç district was 17,402.19 tons. The amount of manure to be obtained from heifers was 43,297.37 tons, whereas the amount to be obtained from cows was 101,909.27 tons, which all totaled 162,608.82 tons. The amount of manure that can be used for biogas production was calculated as 81,304.41 tons.

The amount of manure to be obtained from calves in dairy cattle enterprises in the Merkez district was 7,617.19 tons. The amount of manure to be obtained from heifers was 20,337.54 tons, and the amount of manure to be obtained from cows was 91,347.82 tons, which all totaled 119,302.56 tons. The amount of manure that can be used for biogas production was found to be 59,651.28 tons.

The amount of manure produced in dairy cattle enterprises in the Yalvaç, Şarkikaraağaç, and Merkez districts of Isparta Province that can be used as biogas corresponded to 54.23% of the amount of manure that can be used for biogas in Isparta Province.

In the entire Isparta Province, the amount of manure to be obtained from calves in dairy cattle enterprises was calculated as 68,007.27 tons. The amount of manure to be obtained from heifers was 173,390.60 tons, and the amount of manure to be obtained from cows was 653,290.87 tons, totaling 894,688.75 tons. The amount of manure that can be used for biogas production was determined to be 447,344.37 tons (Table 7).

Table 7. Annual amount of manure produced by the dairy cattle

Districts	Manure production (tons $year^{-1}$)			Total manure production (tons $year^{-1}$)	The amount of manure to be used in biogas production (tons $year^{-1}$)	Ratio (%)
	Calf (<12 month)	Heifer (12-24 month)	Cow (+24 month)			
Yalvaç	11,987.40	30,379.67	160,967.18	203,334.25	101,667.13	22.73
Şarkikaraağaç	17,402.19	43,297.37	101,909.27	162,608.82	81,304.41	18.17
Merkez	7,617.19	20,337.54	91,347.82	119,302.56	59,651.28	13.33
Eğirdir	6,805.45	20,575.93	70,748.37	98,129.75	49,064.88	10.97
Sütçüler	5,122.18	10,474.21	49,943.65	65,540.04	32,770.02	7.33
Keçiborlu	3,668.59	9,431.26	36,631.50	49,731.34	24,865.67	5.56
Aksu	3,533.29	13,603.06	29,457.11	46,593.46	23,296.73	5.21
Gelendost	3,602.51	5,296.70	31,776.72	40,675.94	20,337.97	4.55
Atabey	2,633.45	7,829.58	23,986.50	34,449.54	17,224.77	3.85
Gönen	2,941.79	4,842.27	22,990.91	30,774.98	15,387.49	3.44
Senirkent	1,598.32	3,836.57	21,553.98	26,988.87	13,494.44	3.02
Yenişarbademli	663.87	2,622.28	6,702.26	9,988.41	4,994.20	1.12
Uluborlu	431.04	864.16	5,275.59	6,570.80	3,285.40	0.73
Total	68,007.27	173,390.60	653,290.87	894,688.75	447,344.37	100.00

When the amounts of manure to be obtained from beef cattle grown in Isparta Province and its districts were evaluated, the amount of manure to be obtained from calves in the Yalvaç district was calculated as 17,626.52 tons, and the amount of manure to be obtained from the heifers was calculated as 29,230.32 tons. The amount of manure to be obtained in beef cattle in the Yalvaç district was 46,856.85 tons in total, and the portion of this manure that can be used for biogas production was 23,428.42 tons.

In the Şarkikaraağaç district, the amount of manure to be obtained from calves in beef cattle enterprises was 24,679.71 tons. The total amount of manure to be produced was 43,926.53

tons, with 19,246.82 tons of manure to be obtained from the heifers. The amount of manure that can be used for biogas production was determined to be 21,963.26 tons.

In the Merkez district, the amount of manure to be obtained from calves in beef cattle enterprises was 9,596.47 tons, and the amount of manure to be obtained from the heifers was 22,972.01 tons, which all totaled 32,568.48 tons. The amount of manure that can be used for biogas production was calculated as 16,284.24 tons.

The amount of manure to be obtained from beef cattle enterprises in the Yalvaç, Şarkikaraağaç, and Merkez districts of Isparta Province that can be used as biogas corresponded to 55.49% of the total amount of manure that can be utilized for biogas in Isparta Province.

In the entire Isparta Province, the amount of manure to be obtained from calves in beef cattle enterprises was 93,430.03 tons, and the amount of manure to be obtained from the heifers was 128,883.30 tons, which all totaled 222,313.33 tons. The amount of manure that can be used for biogas production was 111,156.66 tons (Table 8).

Table 8. Annual amount of manure produced by beef cattle

Districts	Manure production (tons year^{-1})		Total manure production (tons year^{-1})	The amount of manure to be used in biogas production (tons year^{-1})	Ratio (%)
	Calf (<12 month)	Heifer (12-24 month)			
Yalvaç	17,626.52	29,230.32	46,856.85	23,428.42	21.08
Şarkikaraağaç	24,679.71	19,246.82	43,926.53	21,963.26	19.76
Merkez	9,596.47	22,972.01	32,568.48	16,284.24	14.65
Eğirdir	7,453.40	9,677.22	17,130.62	8,565.31	7.71
Sütçüler	6,721.83	7,731.84	14,453.67	7,226.84	6.50
Keçiborlu	7,655.66	11,159.01	18,814.67	9,407.34	8.46
Aksu	3,808.46	10,339.47	14,147.94	7,073.97	6.36
Gelendost	5,232.87	3,038.10	8,270.97	4,135.49	3.72
Atabey	3,696.58	7,375.88	11,072.45	5,536.23	4.98
Gönen	3,421.16	3,087.77	6,508.93	3,254.47	2.93
Senirkent	2,237.74	2,160.61	4,398.35	2,199.18	1.98
Yenişarbademli	710.05	1,026.50	1,736.55	868.27	0.78
Uluborlu	589.56	1,837.76	2,427.32	1,213.66	1.09
Total	93,430.03	128,883.30	222,313.33	111,156.66	100.00

When Table 7 and Table 8 were evaluated together, the amount of manure to be obtained from dairy cattle was calculated as 894,688.75 tons, the amount of manure to be obtained from fattening beef cattle was calculated as 222,313.33 tons and in total 1,117,002.08 tons. The amount of manure that can be used for biogas production was found to be including 447,344.37 tons in dairy cattle, 111,156.66 tons in beef cattle and 558,501.03 in total.

When the amount of biogas to be produced from the manure of cattle in Isparta Province and its districts was analyzed, the amount of biogas that can be produced by utilizing the manure obtained from dairy cattle in the Yalvaç district was calculated as 2,053,675.94 m^3 and the amount of biogas that can be produced by utilizing beef cattle manure was 796,566.38 m^3. It was observed that a total of 2,850,242.31 m^3 of biogas production is possible in the Yalvaç district.

In the Şarkikaraağaç district, the amount of biogas that can be produced by utilizing manure obtained from dairy cattle was 1,642,349.10 m^3, and the amount of biogas that can be produced by utilizing beef cattle manure was 746,750.96 m^3 It was determined that a total of 2,389,100.06 m^3 of biogas production is possible in the Şarkikaraağaç district.

In the Merkez district, the amount of biogas that can be produced by utilizing manure obtained from dairy cattle was 1,204,955.82 m^3, and the amount of biogas that can be produced by utilizing beef cattle manure was 553,664.08 m^3. It was calculated that a total of 1,758,619.91 m^3 of biogas production is possible in the Merkez district.

The amount of biogas obtained as a result of the conversion of manure collected from dairy and beef cattle enterprises into biogas in the Yalvaç, Şarkikaraağaç, and Merkez districts of Isparta Province corresponded to 54.60% of the total biogas production in Isparta Province.

The amount to be obtained as a result of converting the manure procured from dairy cattle enterprises into biogas in Isparta Province was 9,036,356.36 m^3. The amount to be obtained as a result of converting the manure procured from beef cattle enterprises into biogas was 3,779,326.57 m^3 and totally 12,815,682.93 m^3 in Isparta Province (Table 9 and Figure 6).

As a result of converting the biogas obtained from the cattle manure in Isparta Province and its districts into electrical energy, it was calculated that 13.396.14 MWe of electrical energy production is possible in the Yalvaç district. The electrical energy that can be produced from biogas in the Şarkikaraağaç district was 11,228.77 MWe, and the electrical energy that can be produced from biogas in the Merkez district was 8,265.51 MW. The electricity generation based on biogas in Isparta Province was 60,233.71 MWe (Table 10, Figure 7 and Figure 8).

As a result of the calculations, it was calculated that 5.30%–6.69% of the monthly electricity consumption of Isparta Province can be met by the electricity generated from manure obtained from cattle in Isparta Province and its districts. On an annual basis, it was calculated that 5.98% of the electricity needs of Isparta Province can be met by converting biogas from cattle manure into electrical energy (Table 11).

Table 9. Amount of biogas to be produced from cattle manure

Districts	Dairy cattle			Beef cattle			Total biogas production (m^3 $year^{-1}$)	Ratio (%)
	The amount of manure to be used in biogas production (tons $year^{-1}$)	Biogas yield (m^3 ton^{-1})	Biogas production (m^3 $year^{-1}$)	The amount of manure to be used in biogas production (tons $year^{-1}$)	Biogas yield (m^3 ton^{-1})	Biogas production (m^3 $year^{-1}$)		
Yalvaç	101,667.13	20.2	2,053,675.94	23,428.42	34.0	796,566.38	2,850,242.31	22.24
Şarkikaraağaç	81,304.41	20.2	1,642,349.10	21,963.26	34.0	746,750.96	2,389,100.06	18.64
Merkez	59,651.28	20.2	1,204,955.82	16,284.24	34.0	553,664.08	1,758,619.91	13.72
Eğirdir	49,064.88	20.2	991,110.51	8,565.31	34.0	291,220.51	1,282,331.02	10.01
Sütçüler	32,770.02	20.2	661,954.35	7,226.84	34.0	245,712.42	907,666.77	7.08
Keçiborlu	24,865.67	20.2	502,286.58	9,407.34	34.0	319,849.45	822,136.03	6.42
Aksu	23,296.73	20.2	470,593.96	7,073.97	34.0	240,514.92	711,108.89	5.55
Gelendost	20,337.97	20.2	410,826.99	4,135.49	34.0	140,606.54	551,433.53	4.30
Atabey	17,224.77	20.2	347,940.31	5,536.23	34.0	188,231.72	536,172.03	4.18
Gönen	15,387.49	20.2	310,827.25	3,254.47	34.0	110,651.84	421,479.09	3.29
Senirkent	13,494.44	20.2	272,587.59	2,199.18	34.0	74,771.99	347,359.58	2.71
Yenişarbademli	4,994.20	20.2	100,882.92	868.27	34.0	29,521.34	130,404.26	1.02
Uluborlu	3,285.40	20.2	66,365.04	1,213.66	34.0	41,264.43	107,629.47	0.84
Total	447,344.37		9,036,356.36	111,156.66		3,779,326.57	12,815,682.93	100.00

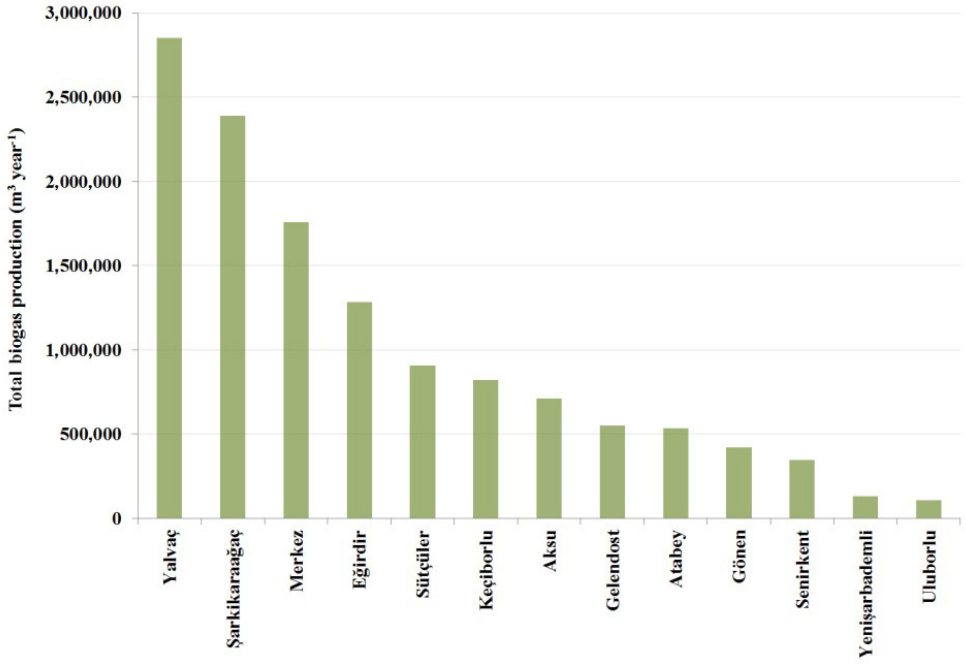

Figure 6. Amount of biogas to be produced from cattle manure in Isparta Province districts

Table 10. Amount of electrical energy to be generated from biogas

Districts	Total biogas production (m^3 $year^{-1}$)	Electricity generation from 1 m^3 biogas (kW $year^{-1}$)	Electricity generation from biogas (kW $year^{-1}$)	Electricity generation from biogas (MWe $year^{-1}$)	Ratio (%)
Yalvaç	2,850,242.31	4.7	13,396,138.88	13,396.14	22.24
Şarkikaraağaç	2,389,100.06	4.7	11,228,770.27	11,228.77	18.64
Merkez	1,758,619.91	4.7	8,265,513.56	8,265.51	13.72
Eğirdir	1,282,331.02	4.7	6,026,955.78	6,026.96	10.01
Sütçüler	907,666.77	4.7	4,266,033.82	4,266.03	7.08
Keçiborlu	822,136.03	4.7	3,864,039.34	3,864.04	6.42
Aksu	711,108.89	4.7	3,342,211.76	3,342.21	5.55
Gelendost	551,433.53	4.7	2,591,737.59	2,591.74	4.30
Atabey	536,172.03	4.7	2,520,008.53	2,520.01	4.18
Gönen	421,479.09	4.7	1,980,951.72	1,980.95	3.29
Senirkent	347,359.58	4.7	1,632,590.01	1,632.59	2.71
Yenişarbademli	130,404.26	4.7	612,900.01	612.90	1.02
Uluborlu	107,629.47	4.7	505,858.49	505.86	0.84
Total	12,815,682.93		60,233,709.76	60,233.71	100.00

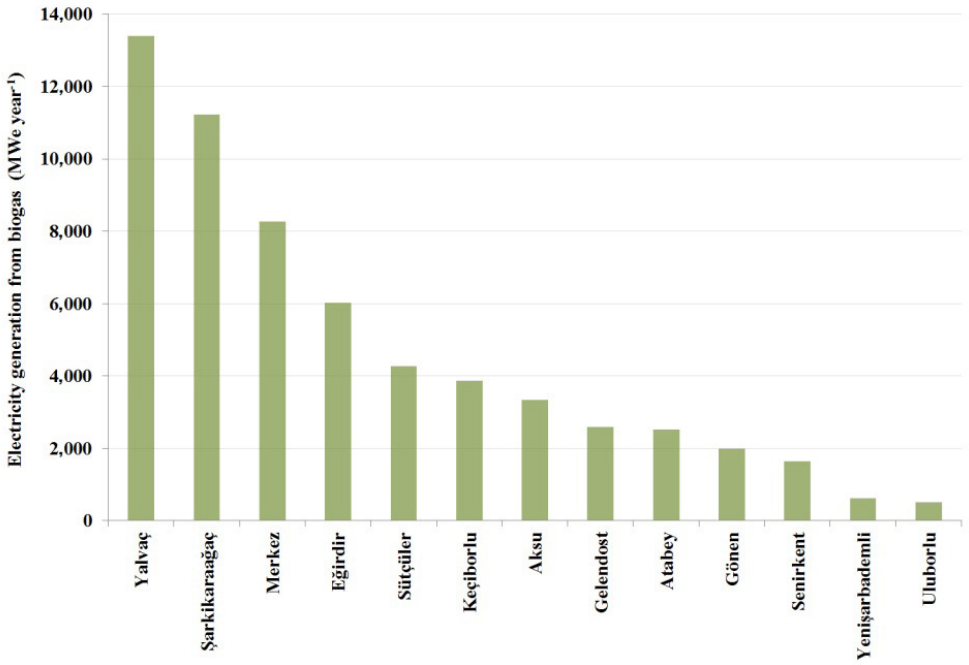

Figure 7. Amount of electrical energy to be generated from biogas in Isparta Province districts

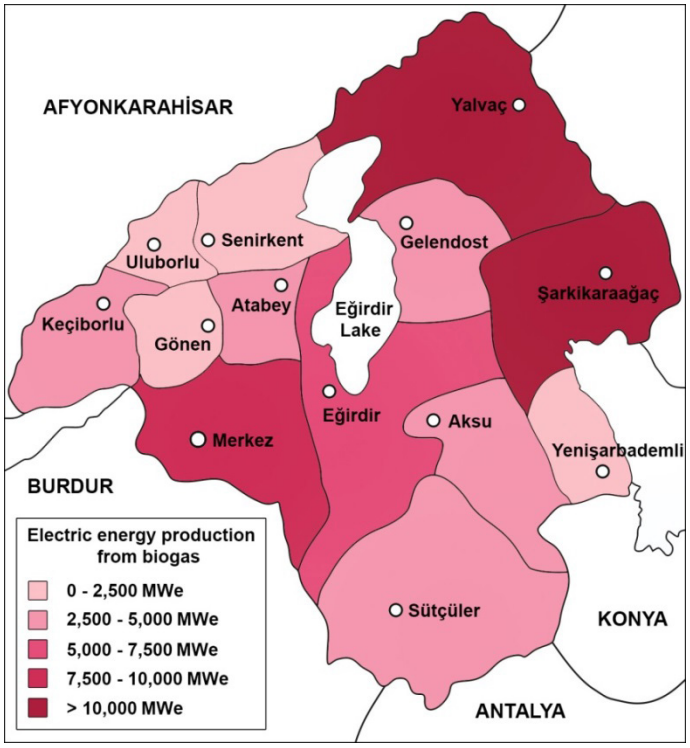

Figure 8. Amount of electrical energy to be generated from biogas by the districts

Table 11. Ratio of the amount of electrical energy to be produced to the electricity consumption

Months	Electricity consumption in Isparta* (MWh month^{-1})	Electricity generation from biogas (MWh month^{-1})	Ratio of production to consumption (%)
January	85,984.20	5,019.48	5.84
February	77,314.13	5,019.48	6.49
March	81,486.98	5,019.48	6.16
April	79,224.84	5,019.48	6.34
May	80,006.21	5,019.48	6.27
June	75,045.98	5,019.48	6.69
July	94,688.74	5,019.48	5.30
August	91,192.81	5,019.48	5.50
September	85,704.44	5,019.48	5.86
October	88,359.41	5,019.48	5.68
November	83,896.57	5,019.48	5.98
December	84,306.22	5,019.48	5.95
Total	1,007,210.53	60,233.71	6.00

*Monthly electricity consumption in Isparta (EPDK, 2019)

Conclusion

As of 2019, the amount of dairy cattle is 108,540 head, the amount of beef cattle is 37,280 head and total bovine animals are 145,820 head in Isparta province. The amount of manure to be obtained from existing dairy cattle is 894,688.75 tons and 222,313.33 tons from beef cattle in total 1,117,002.08 tons. The portion of this manure that can be collected and converted to biogas is 447,344.37 tons in dairy cattle, 111,156.66 tons in beef cattle and in total is 558,501.03 tons. The amount of biogas to be obtained by converting dairy cattle manure to biogas is 9,036,356.36 m^3, the amount of biogas to be obtained by converting beef cattle manure to biogas is 3,779,326.57 m^3 and in totally 12,815,682.93 m^3. The amount of electrical energy to be produced from biogas is 60,233.71 MWe.

The fact that Isparta province can meet 6.00% of its current electricity consumption if the existing cattle potential in Isparta Province is used for the production of electrical energy requires major projects to be conducted in the regional plan. It is necessary to determine the wastes that are obtained through animal and plant production in each province in Turkey, and make the necessary investments for their utilization. In this way, the use of electrical energy that can be produced by utilizing wastes obtained via animal and plant production in the agricultural sector will provide financial relief for the agricultural sector, as well.

Moreover, by converting animal and plant wastes into electrical energy, the negative effects that emerge due to these wastes will be eliminated. Many negative environmental factors, such as the risk of disease, bad odors, and the contamination of groundwater that emerge as a result of the accumulation of manure, will be prevented.

Compliance with Ethical Standards

Conflict of interest

The authors declare that for this article they have no actual, potential or perceived the conflict of interests.

Author contribution

The contribution of the authors is equal. All the authors read and approved the final manuscript. All the authors verify that the Text, Figures, and Tables are original and that they have not been published before.

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