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INVESTIGATION OF BIOGAS GENERATION CAPACITY FROM ANIMAL MANURE IN BITLIS PROVINCE

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ABSTRACT

Today, most of the energy needs are met from exhaustible fossil fuels, which leads to environmental problems. Therefore, the development and use of renewable energy sources is becoming increasingly important. This study examined the biogas potential derived from local animal manure waste in the city center and areas of Bitlis. Additionally, the equivalent heat and electricity energy potential of the determined biogas amount was calculated. According to the data obtained in the study, the biogas production capacity varied between 27.235 million m³, 27.486 million m³, 24.838 million m³, 20.760 million m³, and 20.594 million m³ from 2019 to 2023, respectively. The equivalent thermal energy amounts that can be obtained based on the biogas production capacity were calculated as 136.18x109 kcal/year, 137.43x109 kcal/year, 124.19x109 kcal/year, 103.80x109 kcal/year, and 102.97x109 kcal/year, respectively. The equivalent amounts of electricity energy in the same years were calculated as 128.00 GWh/year, 129.19 GWh/year, 116.74 GWh/year, 97.57 GWh/year, and 96.79 GWh/year, respectively. Biogas production from animal manure not only reduces the environmental impact of waste but also increases agricultural productivity by providing valuable byproducts such as fermented fertilizer. This process offers both economic and ecological benefits, contributing to sustainable energy production.

Keywords: Renewable energy, Biogas, Animal waste, Thermal energy, Electricity energy.

1 INTRODUCTION

Energy, defined as the ability to do work, plays an important role both in people's lives and in the development of economies. In recent years, the increase in human population, technological advances, and industrial developments has led to an increase in global energy demand [1]–[3]. The inability of the existing energy supply to meet this increasing energy

demand leads to a continuous increase in energy prices [4], [5]. Although energy can be obtained from various sources today, most of the consumed energy is derived from fossil fuels (such as coal, oil and natural gas), which are limited and will eventually be depleted. Fossil fuel-based energy sources contribute to harmful environmental issues such as global warming and climate change. Additionally, in many countries, the insufficiency of fossil fuel resources increases dependence on external sources [6]–[8].

Countries have started to review their energy strategies and policies to minimize these problems. Various methods have been proposed to partially or fully mitigate the problems associated with fossil fuels, such as improving the efficiency of existing technologies, developing new devices with higher efficiency and lower environmental impact, and partially or fully switching to renewable energy sources. Among these methods, the transition to renewable energy sources is the most promising approach to rapidly move away from fossil fuels [9]–[12].

The advancement of renewable and sustainable energy is essential for fulfilling global energy requirements. Preferably, these sources ought to exert minimum adverse effects on the environment. Generating renewable energy from locally obtained materials provides substantial benefits, including reduced manufacturing expenses. Biogas, due to its ability to convert waste materials into energy, is one of the attractive renewable sources. In regions rich in agricultural and livestock waste, energy obtained from organic waste can be provided continuously and consistently, making the use of biogas more advantageous compared to other renewable energy sources. Biogas is a combustible gas mixture formed by the breakdown of biomass, which consists of organic matter and can be used for energy production, by microorganisms in an anaerobic environment. It arises from the fermentation of organic matter under anaerobic conditions by bacteria naturally found in environments such as wetlands, sediments, and marshes. Biogas is an aggregated gas mixture consisting mainly of methane, carbon dioxide, and hydrogen sulfide [13]–[16].

Today, organic wastes from livestock and poultry have caused significant environmental problems. In rural areas, uncontrolled storage or burning of large quantities of animal manure for heating purposes has caused various health and environmental problems, such as decreased quality of manure, loss of a significant portion of its energy, odor and visual pollution, as well as soil and water pollution. Organic wastes that cause these problems can be used for biogas production through anaerobic digestion. Biogas production from animal manure is highly beneficial as it significantly reduces the environmental impact of the waste, acts as a source of

energy, and provides fermented manure, a by-product of the biogas production process [17], [18].

Biogas containing energy-rich methane is produced by microbial decomposition of organic material under anaerobic conditions. In this method, called anaerobic digestion, the decomposition of organic matter is a biological process that takes place in four main steps: hydrolysis, acidogenesis, acetogenesis, and methanogenesis. Most of the control in anaerobic digestion is carried out directly by the microorganisms. However, factors such as temperature, residence time, mixing, pH, C/N ratio, nutrient value, and harmful substances can play an important role in changing the efficiency and reaction rates of biogas production processes. In order to achieve optimum biogas yield at the lowest cost, these factors, which directly affect microbial activity, need to be controlled. Depending on the type of feedstock, biogas produced contains methane (CH_4), carbon dioxide (CO_2), nitrogen (N_2), hydrogen (H_2), oxygen (O_2), carbon monoxide (CO), ammonia (NH_3), and hydrogen sulfide (H_2S). The content of CO_2, H_2S, and water vapor in biogas can affect the performance and lifetime of energy conversion devices, so their removal is essential to improve the quality of biogas [19]–[23].

The main advantages of biogas include energy production, reduction of waste, reduction of pathogens, conversion of organic waste into high-quality fertilizer, protection of vegetation, soil, and water, as well as increased productivity in livestock and agriculture. Disadvantages include limited and small-scale technology, the presence of impurities, the impact of temperature on biogas production, unsuitability for urban and densely populated areas, and relatively high cost [24]. Biogas, after production, can be processed through certain stages and used to meet various energy needs. It can be used as fuel for heat and electricity generation or injected into the gas grid as biomethane. More than 90% of the biogas produced worldwide has been used for electricity and heat generation, while the remaining 9% has been used in the mobility sector as biomethane or injected into natural gas grids. In addition, the methane (CH_4) and hydrogen (H_2) gases made during biogas production can be turned into electricity using fuel cells [25]–[27]. Although Türkiye is rich in biomass resources, it imports 70% of its energy needs. Since 65% of the waste in our country is organic, the effective use of biomass resources can contribute to meeting energy needs and reducing environmental pollution. The wastes used in biogas production can also be used as organic fertilizer after energy production [28]. In our country, livestock waste, poultry waste, agricultural residues, urban solid waste, and sewage sludge are used for biogas production. The first biogas plant was established in 1980, and its

importance was better understood in the 2000s. These plants contribute to the economy by producing energy from animal waste in rural areas [29].

In recent years, the interest in biogas produced from animal waste has increased, and the biogas potential of many provinces in our country has been studied. Some studies in the literature that involve calculating the biogas potential from animal manure are provided below.

Kalaycı, E. et al. [30] examined the relationship between animal waste and biogas, the factors affecting the biogas production process, the identification of wastes used in biogas production, and the identification and interpretation of the existing biogas potential from animal waste in Kırklareli province, together with recommendations for the future. This study emphasized the role of biogas production in sustainable energy production and discussed the necessary steps to ensure maximum biogas production from animal wastes. Işık, S., and Yavuz, S. [31] calculated the annual biogas potential based on the livestock data for cattle, ovine, and poultry in Bingöl province between 2015 and 2020. Additionally, they determined the amount of manure, biogas potential, electricity, and heat energy based on the 2020 animal data for the districts in Bingöl. The results of the study indicated that, in 2020, approximately 754 thousand tons of usable manure, 36.5 million m^3 of biogas, 171.4 GWh of electricity, and 171449.106 kcal/m^3 of heat energy could be obtained from the 5694302 animals, including 865202 cattle and ovine in Bingöl province. Salihoğlu, N. K., et al. [32] aimed to determine the potential biogas production and energy potential from the waste generated by cattle and ovine raised for meat and milk production within the borders of Balıkesir province. The results showed that the 5955318 tons of animal waste expected to be generated annually in Balıkesir province have a biogas potential of 82.82 million m^3. Seyhan, A. K., and Badem, A. [33] calculated the annual amount of biogas that can be obtained from animal wastes in Erzincan province as approximately 15.51 million m^3, electrical energy as 38.03 GWhe, and heat energy as 35.82x109 kcal. They stated that Erzincan has a potential of 4.3 MW in terms of biogas-based electricity installed power and that it has a remarkable quality in terms of biogas and energy production values. Altıkat, S., and Çelik, A. [34] determined the biogas potential derived from animal waste in Iğdır province and its districts. As a result of their research, they stated that Iğdır province has an annual biogas energy potential of 21.441 million m^3 derived from animal waste. They also mentioned that the biogas potential from animal waste in Iğdır constitutes 3.76% of the Eastern Anatolia Region and 0.679% of Türkiye. Kumaş, K., et al. [35] developed a digital map by assessing biogas production and energy potentials derived from agricultural and animal waste in Isparta province. The study determined that 25.83 million m^3/year of biogas

may be derived from animal manure, yielding a thermal value of 586369.70 GJ/year, while the total energy potential from certain agricultural wastes is 3549790.42 GJ/year. Bulut, A. P. et al. [36] examined the biogas and potential for energy of animal waste by assessing the populations of cattle, ovine, and poultry in Sivas province. As a result, they determined that 6.5% of the annual electricity needs of Sivas province can be met with the energy to be produced from the wastes obtained.

In this study, the biogas production capacity that can be obtained from animal waste in Bitlis province and its districts between 2019 and 2023 was theoretically calculated. Additionally, the electrical and thermal energy production capacities that can be achieved by utilizing the biogas obtained from animal waste sources were examined. The Turkish Statistical Institute (TUIK) and the Bitlis Provincial Directorate of Agriculture and Forestry obtained the animal numbers used in the study. The amount of animal manure used in the calculation of the amount of biogas was calculated using the species and number of animals.

2 MATERIAL AND METHOD

2.1 Bitlis Province

Bitlis province is located in the Upper Euphrates Section and Upper Murat-Van Section of the Eastern Anatolia Region, between the longitudes of 41°33' and 43°11' east and latitudes of 37°54' and 38°58' north. The province consists of 7 districts: Adilcevaz, Ahlat, Güroymak, Hizan, Center, Mutki, and Tatvan (Figure 1). The province has a total of 8 towns, 334 villages, and 290 hamlets, with 245 of the villages being forest villages. Due to the mountainous and rugged topography of the province, the settlement areas are scattered [37].

Figure 1. Bitlis Civil Administration Provincial Map [38].

Bitlis has a total area of 6,707 km². When including the 1,876 km² portion of Lake Van that lies within the boundaries of Bitlis province, as well as other lake surfaces, the total area of the province is 8,645 km². With this area, Bitlis covers 1% of Türkiye's total land area and 5.5% of the land area of the Eastern Anatolia Region. The province is bordered by Van province and Lake Van to the east, Siirt and Batman to the south, Muş to the west, and Ağrı to the north [37]. The population of Bitlis province is 359747 people, according to the results of the 2023 Address-Based Registration System. While 64.47% of the population live in cities, 35.53% live in towns and villages. The largest districts in terms of population density are Tatvan, Center, Güroymak, and Ahlat. Bitlis province is below the average of Türkiye in terms of urbanization rate, population growth rate, gross domestic product per capita, and total employment rate of those working in industry, while the total employment rate of those working in agriculture is above the average of Türkiye. The city generates income from agriculture, the sale of livestock and dairy products, and the beekeeping sector. Table 1 shows the province/district center, town/village population, and annual population growth rate according to Bitlis Province and districts in 2023 [39].

Table 1. Bitlis province population and annual population growth rate in 2023 [39].

Province and district	Population			Annual growth rate of population (%)
	Total	Province and district centers	Towns and villages	
Bitlis	359747	231921	127826	16.1
Center	73264	55959	17305	15.7
Adilcevaz	29697	15059	14638	5.3
Ahlat	44475	30004	14471	38.2
Güroymak	49161	29843	19318	12.0
Hizan	31911	13194	18717	2.4
Mutki	29203	2570	26633	-23.9
Tatvan	102036	85292	16744	28.2

2.2 Method

In this study, data on livestock in Bitlis province and its districts between 2019 and 2023 were obtained from the Turkish Statistical Institute (TÜIK) and the Provincial Directorate of Agriculture and Forestry. In line with these data, the distribution of animals by years was analyzed, and the amount of waste was calculated according to the species and number of animals. Then, the amount of usable waste was determined, and the amount of biogas that can be produced from this waste was calculated. Different calculation methods can be used to

calculate the biogas production potential from animal wastes. In the study, the amounts of manure per animal determined within the scope of the Agro-Waste project were used. Accordingly, it was assumed that cattle produce an average of 9.94 tons of manure per year, a ovine produces 0.82 tons, and poultry produces 0.029 tons. Additionally, it was assumed that 65% of cattle manure, 13% of ovine manure, and 99% of poultry manure are usable for biogas production. The remaining portion was assumed to be absorbed into nature in pastures. According to research, 33 m^3 of biogas is obtained from 1 ton of cattle manure, 58 m^3 from ovine manure, and 78 m^3 from poultry manure. These values, taken as a basis in calculations, are given in Table 2. In addition, the electrical energy equivalent of 1 m^3 of biogas is determined as 4.7 kWh [40], [41].

Table 2. Acceptances for biogas energy potential.

Animal Species	Annual Manure (tons/years)	Biogas generated from 1 ton of manure (m^3)
Cattle	9.94	33 m^3
Ovine	0.82	58 m^3
Poultry	0.029	78 m^3

3 RESULTS AND DISCUSSION

According to the data of the Turkish Statistical Institute (TÜIK) and the Provincial Directorate of Agriculture and Forestry, the number of cattle, ovine, and poultry in Bitlis province center and six districts between 2019 and 2023 is given in Table 3. In the study, the numbers of cattle and buffalo as cattle, ovine and goats as ovine animals, and laying hens, turkeys, geese, ducks, and guinea fowls as poultry were taken as reference.

When the number of animals and the change in these numbers between 2019-2023 are analyzed; the number of cattle in the Adilcevaz district, which was 6919 in 2019, decreased to 3126 in 2023. In the five-year period, a 55% decrease was observed in the cattle population. While the ovine population was 141483 in 2019, it became 176999 in 2023. Despite the annual changes in the ovine population, there is a general upward trend. The number of ovine animals peaked in 2022 with 189163 and experienced a small decline in 2023. The number of poultry is 26249 in 2019 and 22362 in 2023. It is determined that the amount of poultry decreases over the five-year period.

Table 3. Number of animals in Bitlis province and districts between 2019-2023.

	Years/ Species	Cattle	Ovine	Poultry		Years/ Species	Cattle	Ovine	Poultry
Adilcevaz	2019	6919	141483	26249	**Center**	2019	11131	44148	13537
	2020	7613	157825	24254		2020	10916	52203	13965
	2021	5086	162715	24181		2021	8913	63945	14051
	2022	3915	189163	23629		2022	6595	66208	13401
	2023	3126	176999	22362		2023	6464	53262	14993
Ahlat	2019	13727	120212	12214	**Mutki**	2019	25746	120083	15224
	2020	17531	127442	30665		2020	18516	123494	16790
	2021	12356	129672	30316		2021	18390	127581	17014
	2022	10850	124000	28822		2022	17955	146312	14564
	2023	9611	120412	28823		2023	21123	110849	14023
Güroymak	2019	25994	89690	8272	**Tatvan**	2019	11073	87726	11091
	2020	28378	116448	8702		2020	10597	87175	11554
	2021	27234	110220	8535		2021	9406	93159	11795
	2022	17233	96444	14148		2022	7408	98330	11780
	2023	17165	78426	14169		2023	7930	91986	10552
Hizan	2019	10220	84897	13997					
	2020	8526	107924	3800					
	2021	7606	107938	3789					
	2022	5396	93821	3856					
	2023	5450	107954	4033					

In the Ahlat district, the number of cattle, which was 13727 in 2019, decreased by approximately 30% to 9611 in 2023. This decrease has become more evident, especially after 2021. While the number of ovine animals was 120212 in 2019, it increased to 120412 in 2023. The number of poultry increased from 12214 in 2019 to 28823 in 2023. In the five-year period, an increase of 136% was observed in the amount of poultry.

In the Güroymak district, the number of cattle animals decreased by 34%, and the number of ovine animals decreased by 12% between 2019 and 2023. The number of cattle, which was 25994 in 2019, decreased to 17165 in 2023. Similarly, the number of ovine animals decreased from 89690 in 2019 to 78426 in 2023. The number of poultry in the district increased from 8272 in 2019 to 14169 in 2023, an increase of approximately 71%.

In the Hizan district, the number of cattle decreased by 34% between 2019 and 2023. The number of cattle, which was 10220 in 2019, showed a continuous decline in the five-year period and decreased to 5450 in 2023. The number of ovine animals in the district increased by

27% from 84897 in 2019 to 107954 in 2023. The number of poultry, which was 13997 in 2019, decreased significantly to 3800 in 2020. In 2023, the number of poultry increased to 4033.

In the center of Bitlis, the number of cattle, which was 11131 in 2019, decreased to 6464 in 2023. In this process, there was a decrease of approximately 42% in the number of cattle. While the number of ovine animals was 44148 in 2019, it increased to 53262 in 2023. A general upward trend is observed in the center over the years. The number of poultry, which was 13537 in 2019, reached 14993 in 2023 with a slight increase.

In the Mutki district, the number of large cattle decreased by 18% between 2019 and 2023. The number of animals, which was 25,746 in 2019, decreased to 21,123 in 2023. The number of ovine, which was 120,083 in 2019, decreased to 110,849 in 2023. The number of poultry, which was 15,224 in 2019, decreased to 14,023 in 2023. In the Tatvan district, the number of cattle decreased from 11073 in 2019 to 7930 in 2023. In the process, the number of cattle decreased by approximately 28%. The number of ovine animals, which was 87726 in 2019, increased by approximately 5% to 91986 in 2023. The number of poultry decreased from 11091 to 10552.

The total number of animals for the years 2019-2023, obtained from the Provincial Directorate of Agriculture and Forestry, is presented in Table 4. Over the five-year period, there was approximately a 32% decrease in the number of cattle in Bitlis province. On the other hand, the number of ovine animals increased by 8%, while the number of poultry increased by 3%. Additionally, in 2023, ovine animals accounted for 80% of the total animal population in the city, poultry made up 12%, and cattle constituted 8%.

Table 4. Changes in the total number of animals in Bitlis province by years.

Years	Cattle	Ovine	Poultry	Total
2019	104810	688239	100584	893633
2020	102077	772511	109730	984318
2021	88991	795230	109681	993902
2022	69352	814278	110200	993830
2023	70869	739888	108955	919712

The decline in cattle breeding can be attributed to factors such as high feed prices, a decrease in pasture areas, and economic difficulties faced by farmers. The shift towards ovine breeding can be explained by factors such as the geographical structure of the province, lower costs, and the potential to generate income in a shorter period of time. In addition, special

incentives for this sector can also be said to be effective. The increase in demand for poultry products may be related to the change in consumer habits, awareness towards healthy food consumption, and faster and cheaper availability of poultry products.

As seen in Figure 2, Adilcevaz district is the district where ovine breeding is the most common in Bitlis province in 2023. This district is followed by Hizan, Mutki, and Tatvan districts, respectively. Mutki district has the highest number of cattle in the province. This district is followed by Güroymak, Ahlat, and Tatvan districts, respectively. The highest number of poultry is found in Ahlat district. This district is followed by Adilcevaz, the provincial center, and Güroymak districts, respectively. These changes in animal numbers can be associated with economic, environmental, agricultural policies, and consumer demands.

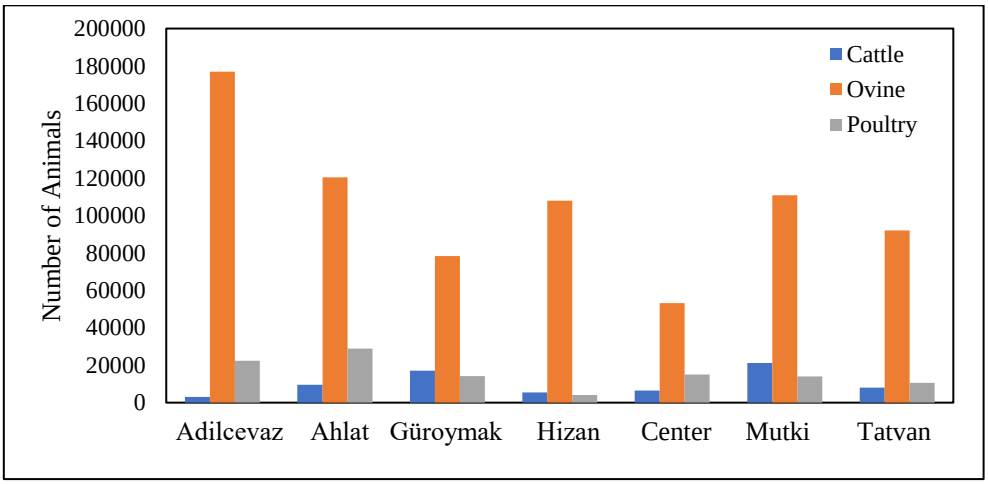

Figure 2. Animal Distribution by Districts (2023).

The total amount of manure that can be obtained from cattle, ovine, and poultry in Bitlis province between 2019 and 2023 and the amount of usable manure are given in Table 5. These data are important in terms of determining the biogas production potential and help to evaluate the capacity of converting animal wastes into energy.

Table 5. Amounts of animal waste generated and usable between 2019-2023.

	The amount of waste generated (tons/year)				**The amount of usable waste (tons/year)**			
Years/ Species	**Cattle**	**Ovine**	**Poultry**	**Total**	**Cattle**	**Ovine**	**Poultry**	**Total**
2019	1041811.4	617419.8	3017.5	1662248.7	677177.4	80264.6	2987.3	760429.3
2020	1014645.4	725194.0	3291.9	1743131.3	659519.5	94275.2	3259.0	757053.7
2021	884570.5	743986.7	3290.4	1631847.7	574970.9	96718.3	3257.5	674946.6
2022	689358.9	758325.0	3306.0	1450989.9	448083.3	98582.3	3272.9	549938.5
2023	704437.9	693790.5	3268.7	1401497.1	457884.6	90192.8	3236.0	551313.3

The biogas potential calculated according to the amount of usable waste is shown in Figure 3. It has been determined that the biogas potential that can be obtained from animal husbandry in Bitlis Center and districts varies according to years. While the highest biogas production potential between 2019 and 2023 was in 2020 with 27.486 million m³, the lowest level was reached in 2023 with 20.594 million m³. This change can be associated with fluctuations in animal numbers and waste management processes.

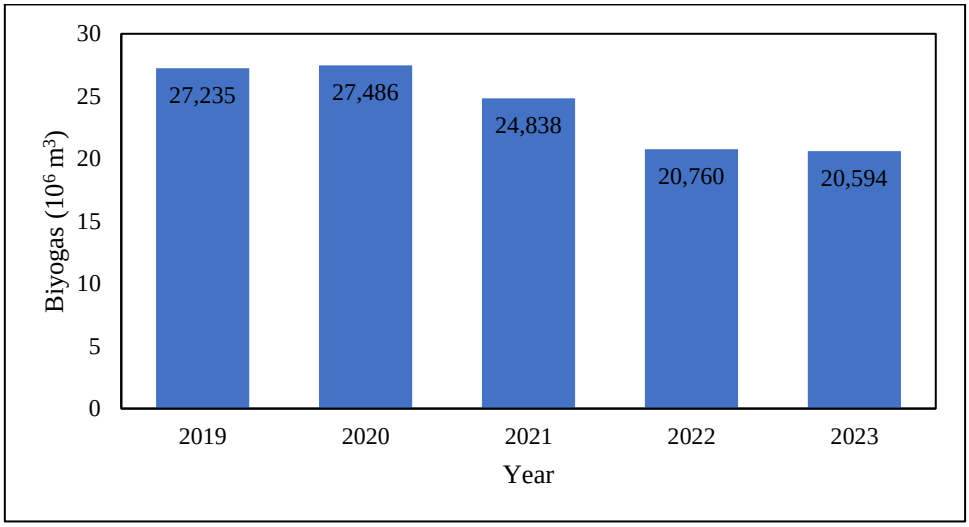

Figure 3. The distribution of biogas production potential of Bitlis province by years.

Figure 4 shows the potential biogas ratios by animal species in Bitlis province in 2023. The amounts of biogas that can be obtained from cattle, ovine, and poultry were compared, and the contribution of each animal species to biogas production was determined. The largest contribution to biogas production is made by cattle with 73.4%. This is followed by ovine with 25.4% and poultry with 1.2%. This distribution is directly related to the amount of manure and organic matter content produced by each animal species. The dominant role of cattle in biogas production can be explained by the high amount of manure produced by these animals and their high organic matter content. Although the contribution of ovine is relatively low, it has an important share. The contribution of poultry to biogas production is very limited.

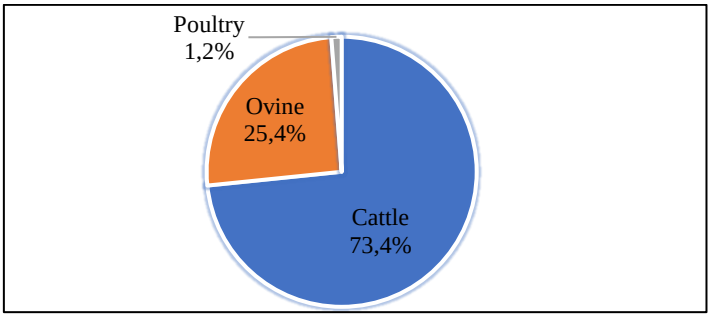

Figure 4. Potential biogas rates by animal species.

The biogas production potential by district for the year 2023 is shown in Figure 5. The highest biogas production potential was determined in the Mutki district, with 5.22 million m³. This is followed by Güroymak with 4.28 million m³, Ahlat with 3.02 million m³, Tatvan with 2.28 million m³, Adilcevaz with 2.05 million m³, Hizan with 1.99 million m³, and Center district with 1.74 million m³. This ranking is shaped by the intensity of animal husbandry activities and fertilizer production capacity in the districts.

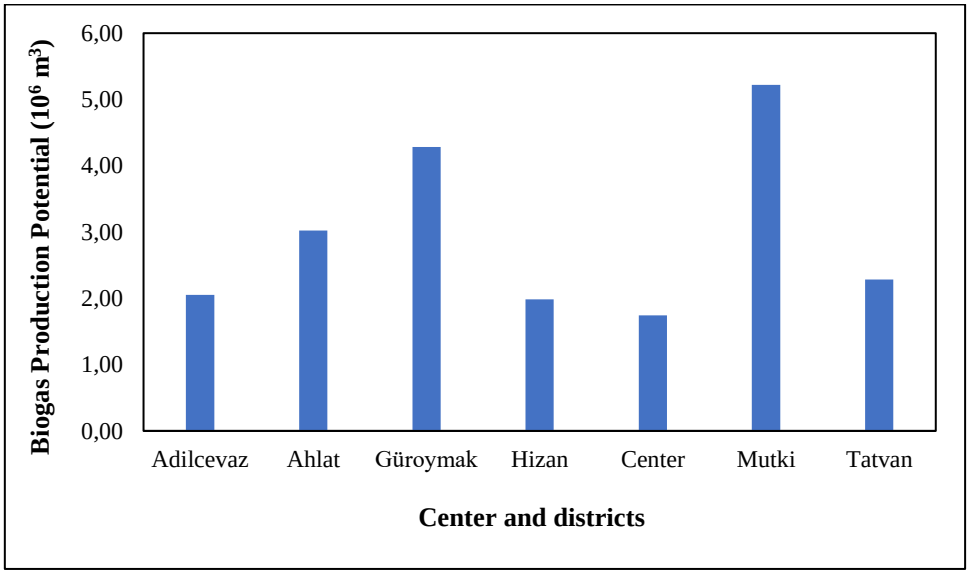

Figure 5. Biogas production potential by districts in 2023.

The percentage distribution of biogas production potential by district for 2023 is shown in Figure 6. Accordingly, the highest biogas production potential was recorded in Mutki district with 25%. This is followed by Güroymak with 21%, Ahlat with 15%, Tatvan with 11%, Adilcevaz with 10%, and Hizan with 10%. The lowest biogas production potential was observed in Center district, with 8%.

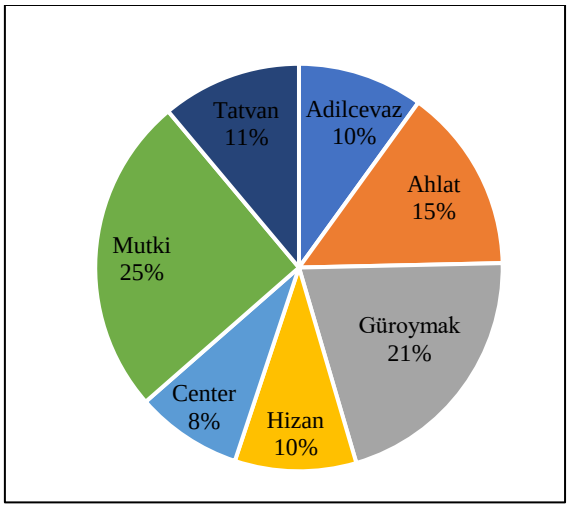

Figure 6. Percentile of biogas production potential by districts (2023).

Approximately 5000 kcal of heat energy and 4.70 kWh of electrical energy are obtained from 1 m^3 of biogas [31]. The total biogas potential of Bitlis province according to years in terms of heat and electrical energy is given in Table 6. In 2023, the amount of 20.59 million m^3 of biogas that can be produced from animal wastes in Bitlis province has the potential to produce approximately 102.97×10^9 kcal of heat energy and 96.79 GWh of electrical energy. These values show that biogas in the region can be an important source of energy production and contribute to sustainable energy use.

Table 6. Energy conversions according to the total amount of biogas.

Years	Biogas (10^6 m^3)	Heat energy (10^9 kcal)	Electric energy (GWh)
2019	27.24	136.18	128.00
2020	27.49	137.43	129.19
2021	24.84	124.19	116.74
2022	20.76	103.80	97.57
2023	20.59	102.97	96.79

In 2023, the equivalent of the theoretical biogas potential produced in Bitlis province center and its districts compared to other energy sources is given in Table 7. According to this, the equivalent of the biogas potential in Mutki district as heat energy is calculated as 26.11×10^9 kcal/year, and the equivalent as electricity energy is calculated as 10.73 GWh/year. These data show the potential of regional biogas resources in energy production and their capacity to be an alternative to fossil fuels.

Table 7. Energy transformations according to the biogas potential of Bitlis provincial center and districts.

Districts	Biogas (10^6 m^3)	Heat energy (10^9 kcal)	Electric energy (GWh)
Adilcevaz	2.05	10.26	9.65
Ahlat	3.02	15.12	14.21
Güroymak	4.28	21.42	20.14
Hizan	1.99	9.93	9.33
Center	1.74	8.71	8.19
Mutki	5.22	26.11	24.54
Tatvan	2.28	11.42	10.73

Considering the number of animals in the provincial center and districts, the electrical energy equivalent of 20.59 million m³ of biogas that can be produced annually is calculated as 96.79 GWh. According to October 2023 residential tariffs, 1 kWh of electricity costs 1.7942358 TL, including taxes [42]. In this case, it was determined that approximately 182.45 million TL could be saved at current prices.

4 CONCLUSION

Today, a significant portion of energy needs is met by limited and non-renewable fossil fuels. However, the use of fossil fuels leads to environmental problems. Therefore, the development of renewable energy sources is of great importance. Generating renewable energy from local resources offers various advantages, such as lower costs. Biogas stands out as an important renewable energy source due to its capacity to convert locally sourced waste materials into energy. In this study, the biogas production capacity has been evaluated based on the amount of manure that can be obtained from cattle, ovine, and poultry in the provincial center and districts of Bitlis. Additionally, the equivalent heat and electrical energy values of the determined biogas production capacity have been calculated. The study utilizes animal population data obtained from TUIK and the Bitlis Provincial Directorate of Agriculture and Forestry for the years 2019-2023.

When examining livestock activities between 2019 and 2023, differences can be observed between the province and its districts. The decline in cattle farming during this period is believed to be related to external factors that affect the economic structure between districts and the farmers' interest in the sector. On the other hand, the increase in ovine farming stands out as a more economical and sustainable option. Additionally, while poultry farming has shown growth in some districts, it has fluctuated in others. The main reasons for these changes in livestock activities include market demands, economic conditions, environmental factors, cost increases, and the role of government support. For the sustainability and efficiency of livestock activities in the region, it can be said that there is a need for more support, education, and the promotion of innovative methods in the sector.

The biogas production capacity of Bitlis province between 2019 and 2023 is calculated as 27.235 million m³, 27.486 million m³, 24.838 million m³, 20.760 million m³, and 20.594 million m³, respectively. Accordingly, the highest production capacity was reached in 2020 with 27.486 million m³, while the lowest level was reached in 2023 with 20.594 million m³. In 2023, the largest contribution to biogas production is made by cattle with 73.4%. This is followed by

ovine with 25.4% and poultry with 1.2%. The district with the highest biogas production capacity in the same year was Mutki, with 5.22 million m³. It was followed by Güroymak with 4.28 million m³, Ahlat with 3.02 million m³, Tatvan with 2.28 million m³, Adilcevaz with 2.05 million m³, Hizan with 1.99 million m³, and Center with 1.74 million m³.

The equivalent heat energy amounts that can be obtained depending on the biogas production capacity of Bitlis province between 2019 and 2023 are calculated as 136.18 x 109 kcal/year, 137.43 x 109 kcal/year, 124.19 x 109 kcal/year, 103.80 x 109 kcal/year, and 102.97 x 109 kcal/year, respectively. Equivalent amounts of electrical energy in the same years were calculated as 128.00 GWh/year, 129.19 GWh/year, 116.74 GWh/year, 97.57 GWh/year, and 96.79 GWh/year, respectively.

Considering the number of animals in the provincial center and districts, the equivalent electrical energy of the annual biogas production of 20.59 million m³ has been calculated, and it has been determined that approximately 182.45 million TL in savings could be achieved at current prices. In addition to providing significant energy savings, biogas production from animal manure also reduces the environmental impact of waste and offers valuable by-products, such as fermented manure. This process will contribute to sustainable energy production while also enhancing agricultural productivity.

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Statement of Research and Publication Ethics

The study is complied with research and publication ethics.

Artificial Intelligence (AI) Contribution Statement

This manuscript was entirely written, edited, analyzed, and prepared without the assistance of any artificial intelligence (AI) tools. All content, including text, data analysis, and figures, was solely generated by the authors.

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