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POTENTIAL, ECONOMIC, AND ENVIRONMENTAL EVALUATION OF BIOGAS ENERGY IN PROVINCES WHERE ANIMAL HUSBANDRY IS DEVELOPED IN TÜRKİYE

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ABSTRACT

The increase in demand for energy due to various reasons, such as population growth, quality of life, and industrial and technological developments, has increased the need for new alternative energy sources. In addition, fossil fuels, which are the most used sources to meet energy needs, have reserve problems and polluting effects on the environment. The import of natural gas, which is another important source, has a negative impact on national economies. These situations have led us to turn to clean alternative sources for energy needs. In this context, biomass energy represents a renewable energy source with untapped potential for further development. Biomass energy is generated by burning various organic wastes such as human waste, agricultural waste, or animal waste. Türkiye is a country rich in agriculture and animal husbandry. Therefore, in this study, provinces with rich potential in terms of animal husbandry in Türkiye have been investigated. The biomass energy that can be obtained from animal wastes in these provinces is calculated annually. If a facility is established in these provinces to obtain this energy, economic indicators have been calculated. Finally, the positive contributions of biogas energy to the environment have been determined with numerical indicators.

Keywords: Renewable energy, Biomass energy, Energy consumption, Environmental effects, Sustainability.

1 INTRODUCTION

Ensuring the reliability and sustainability of energy, making it affordable, decarbonizing the energy system, and achieving net zero emissions are the main goals of today's global energy system. For the future of the energy sector, the BP 2023 energy outlook and IEA 2023 World Energy Outlook reports emphasize the following points [1], [2]:

- In addition to population growth, industrial and technological developments, the global warming problem, various wars, and inflation problems experienced in large countries in recent years have emphasized the importance of a successful and permanent energy transition. It has been stated that even a possible minor interruption will lead to significant economic and social consequences for the nations' economies.
- It has also been stated that although the shares of coal, oil, and natural gas, which have a large share in meeting energy, demand in global energy supply, have decreased, this decrease is still not sufficient, and more work needs to be carried out.
- In addition, it has been stated that greenhouse gas emissions are still increasing even though countries committed to reduce greenhouse gas emissions in the Paris agreement in 2015. It is stated that the later steps are taken towards this, the bigger problems will arise.

Türkiye has the fastest-growing energy demand among OECD countries. It is also the second country in the world after China in terms of electricity and natural gas demand. Therefore, the above-mentioned objectives are very important in Türkiye's energy policy strategy, and the main items are diversifying energy resources, ensuring energy security, increasing the share of new and renewable energy in electricity generation, and considering environmental impacts [3].

Türkiye's electricity energy consumption was 326.3 TWh in 2023. According to the results of Türkiye's National Energy Plan, electricity consumption is expected to reach 380.2 TWh in 2025, 455.3 TWh in 2030, and 510.5 TWh in 2035. In 2023, 36.3% of our electricity generation was from coal, 21.4% from natural gas, 19.6% from hydroelectric power, 10.4% from wind, 5.7% from solar, 3.4% from geothermal, and 3.2% from other sources [4].

In Türkiye, significant investments have been made in the last decade to increase renewable energy sources such as hydro, wind, and solar energy, and the share of these sources in the installed capacity has increased. However, although it is potentially rich in biomass, another important renewable energy source, it has not been able to fully utilize this resource. Figure 1 shows the installed capacity of biomass energy in Türkiye by years [5].

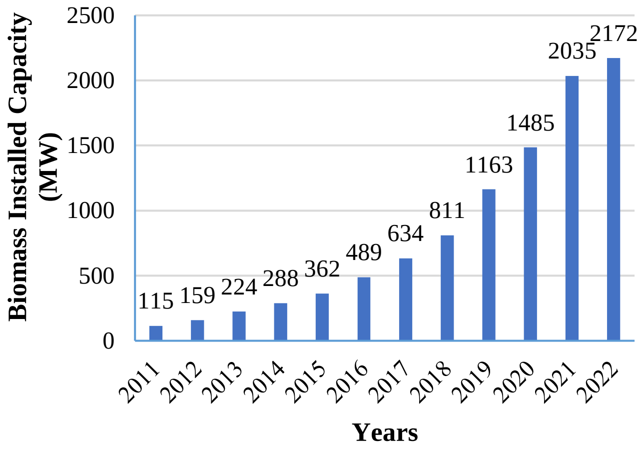

Figure 1. Biomass installed capacity in Türkiye by years.

Biomass studies have gained popularity, especially in recent years, since biomass energy is not used at the desired performance both globally and in Türkiye, is renewable, its cost is much lower than other systems, and resources are abundant. Some of the studies on this subject in the literature are as follows:

Iglinski et al. investigated the biogas potential that could be obtained from the biological fraction of cattle manure, pig manure, poultry, corn, and municipal waste for Poland and emphasized that biogas energy would provide continuous and uninterrupted energy, unlike wind and solar energy [6]. Abdeshahian et al. mentioned the development of livestock farming in Malaysia and calculated that a biogas potential of 4589.49 million m^3 year-1 could be produced from animal wastes annually and that this potential could generate 8.27×10^9 kWh year-1 of electricity [7]. Özer investigated the biogas potential of the region by using the resources of agriculture and animal husbandry in the Ardahan region and calculated that the energy obtained from biogas sources is 323 GWh per year [8]. Avcıoğlu et al. investigated the energy potential of agricultural biomass residues for Türkiye by using studies on the properties of agricultural biomass residues in many countries. They calculated the energy potential of agricultural biomass residues as 298,955 TJ for field crops and 65,491 TJ for horticultural crops [9]. Ramos-Squarez et al. researched the amount of fertilizer that could be produced from animals on farms in the Canary Islands and its biogas equivalent. It has been stated that this potential is equivalent to 0.68%-8.56% of the region's renewable energy production in 2016 [10]. Başcetincelik et al. discussed the evaluation of the use of agricultural wastes in Türkiye for electricity generation and thermal energy, market difficulties, incentive elements, and strategic developments as a whole [11]. Karaca determined the potential of plant wastes in Türkiye in terms of quantity, mapping, and calculated their total calorific values. He also stated that with the use of these wastes, the amount of CO_2 would decrease by 30 Mt per year [12]. Karaca investigated the biogas potential that can be obtained from animal manure in Türkiye in his study and showed that the potential obtained from these wastes could meet 1.1% of Türkiye's annual energy consumption [13]. Jekayinfa et al. investigated biogas resources for Nigeria and calculated the biogas energy potential of different sources such as forest residues, agricultural residues, human and animal waste [14]. Ardebili investigated the potential for bioenergy from animal and agricultural waste in Iran and found that 62,808 GWh of energy could be produced annually, which corresponds to 27% of the country's electricity consumption. It was also stated that this value would reduce greenhouse gas emissions by 4.1 Mt of CO_2 per year [15]. Yaqob et al. mentioned the problems such as long power outages in Pakistan and examined a solution to this problem by using abundant wastes such as animal manure, poultry waste, sugarcane bagasse, and kitchen waste and converting them into biomass energy. As a result of their calculations, they stated that 59,536 GWh of electricity could be generated from these wastes per year, and this value could meet half of the country's electricity consumption [16]. Seyitoğlu and Avcıoğlu investigated the biogas potential of Çorum province by using the data on the number of cattle, ovine, and poultry in 2021. As a result of the calculations, they stated that it can generate 100.32 GWh of electricity, and this production will reduce 2608.06 tons of CO_2 emissions [17]. Mana et al. calculated the amount of animal manure that could be produced from animals on farms in the Canary Islands and stated that this manure was equivalent to 6.8 MWe equivalent installed power biogas potential [18]. Alnhoud et al. noted that the increase in livestock and chicken manure is a threat to public health in the AL-Mafraq region in northern Jordan and investigated the use of these manures as biogas energy. They concluded that 10.1×10^6GJ of energy could be obtained annually from these manures, which could meet 5% of the population's electricity consumption [19]. Nehra and Jain investigated the biomass energy potential from animal manure for the Haryana region in India. They calculated that 106.11 GJ of heating value and 9.84 TWh of electrical power could be produced annually from this potential. They also stated that this value would reduce 2.56 Mt CO_2 emissions [20]. Akter et al. investigated the biomass potential of 25 different agricultural crops in Bangladesh and found that they have a biogas production capacity of 9,868 million m^3. They stated that this potential can meet 88% of the total electricity consumption of the country [21].

In this study, considering that Türkiye has a developed potential in the field of animal husbandry and does not fully use this potential, seven provinces that are rich in terms of the number of cattle, sheep, and poultry in 2023 have been determined. Depending on the number of animals in these provinces, manure amounts, methane values, and biogas energy potentials have been calculated for each province. The installed power values corresponding to these potentials and the values that meet the energy consumption of those provinces have been found. If there are relevant investments in the regions, these investments have been evaluated economically and the environmentally positive effects of these investments have been proven with numerical data.

2 BIOGAS AND BIOMASS ENERGY

Biogas is obtained from the biochemical fermentation and microbiological activity of various organic wastes under anaerobic conditions. The energy obtained from biogas is called biomass energy. Biomass sources are diverse as shown in Figure 2 [22]. The formation stages of biogas using resources and their explanations are given in Figure 3 [23]-[24].

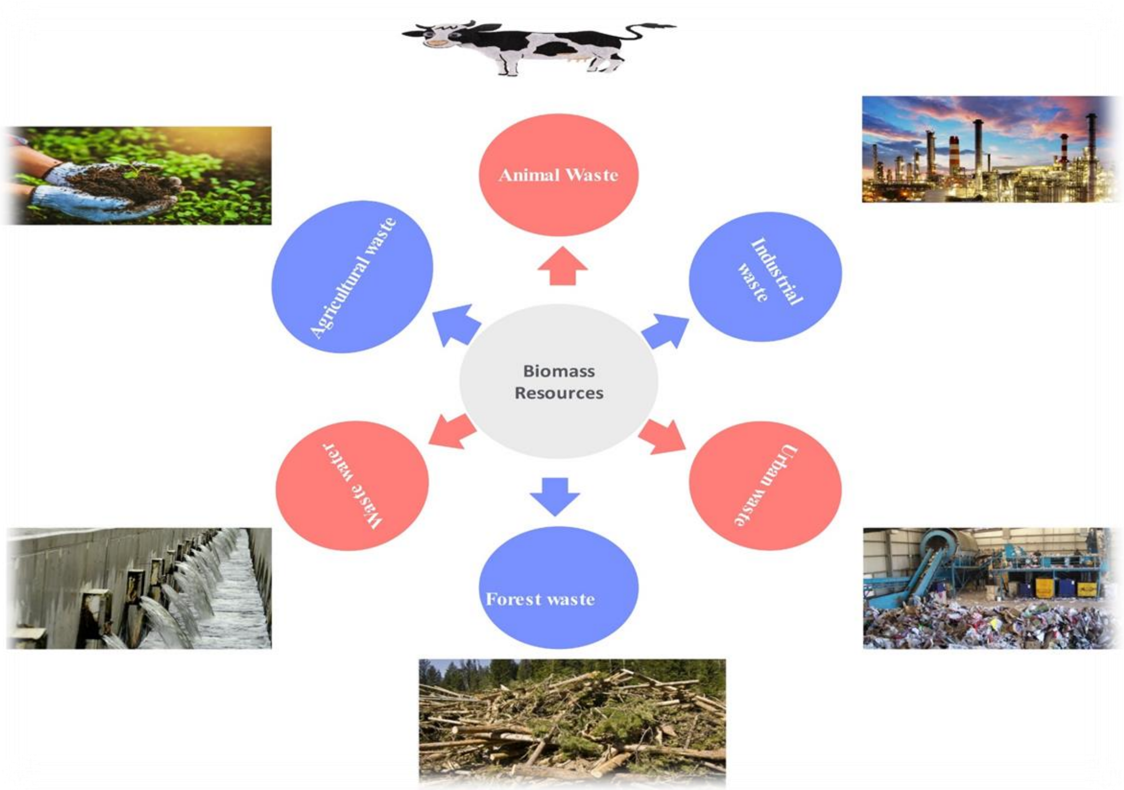

Figure 2. Biomass resources.

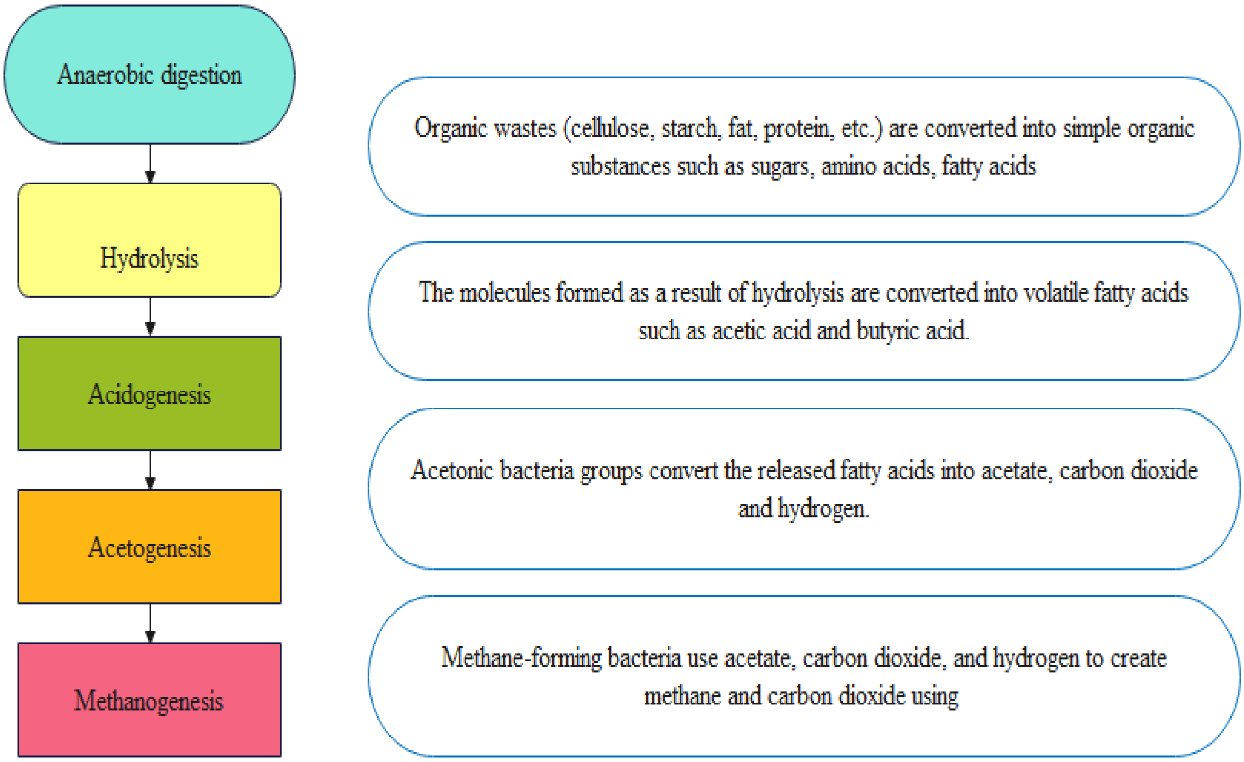

Figure 3. Formation stages of biogas.

The content of biogas, which is a colorless, odorless, lighter than air and gas mixture with high thermal value that burns with a bright blue flame, is given in Table 1. The composition of the gas varies according to factors, such as ambient temperature, water content, acidity, and type of residues [25].

Table 1. Composition content of biogas.

Components	Volume content (%)
Methane (CH_4)	40-70
Carbon dioxide (CO_2)	30-60
Hydrogen (H_2)	5-10
Nitrogen (N_2)	1-2
Water vapor (H_2O)	0.3
Hydrogen Sulphide (H_2S)	Small quantities

Although it depends on the components in terms of calorific value, one cubic meter of biogas has 5500-6000 kcal energy. When biogas is compared to other fuels; 1 m^3 of biogas is equivalent to 0.60 m^3 of natural gas, 0.70 liters of gasoline, 0.65 liters of diesel fuel, and 0.80 kg of coke [25]. From an electrical point of view, biogas is equal to 4.70 kWh of electrical energy [25], making this gas produced by burning various biomasses an important renewable energy source today.

3 MATERIAL AND METHOD

In this section, the data set and mathematical formulas regarding the production of biogas from animal waste and its energy, economic and environmental evaluation are presented.

3.1 Material

Türkiye has a favorable potential for animal husbandry due to its natural resources and ecological conditions, and the animal husbandry sector has an important place in the national economy. Therefore, the approach in this study is to prevent the harm of these wastes to the environment and to support meeting the increasing energy demand by converting these wastes into energy.

Accordingly, 7 provinces rich in large animals, small animals, and poultry have been identified in Türkiye for 2023. Another important feature of these provinces is that they are among the most populous provinces of the country and have high electricity consumption. These provinces are Konya, Erzurum, Ankara, İzmir, Diyarbakır, Balıkesir and Aydın. The number of large animals, small animals and poultry animals including chickens, turkeys and goose in these provinces in 2023 is given in Table 2 [26].

Table 2. The number of animals of provinces for 2023.

Province	Large Animals	Small Animals	Chicken (Laying hens)	Chicken (Broiler)	Goose	Turkey	Poultry Animals
Konya	928,335	3,059,048	10,702,230	209,200	18,976	32,093	10,962,449
Erzurum	696,321	877,869	141,859	0	14,669	8,184	164,712
Ankara	610,514	1,879,345	9,011,815	610,514	18,249	16,756	9,657,334
İzmir	816,337	813,211	5,230,818	12,241,010	3,748	210,972	17,686,578
Diyarbakır	580,335	2,070,682	533,880	270,400	20,542	87,658	912,480
Balıkesir	532,646	1,327,116	5,674,117	29,174,723	1,027	40,239	34,890,106
Aydın	491,087	363,364	858,308	2,397,250	3,312	5,403	3,264,273

3.2 Method

The following steps and relevant mathematical equations are used to calculate the biomass energy to be obtained from animal waste.

3.2.1 Determination of Biomass Energy Potential and Generation

Depending on the number of animals, the annual amount of wet manure that can be produced from large-small animals and laying hens chicken, broiler chicken, goose, and turkey can be found by using the Equations between 1 and 4, respectively [7]-[8], [27],[28].

$$T_{AWM\,(1)} = \frac{\sum_{i=1}^{N} q * 365}{1000} \tag{1}$$

$$T_{AWM\,(1)} = \frac{\sum_{i=1}^{N} q * 42}{1000} \tag{2}$$

$$T_{AWM\,(1)} = \frac{\sum_{i=1}^{N} q * 98}{1000} \tag{3}$$

$$T_{AWM\,(1)} = \frac{\sum_{i=1}^{N} q * 110}{1000} \tag{4}$$

where N, T_{AWM} and q represent the number of animals, total amount of annual wet manure (t year^{-1}) the average amount of manure per animal, respectively. Considering the animals' stay in the shelter, the amount of utilizable wet manure can be calculated from the total amount of fertilizer with the help of the Equation 5 [27].

$$T_{AUWM} = T_{AWM} * b_f \tag{5}$$

where T_{AUWM} is the total amount of utilizable wet manure per year (t year^{-1}) and b_f represents the benefit rate as a percentage. The proportion of solids in the utilizable wet manure (T_{sm}) obtained is found by using Equation 6, and the proportion of volatile solids in the solids (T_{vsm}) is found by using Equation 7 [27].

$$T_{sm} = T_{AUWM} * \eta_{sm} \tag{6}$$

$$T_{vsm} = T_{sm} * \eta_{vsm} \tag{7}$$

where η_{sm} and η_{vsm} are percentage for the proportion of solids in wet manure and the proportion of volatile solids in solid manure, respectively. The methane production of manure from (T_{CH4}) is calculated by multiplying the volatile solids content by the percentage of methane production (μ). The equation for this is shown in Equation 8 [7]-[8],[27].

$$T_{CH_4} = T_{vsm} * \mu \tag{8}$$

The energy potential that can be generated from methane gas (E_p) is calculated by multiplying the amount of methane and the energy equivalent of methane [7], [27].

$$E_p = T_{CH_4} * e_{CH4} \quad (9)$$

where e_{CH4} is the energy equivalent of 1 m^3 methane (kWh). The energy equivalent of methane is taken as 10 kWh. The electrical energy equivalent to be produced from methane is found with the help of Equation 10 [7]-[27].

$$E_g = T_{CH_4} * e_{CH4}\ \eta_c \quad (10)$$

where η_c is the electricity conversion coefficient. η_c value varies between 25% and 40% depending on the power generation plant. For this study, this value is taken as 35% [7]-[27]. The coefficients between Equations 5-8 have been determined as a result of literature reviews and market research, and the values used in the study are given in Table 3 [7]-[27].

Table 3. Coefficients related to equations.

Animal Type	q (kg)	b_f (%)	η_{sm} (%)	η_{vsm} (%)	μ (%)
Large animals	29	90	15	83	25
Small animals	2.1	13	23	75	30
Chicken	0.16	70	19	75	35
Turkey	0.38	68	19.36	76	35
Goose	0.33	68	17.27	61.28	35

3.2.2 Performing Economic Analysis

The inputs that make up the costs of the biomass facility consist of items such as installation costs, operating costs, general maintenance and intermediate maintenance costs, commissioning costs of generators, personnel costs; and Equation 11 is used to calculate the total cost [29].

$$C_T = C_i + C_O + C_M + C_L + C_{GR} \quad (11)$$

where C_T, C_O, C_M, C_L, C_{GR} is the installation, operation, maintenance, labour, and generation reinstallation cost, respectively. The payback period defines how many years it will take to recover the initial investment amount. This value is calculated as follows [29]:

$$n = \frac{Capital\ investment}{net_{cash-i}} = \frac{C_i + C_O}{rev_{ees} - c_{oth}} \quad (12)$$

where n is the payback period (year), net_{cash-i} is the annual net cash inflow. rev_{ees} is the income obtained from the sale of electrical energy in that year, and c_{oth} is the sum of expenses such as maintenance and personnel expenses that may occur in that year.

3.2.3 Performing Emission Analysis

The biggest advantages that biomass energy can provide to the environment are collecting waste released into the environment through recycling, preventing sediment formation in the environment, and reducing greenhouse gas emissions, which are the biggest danger in terms of global warming. The amount of total greenhouse gas reduction with biomass energy generation is found with the help of Equation 13 [30].

$$T_{GHG-R} = E_g * \eta_{GHG} \tag{13}$$

where T_{GHG-R} is the total amount of greenhouse gas reduction (GHG), η_{GHG} is the greenhouse gas conversion coefficient. Another important perspective of GHG mitigation is the carbon market. The carbon market stands for carbon trading, where a carbon quota is equal to 1 ton of carbon dioxide. In basic practice, countries are given a specific carbon emission quota, which is expected to be shared equally among producers. If any producer exceeds its quota, it can buy it from another producer that already has a quota. In this way, a carbon trading market has emerged. Carbon markets are divided into two. These are called mandatory markets and voluntary markets. In voluntary markets, a ton of carbon is worth between 4.5-5.5 Euros/dollar, while in mandatory markets this value goes up to 80 Euros. In Türkiye, voluntary "Voluntary Carbon Markets" practices aiming to reduce carbon emissions have been ongoing since 2005. Accordingly, the market value of reducing 1 ton CO_2 (Mv) is found with the help of Equation 14.

$$M_V = T_{GHG-R} * p_{CO2} \tag{14}$$

where p_{co2} is the price of one ton of carbon. Also, the equivalencies of the GHG reduction achieved through energy from biomass in terms of gasoline, forest land, and recovered waste have been evaluated in the emission analysis. Reduction of 1 ton of CO_2 is approximately equivalent to 429.6 L of unconsumed gasoline ($N_{uncongasoline}$), 227.6 acres of carbon absorbing land ($N_{forestland}$) and 344.9 tons of recovered waste ($N_{recoveredwaste}$). Using these values, the relevant equations are given below [31].

$$N_{uncongasoline} = T_{GHG-R} * 429.6 \quad (15)$$

$$N_{forestland} = T_{GHG-R} * 227.6 \quad (16)$$

$$N_{recoveredwaste} = T_{GHG-R} * 344.9 \quad (17)$$

4 RESULTS AND DISCUSSION

The annual methane production amount, total energy potential, and annual energy production amounts that can be produced in these provinces have been calculated by using the number of animals in the provinces with developed animal husbandry in Türkiye (Table 1) and various mathematical equations and coefficients in section 3.2.1. The values found are summarized in Table 4.

The annual electricity production that can be obtained as a result of the use of animal manure in the regions is shown in Figure 4. Accordingly, the highest electricity production is realized in Konya province with 1,095.36 GWh, while the lowest electricity consumption is realized in Aydın province with 524.43 GWh.

Table 4. Total CH_4, energy potential and electricity generation values of provinces.

Province	Animal Type	T_{CH4} (km^3 year^{-1})	Ep (Gwh year^{-1})	Eg (Gwh year^{-1})
Konya	Large Animals	275,262.7	2,752.7	963.4
	Small animals	15,774.4	45.26	55.2
	Poultry	21,932.188	3.13	76.76
Erzurum	Large Animals	206,467.8	2,064.7	722.6
	Small animals	4,526.8	45.26	15.8
	Poultry	313.163	3.13	1.096
Ankara	Large Animals	181,024.9	1,810.2	633.6
	Small animals	9,691.1	96.91	33.9
	Poultry	18,556.7	185.57	64.95
İzmir	Large Animals	242,053.9	2,420.5	847.2
	Small animals	4,193.4	41.93	14.7
	Poultry	13,848.8	138.488	48.471
Diyarbakır	Large Animals	172,224.7	1,722.2	602.8
	Small animals	10,677.7	106.77	37.4
	Poultry	1,297.0	12.97	4.54
Balıkesir	Large Animals	157,936.1	1,579.4	552.8
	Small animals	6,843.4	68.43	23.9
	Poultry	18,473.37	184.73	64.66
Aydın	Large Animals	145,613.3	1,456.1	509.7
	Small animals	1,873.7	18.73	6.6
	Poultry	2,323.0	23.23	8.13

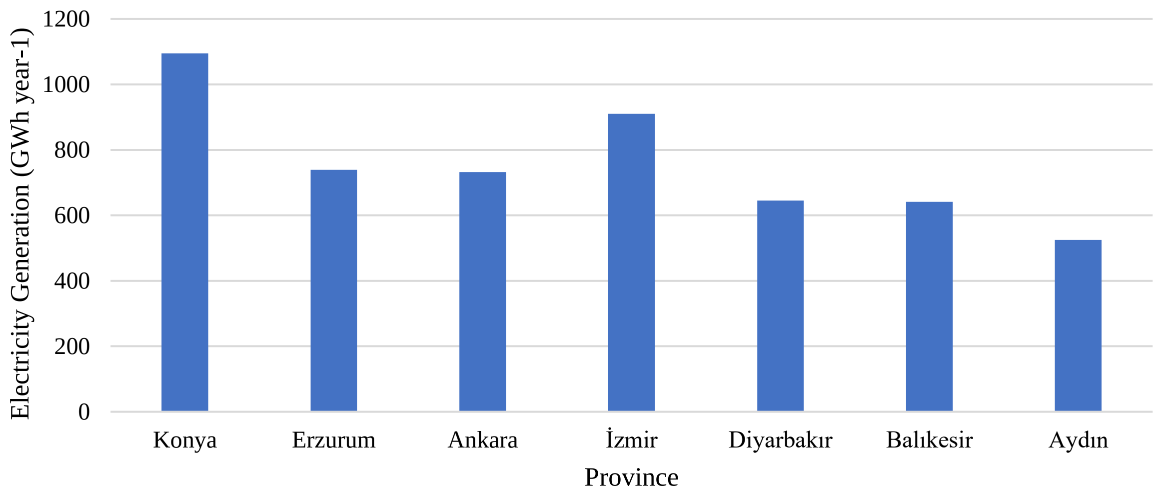

Figure 4. Electricity generation from biogas in provinces.

The graphical representation of the electricity generation values obtained according to animal species in the provinces is given in Figure 5. In addition to the fact that the majority of biomass energy production in the provinces is generally obtained from large animal wastes, poultry has a significant impact on biogas energy for Balıkesir province.

After calculating the amount of biogas energy production with animal manure, the total energy consumption of the regions and especially the electricity consumption of the households in the regions have been investigated. According to the 2023 report of the Energy Market Regulatory Authority [32], the total electricity consumption and residential electricity consumption values of these provinces in that year are given in Table 5. In addition, the percentages of the energy obtained from biogas covering these consumptions have also been calculated.

As seen in Table 5, biogas is an especially important energy source. Even in Erzurum alone, all of the household consumption can be met by biomass energy. Therefore, it would not be wrong to say that biomass energy will be one of the most important renewable energy sources for the provinces in the coming years if the potential of biogas is utilized.

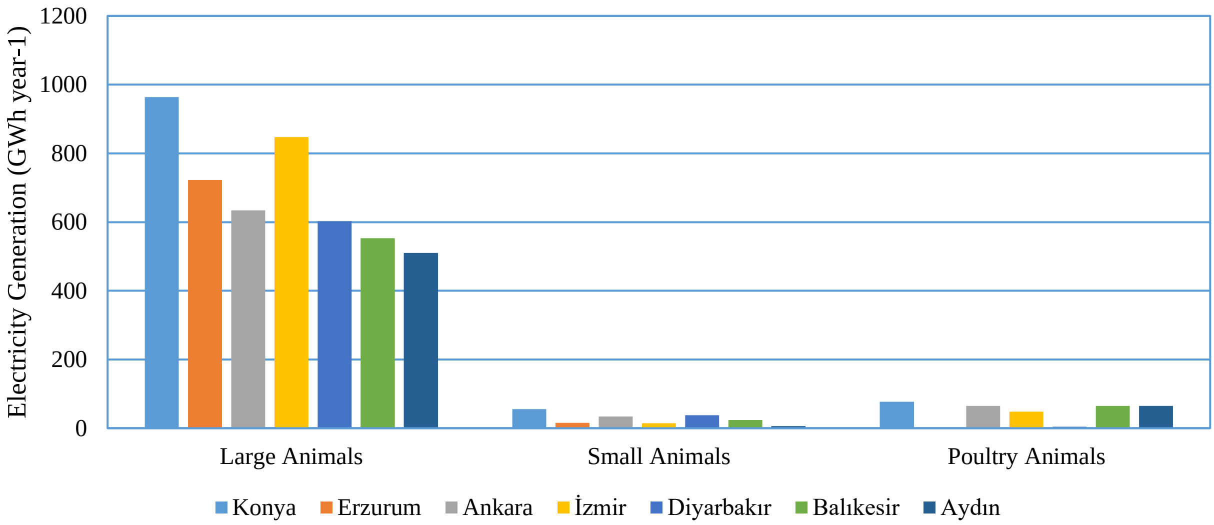

Figure 5. Electricity generation values from biogas by animal type in provinces.

Table 5. Percentages of production meeting consumption.

Province	Total electricity consumption (GWh)	Residential electricity consumption (GWh)	Covering total electricity consumption (%)	Covering residential electricity consumption (%)
Konya	8,031.271	1,598.422	13.63	68.52
Erzurum	964.453	395.556	76.67	100
Ankara	14,879.935	4,835.479	4.92	15.14
İzmir	16,422.049	4,627.856	5.54	19.67
Diyarbakır	3,137.268	1,070.959	20.55	60.20
Balıkesir	3,950.758	1,155.818	16.23	55.49
Aydın	3,098.515	1,167.488	16.93	44.92

After comparing energy generation values and consumption values, necessary calculations have been made to evaluate the investments economically in the case of investing in a biogas facility in these regions. Based on the fact that a year consists of 8,760 hours in these facilities, the installed power values that can be installed in the regions have been calculated by assuming that the facilities operate for approximately 8000 hours. Accordingly, an installed power potential of 137 MW in Konya, 92 MW in Erzurum, 91 MW in Ankara, 113 MW in Izmir, 81 MW in Diyarbakır, 80 MW in Balıkesir, and 67 MW in Aydın has been found.

Cost items of biogas facilities change from day to day. However, as a result of literature research and market research, it is generally accepted that the average cost of electrical output power per kW is 3,600 Euros [33]. The Euro-TL exchange rate has been taken as 35 TL, and capital investment has been calculated according to the installed capacities of the regions. Likewise, as of July 1, 2024, the electrical energy sales price of biomass in Türkiye is 2.9047 TL and the evening support is 0.4836 TL [34]. Considering the evening support, the annual electricity returns of the investments have been calculated by taking the average electrical energy sales price as 3.00 TL. Since installed power values have been determined according to the amount of raw materials, the payback period for investments to be established for all provinces has been found to be five years. In case of any equity, this value will decrease further. If investments have a lifespan of approximately 25 years, the profitability rates to be achieved after five years are quite high. Therefore, it is recommended to make these investments in these provinces. The relevant results are listed in Table 6.

In analysing the contribution of energy from biomass to the environment, the amount of greenhouse gas reduction with the energy obtained from biomass in the provinces and its market value in the carbon markets have been calculated. As of January 1, 2024, the greenhouse gas conversion coefficient of the final electrical energy for Türkiye is determined as 0.689 t_C0$_{2}$-eq. per MWh [35]. In the calculation of the market value, 1 Euro has been accepted as 35 TL. In addition, the equivalents of unconsumed gasoline, forest land, and recycled waste of the annual greenhouse gas reduction for the provinces have been also calculated. The calculated values are listed in Table 7. As can be seen from the values in Table 7, while generating income with biomass energy, the environment is protected in many ways.

Table 6. The results of economic analysis.

Province	Installed power capacity (MW)	Capital investment (million TL)	Income electricity sales (million TL/year)	Payback period (year)
Konya	137	17,262	3,286.08	~5
Erzurum	92	11,592	2,218.5	~5
Ankara	91	11,466	2,197.4	~5
İzmir	113	14,238	2,731.11	~5
Diyarbakır	81	10,206	1,934.21	~5
Balıkesir	80	10,080	1,924.08	~5
Aydın	65	8,190	1,573.29	~5

Table 7. The results of emission analysis.

Province	E_g (GWhyear^{-1})	T_{GHG-R} (ktonyear^{-1})	M_v (millionTL year^{-1})	$N_{uncomgasoline}$ (kL/year)	$N_{forestland}$ (km^2/year)	$N_{recoveredwaste}$ (Mtonyear^{-1})
Konya	1,095.36	754.70	118.86	324.22	171,769	260.3
Erzurum	739.496	509.51	80.25	218.89	115,964	175.73
Ankara	732.45	504.66	79.48	216.80	114,861	174.1
İzmir	910.371	627.25	98.79	269.47	142,762	216.3
Diyarbakır	644.739	444.23	69.96	190.84	101,107	153.2
Balıkesir	641.36	441.90	69.59	189.84	100,576	152.4
Aydın	524.43	361.33	56.91	155.23	82,238	124.6

5 CONCLUSION

In this paper, seven provinces in Türkiye where animal husbandry is developed have been identified, and biomass energy in these regions has been investigated. The numbers of large animals, small animals, and poultry in these provinces as of 2023 have been researched. Depending on the number of animals, the amount of fertilizer, methane amount, and biomass energy have been calculated annually. It has been observed that a minimum of 524.43 GWh and a maximum of 1095.36 GWh of electrical energy can be obtained in 7 provinces. In addition, the electricity generated has a coverage rate varying between 15.14% and 100% of household electricity consumption in the provinces. It has been numerically shown that if biomass energy-based facilities are built in the provinces, these facilities will pay back in five years without any equity capital, and since the investment period is 25 years, they will bring a substantial profit after five years. Finally, the positive effects of biomass energy on the environment have been investigated. It has been calculated that biomass energy will reduce greenhouse gas by a maximum of 754.7 ktons and a minimum of 361.33 ktons per year for the provinces, and this will provide extra profit to the investor due to carbon credits. It has also been emphasized that evaluating biomass energy is environmentally important by calculating the values of unconsumed gasoline, unused land, and recycled waste depending on greenhouse gas reduction values.

Conflict of Interest Statement

There is no conflict of interest between the authors.

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.

Contributions of the Authors

Yağmur Arıkan Yıldız worked on the data collection, analysis, and concept of the study. Mehmet Güçyetmez contributed to the scope, integrity and writing of the study.

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