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Research Paper

Biogas Potential of Afyonkarahisar, Türkiye-based on Animal Manure: Energy Equivalents and its Contribution to Economy and Carbon Emissions

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Abstract: Energy demand is increasing rapidly all over the world. It is seen that the fossil fuel reserves, which are used extensively to meet the energy needs of the world, will not be enough to meet the necessary energy needs in the future. Countries that have not been able to solve their energy problem have started to seek new ways such as finding new energy sources and developing energy technology. Biogas can be thought of as a type of energy that can be obtained through many different sources. One of them is animal manure, which consists of organic matter. The livestock sector has strategic importance in Turkey in terms of economic and social aspects such as adequate and balanced nutrition for the population, the realization of rural development, and the prevention of rural-urban migration by reducing agricultural unemployment. In this study, the biogas potential that can be obtained from animal manure was examined according to the animal data of the Turkish Statistical Institute for 2020 in different categories throughout the province of Afyonkarahisar, Türkiye. According to the statistical data of different animal species, the theoretically calculated amount of animal manure throughout the province is 502786 tons/year. The amount of methane that can be produced on a district basis from the collectible useful manure is 125 Mm^3CH_4/year. The amount of biogas produced from recyclable wastes is 208.44 Mm^3 annually. The energy and thermal energy equivalent of the methane amount is 4503342 GJ/year in total. The conversion of the obtained biogas potential to other energy sources has been evaluated and it has been determined how much economic benefit can be obtained from each energy source. In addition, the carbon emissions of the province originating from animal husbandry were analyzed theoretically.

Keywords: Animal manure, Biogas, Carbon emission, Energy, Methane

1. Introduction

With population growth, industrialization, and economic and technological developments, the demand for energy resources is increasing in the world. Most of this demand is met by fossil resources. The combustion of fossil resources emits greenhouse gases such as carbon dioxide, methane, and nitrous oxide. Greenhouse gas emissions are the main cause of global warming. Due to the depletion of fossil fuel reserves and the negative effects of greenhouse gas effects, renewable and clean energy sources come to the fore [1,2]. Renewable energy sources have many advantages such as being harmless, inexpensive, and inexhaustible. Among these energy sources, biogas has come to the fore in recent years. Biogas energy can be produced from microalgae, food and agricultural waste, animal manure, municipal solid waste, industrial waste, forest waste, and various energy plants [3-5]. Animal manure is one of the main organic wastes that are dangerous for the environment if not well controlled. During the disposal of manure, soil, and water are polluted and the environment can be harmed. For this reason, our health needs to process animal manure and slurry with an anaerobic digestion process, to produce quality fertilizers with sustainable energy sources, and to reduce odors and microbial pathogens [6-7]. Animal manure is one of the renewable energy sources that have

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biogas energy potential and is easily accessible in every place dealing with animal husbandry. In this context, many studies have been carried out to determine the amount of biogas and energy potential that can be obtained based on region and enterprise.

Özcan et al. [8] determined the total biogas potential of Türkiye resulting from urban solid waste, energy crops, animal manure, and wastewater treatment sludge as 188.21 TWh/year. Abdesahian et al. [9] determined that Malaysia's biogas potential is approximately 4.6 billion m^3 and the electrical energy that can be obtained from biogas is 8270 GWh. Baran et al. [10] theoretically determined that Adıyaman, Türkiye has a biogas potential of approximately 15 Mm^3 per year for cattle, small ruminants, and poultry assets. It has been stated that in the case of using biogas, approximately 70.5 GWh of energy can be produced. Özer [11] examined the biogas energy potential of Ardahan, Türkiye from animal and agricultural wastes and determined that when this potential is used, 323 GWh/year of electricity can be produced, and there can be approximately 2 million tons of CO_2 emission reduction per year. Arshad et al. [12]. investigated electricity generation from biogas from poultry waste in Pakistan. It has been determined that up to 97.50 Mm^3 of biogas will be obtained from 25000 poultry farms through anaerobic digestion. Blandzija et al. [13] examined Croatia's biomass and energy value from agricultural waste. The study was conducted for three scenarios. Scarlat et al.[14] stated that theoretically 26 billion m^3 of biomethane could be produced for Europe depending on the amount of waste from farms and poultry. Khayum et al. [15] studied the potential of biogas from tea waste. In the study, tea wastes were mixed with cow dung in different proportions to produce biogas and the effect of digestion time and important input parameters such as pH and carbon/nitrogen ratio in biogas production were investigated. Cucchiella et al. [16] investigated the economic effects of Italy's animal waste and biomethane plants in their study. Biogas and biomethane plants of different capacities were compared and an economic perspective for entrepreneurs was developed. Khalil et al. [17] studied the potential of biogas from animal waste in Indonesia. They determined that approximately 9597.4 Mm^3/year of biogas can be produced from the wastes. Şenol [18] determined the biogas potential of hazelnut waste and hazelnut shell residue of Giresun, Turkey. In the study, it is stated that the biogas potential that can be produced for 2019 is 317636 m^3/year and thus 273.954 tons of CO_2 emissions could be decreased. Tasova and Yazırel [19] calculated the biogas, heat, and electrical energy of Yozgat, Türkiye using the number of animals between 2013 and 2017. The highest energy value of dry matter and biogas was found for cattle in 2013 and small ruminants and poultry in 2015. The maximum potential value of total animal waste and biogas was formed in 2013. These values were obtained as 420988 tons of waste and 13892.63 m^3 of biogas, respectively. Ersoy and Uğurlu [20] examined Türkiye's biogas production potential from provincial-based animal manure through anaerobic digestion technology. The biogas potential has been estimated as 8.41 billion m^3 in the scenarios where the total amount of animal feces produced was assumed to be used in the anaerobic digestion method for biogas production. In the scenarios related to the fertilizer recovery values that vary according to the type of farm animals, the biogas potential is calculated as 4.18 billion m^3. Melikoğlu and Menekse [21] estimated Türkiye's cattle and sheep manure-based biomethane potential until 2026. In the study, semi-empirical models based on per capita meat consumption and milk production were used to estimate Türkiye's cattle and sheep population. According to the estimations, it was predicted that the cattle population of Türkiye will reach 18.7 million and the sheep population will reach 39.2 million in 2026. They stated that biomethane can be produced from cattle manure to 1.99 billion m^3, and from sheep manure to 0.15 billion m^3. Nuralan Poyraz et al. [22] investigated the biogas and electricity production potentials of cattle wastes in the Kocasinan and Melikgazi districts of Kayseri, Turkey. In the study, biogas and electricity production were evaluated in three different situations in terms of economic and environmental aspects. Çalışkan and Tümen Özdil [23] calculated the biogas potential that can be obtained from animal manure in different regions of Turkey between the years 2007-2019. It has been stated that Eastern Anatolia and Central Anatolia Regions stand out with 19% in biogas production compared to other regions. Seyitoğlu and Avcıoğlu [24] investigated the biogas potential that can be obtained from animal wastes of Çorum, Türkiye. The study used data from cattle, buffalo, goat, sheep, chicken, goose, duck, and

turkey animals. Depending on the amount of biogas that can be produced, the total amount of electricity has been determined as 100319.9 MWh. Kumaş and Akyüz [25] determined the biogas production potential of Tokat, Türkiye according to the total animal data. It has been determined that the amount of waste is 249596 tons per year and the amount of biogas that can be obtained is 49.92 Mm^3.

Türkiye is one of the countries with significant biogas potential. It has a large number of animal farms but has not reached the desired levels. In Türkiye, the number of cattle increased by 1.6% in 2020 compared to 2019 and reached 18 million 158 thousand. Also, it has been reported that the number of sheep and goats increased by 11.6% compared to the previous year and reached 54 million 113 thousand [26].

In this study, the annual biogas production potential of Afyonkarahisar, Turkey province was determined theoretically based on cattle, small ruminants, and poultry manure. Using this potential, different energy equivalents that can be produced annually have been calculated. In addition, the amount of electricity production and carbon dioxide emissions and the economic benefit for Afyonkarahisar have been evaluated

2. Materials and Method

The surface area of Afyonkarahisar is 1423000 hectares and 68775050 hectares of its surface area consists of lands suitable for culture. 215558 hectares of meadow and pasture lands, 20686050 hectares of forest and heathland, and 312831 hectares of non-agricultural lands can be specified. Dry farming is practiced in 68% of the cultivated lands and irrigated farming in 32% [27].

Table 1. Animal Numbers for Afyonkarahisar

District	Dairy Cattle	Meat Cattle	Calf	Sheep	Goat
Bayat	1953	569	1578	56235	6304
Başmakçı	9837	1652	3617	37647	14071
Bolvadin	19007	7924	8158	151673	5452
Dazkırı	5660	1917	2773	17223	2860
Dinar	12723	4953	6422	77479	17254
Emirdağ	8429	2769	5029	175395	8485
Evciler	8490	869	4113	16998	169
Hocalar	5222	1695	2290	30471	11464
Kızılören	945	117	445	8858	510
Center	42383	16197	20544	124679	3861
Sandıklı	18264	6070	11059	53176	2205
Sinanpaşa	28026	7620	12759	46395	720
Sultandağı	5176	1723	2285	60615	6251
Çay	20821	7093	9352	61741	1653
Çobanlar	8980	1320	3399	35125	1570
İhsaniye	17011	4697	9979	52526	14054
İscehisar	6310	2607	3892	39070	13200
Şuhut	21907	7550	11079	78930	727
Total	**241144**	**77342**	**118773**	**1124236**	**110810**

The main income source of Afyonkarahisar is agriculture and animal husbandry. Animal husbandry has developed in Afyonkarahisar as it has wide pastures. In Afyonkarahisar, traditional animal

husbandry has decreased and meat product production has developed with modern animal husbandry. Small and bovine livestock, beekeeping, and poultry farming are carried out intensively in the Afyonkarahisar center and almost every district. Afyonkarahisar has a higher potential in animal husbandry than neighboring provinces. Poultry and egg production is carried out in large quantities and therefore Türkiye's egg prices are determined in Afyonkarahisar. According to TUIK 2020 data, there are 437259 cattle, 1235046 small ruminants, and 16893961 poultry in Afyonkarahisar. Data on the number of animals are given in Table 1 [8, 28, 29].

Table 1. Continued (Animal Numbers for Afyonkarahisar)

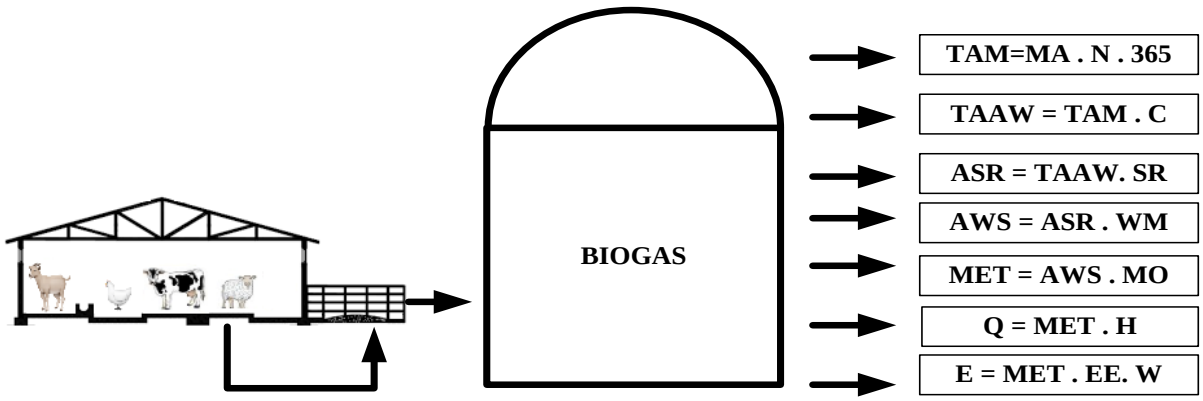
District	Horse Donkey Mule	Meat Chicken	Egg Chicken	Turkey	Goose + Duck
Bayat	216	0	3940	275	785
Başmakçı	272	0	3671049	8705	615
Bolvadin	249	25000	1469870	1153	2900
Dazkırı	46	0	85222	252	311
Dinar	174	0	563646	514	1530
Emirdağ	400	0	1020960	850	605
Evciler	43	0	11530	60	370
Hocalar	798	0	7600	150	70
Kızılören	39	0	885	90	225
Center	528	81000	7325600	16300	7200
Sandıklı	603	61000	970650	712	890
Sinanpaşa	554	97000	401100	4200	6100
Sultandağı	125	62000	2026	496	959
Çay	122	0	27283	2013	2640
Çobanlar	43	16000	6500	950	2600
İhsaniye	391	195000	709000	800	6520
İscehisar	49	0	2300	160	1800
Şuhut	270	0	2978	302	720
Total	**4922**	**537000**	**16282139**	**37982**	**36840**

In this study, the daily waste amounts and characteristics accepted in the livestock sector in Türkiye were taken into consideration. Daily manure amounts depend on the animal type, wet manure formation per unit animal (kg/day-animal), solid substance ratio (SR), volatile solids ratio (WM), volatile solids ratio in solid matter, and methane ratio produced from volatile solids given in Table 2 [30,31].

Figure 1 was used for the theoretical calculation of the biogas potential [30,31]. Depending on the electricity consumption, the carbon emission can be obtained by multiplying the electricity consumption and the emission factor [32]. The amount of CO_2 emission varies depending on the amount of carbon in the type of oil-based energy consumed. The fixed carbon rate in natural gas is known to be approximately 75%. As a result of burning 1 Sm^3 of natural gas from here, 2.75 kg of CO_2 is formed. Similarly, 0.55 kg of CO_2 is generated from 1 kWh of electricity consumption. As a result, the amount of CO_2 is calculated in kg as the sum of the amount of CO_2 consisting of all consumed energy sources. As a result of the consumption of electrical energy, the IPCC-Intergovernmental Panel on Climate Change has set a multiplier value between 0.5 and 0.6 per kWh of electricity.

Table 2. Parameters and values used in the study

Animal type	Average Daily Manure Production per Animal (kg/day-animal))	Solid Substance Ratio (SR) (%)	Volatile Solid Content in Solid Manure (WM) (%)	Collectible Useful Manure Ratio (C) (%)	Methane Production (m^3CH_4/kg-WM)
Dairy Cattle	43.00	13.95	83.36	65	0.18
Meat Cattle	29.00	14.66	84.65	25	0.33
Calf	2.48	8.39	44.23	50	0.33
Sheep	2.40	27.50	83.63	13	0.30
Goat	2.05	31.71	73.06	13	0.30
Horse-Donkey-Mule	20.40	29.41	66.67	29	0.30
Laying hen	0.13	25.88	77.27	99	0.35
Meat chicken	0.19	25.88	77.27	66	0.35
Turkey	0.38	25.53	75.83	68	0.35
Goose-Duck	0.33	28.18	61.28	68	0.35



TAM : total amount of manure (kg/year) — MA : amount of manure (kg / year-animal)

N: number of animals — SR: solid matter ratio (%) in the wet manure

TAAW: total amount of wet manure (kg/year) — C : rate of collectible manure %

ASR: total amount of solids in manure (kg/year) — MET : total annual amount of methane (m^3CH_4 /year)

MO : amount of methane produced from 1 kg WM — AWS : annual total volatile solids amount (kg /year)

WM : volatile solids content in the solid matter (%) — Q : energy equivalent of methane (MJ /year)

E : electricity of CHP engine (Mwhe/Year) — EE : electric efficiency of the CHP engine (35%)

W : energy value (10 kWh/m^3) of methane gas

Fig. 1. Theoretical calculation of the biogas potential [30,31]

The unit kWh and production-related emission value for Türkiye have been determined as 0.58 $kgCO_2$, and the emission value is calculated with the following formula [33,34,35].

$$\text{Emission Value (kgCO2)} = \text{Electrical Energy (kWh)} \times 0.58 \quad (1)$$

The amount of heat provided by 1 m^3 of biogas is equivalent to 0.63 liters of kerosene, 3.47 kg of wood, 0.43 kg of butane gas, 0.62 m^3 of natural gas, and 0.8 liters of gasoline [36]. The population of Afyonkarahisar was 736912 for the year 2020 and the electricity consumption per capita is 2529 kWh/year [37]. The population numbers of Afyonkarahisar province according to the districts are given in Table 3.

Table 3. Population of Afyonkarahisar

District	Population	District	Population
Center	313063	İscehisar	25043
Sandıklı	55252	Sultandağı	14517
Dinar	47516	Çobanlar	14355
Bolvadin	45133	Dazkırı	11397
Emirdağ	39518	Başmakçı	9617
Sinanpaşa	39432	Hocalar	9245
Şuhut	36690	Bayat	7573
Çay	31174	Evciler	7311
İhsaniye	27807	Kızılören	2269

3. Results and Discussion

Afyon Biogas Power Plant is in the Central district. With an installed power of 4.02 MWe, the power plant is Afyonkarahisar's 8th largest power plant, and the plant's facility is Türkiye's 62nd largest biogas facility. With an average of 24037504 kWh of electricity production, Afyon Biogas Power Plant can meet all the electrical energy needs of 6618 people in their daily lives (such as housing, industry, metro transportation, government offices, and environmental lighting). When only the residential electricity consumption is taken into account, Afyon Biogas Power Plant produces electricity that can meet the electrical energy needs of 8047 houses [38].

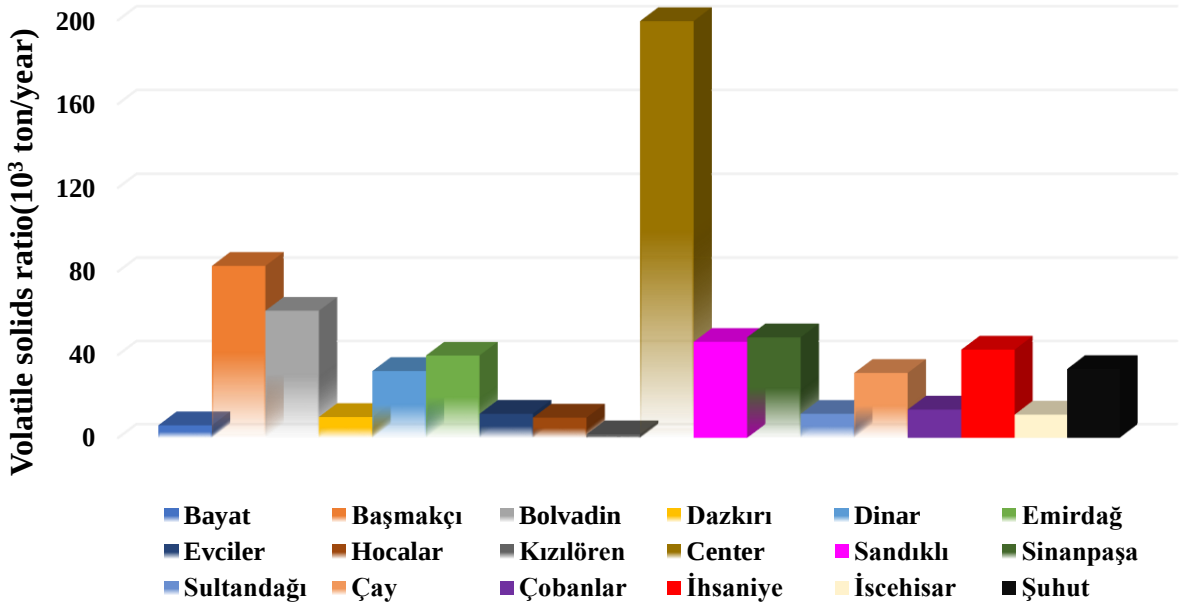


Figure 2. Volatile solids ratio by districts of Afyonkarahisar

Afyonkarahisar is one of the important provinces of Türkiye in terms of animal husbandry. It is also in a very important position in terms of animal waste and biogas established facilities. Wastes

generated in animal production facilities vary according to animal type and weight. The amount of volatile solids calculated on a district basis according to the number of animal species according to TUIK 2020 statistical data is given in Figure 2. The parameters given in Table 2 and Figure 1 were used to determine the amount of manure. The amount of obtainable animal manure is 502786 tons/year in total in Afyonkarahisar. The first three districts with the highest amount of waste manure calculated for different animal species were the Center (127732 tons), Başmakçı (47460 tons), and Bolvadin (43249 tons), respectively. Kızılören (1440 tons) was the district with the lowest amount of manure.

The terms potential manure and collectible manure are different. The collectability of the manure, how long the animals are kept indoors, and how much of the manure can be collected are important. The amount of useful manure that can be collected is directly related to the technical biogas potential. There are many studies in the literature about the duration of indoor stay of animals according to animal species.

In this study, the coefficients in Table 2 were used in the calculation of the biogas potential. The theoretically calculated total amount of biogas is 208.44 Mm^3/year. According to the amount of biogas that can be obtained, the highest rate is in the Center with 28.7%, and the lowest rate is in Kızılören with 0.2%. Moreover; Başmakçı with 11.6%, Bolvadin with 8.8%, and Sinanpaşa with 7.2% follow the Center. Biogas amounts by districts are given in Figure 3.

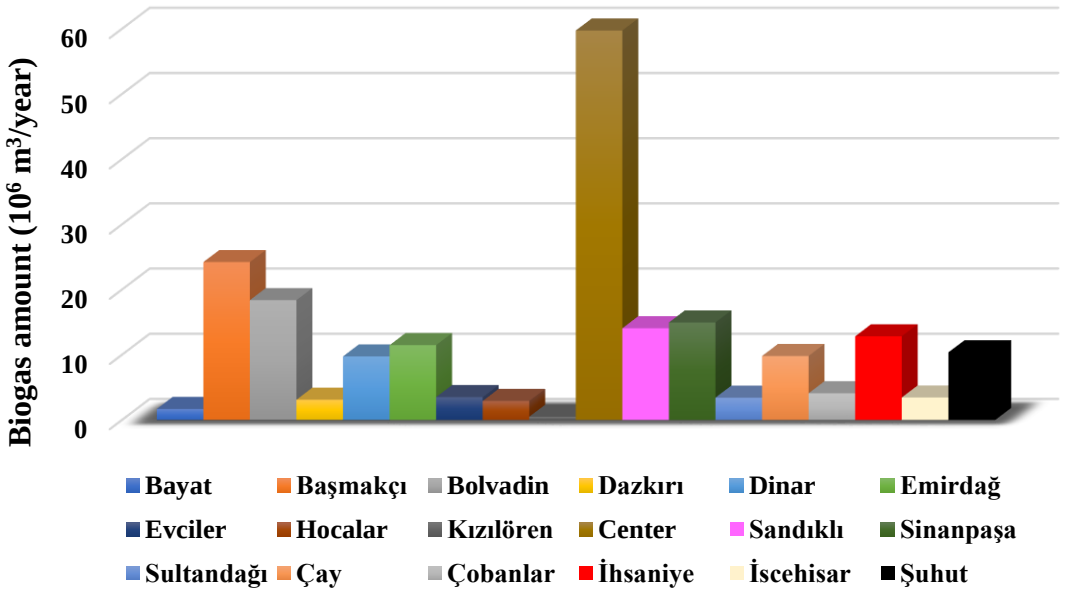


Figure 3. Biogas amounts by Afyonkarahisar districts

The methane content indicates the purity of the biogas. The methane amount of the districts that can be produced from the collectible useful manure according to the animal type is given in Figure 4. According to Figure 4, a total of 125.092 Mm^3CH_4/year of methane can be produced. Districts according to methane amount are the central district (28.7%), Başmakçı (11.7%), Bolvadin (8.9%), Sinanpaşa (7.18%), İhsaniye (6.15%), Emirdağ (5.6%), Şuhut (4.98%) and Dinar (4.7%). Of the total methane amount, 48.3% comes from cattle, 43.1% from chickens, 7.7% from sheep and goats, and the remaining 0.9% comes from other animal species.

The heat equivalents that may occur depending on the amount of methane are given in Figure 5. A total of 4503342 GJ/year of heat can be obtained from the amount of methane. When the heat equivalent is evaluated according to the districts, it is directly proportional to the methane potential.

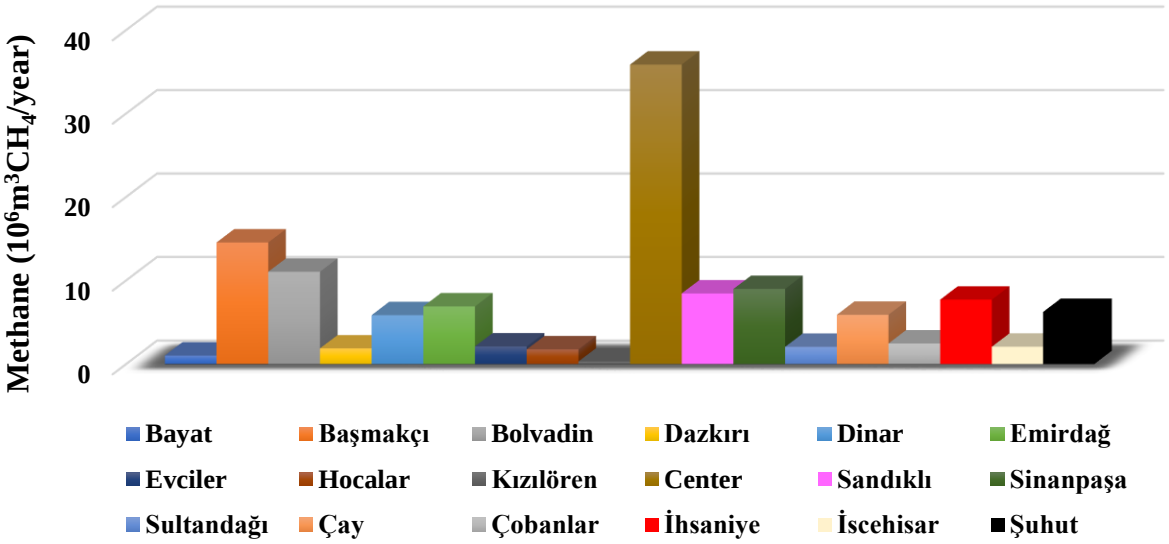


Figure 4. Theoretical Methane amount of Afyonkarahisar

While the heat energy value is high in districts with high methane potential, it is less in districts with low methane potential. The first three districts with the highest heat energy equivalent were Merkez, Başmakçı, and Bolvadin.

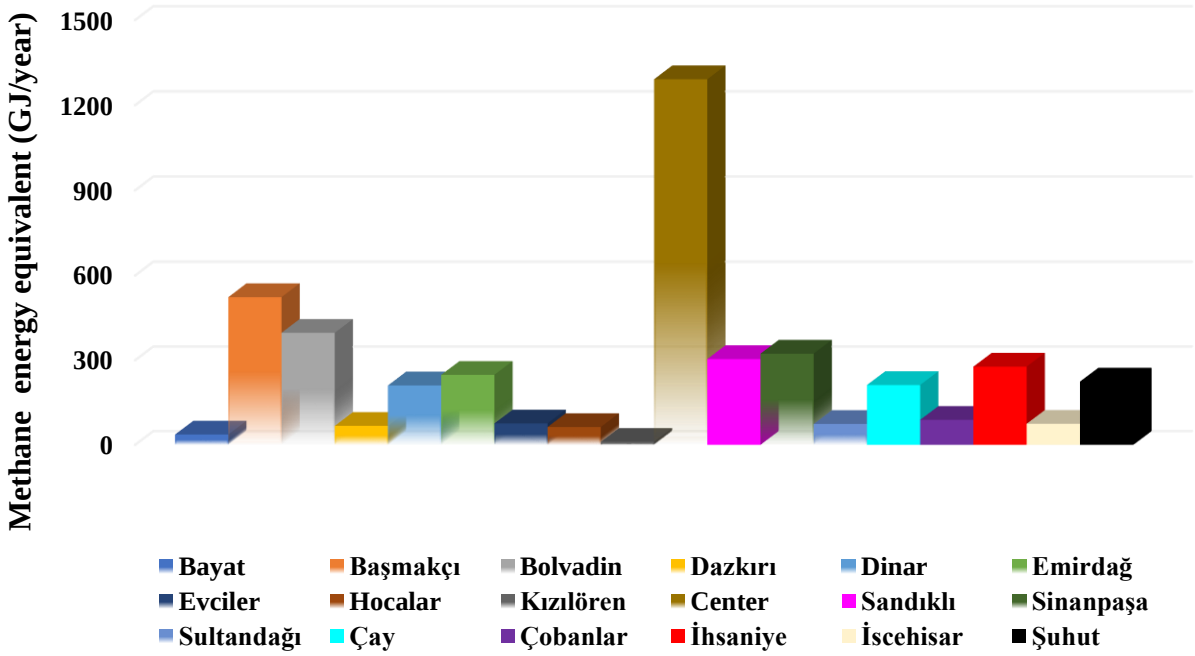


Figure 5. The methane energy equivalent of Afyonkarahisar animal manure

Biogas can be used directly in gasoline-powered engines without the need for any additives, or it can be used by purifying the methane gas it contains. If it is used in diesel engines, it should be mixed with diesel in certain proportions. The graph showing the equivalent value of gasoline, diesel, and kerosene that can be obtained depending on the amount of biogas is given in Figure 6. Gasoline is 166.749, diesel is 167.567, and kerosene is 131.315 ML. Among the three energy equivalents, gasoline has come to the fore as having the highest value. The Center district has the highest value in gasoline, diesel, and kerosene equivalents. The Center is followed by Başmakçı, Bolvadin, and

Sinanpaşa. Kızılören is the district with the least value for each category. As of the end of 2021, the gasoline price in Afyonkarahisar was 15.38 (TL/liter), the price of diesel oil was 15.63 TL/liter, and the price of kerosene was 14.46 (TL/liter) [39]. By the end of 2021, the energy that can be obtained in Afyonkarahisar would be 2564599620 TL based on the gasoline energy equivalent value, 2619072210 TL based on the diesel equivalent value, and 1898814900 TL in the kerosene-equivalent value.

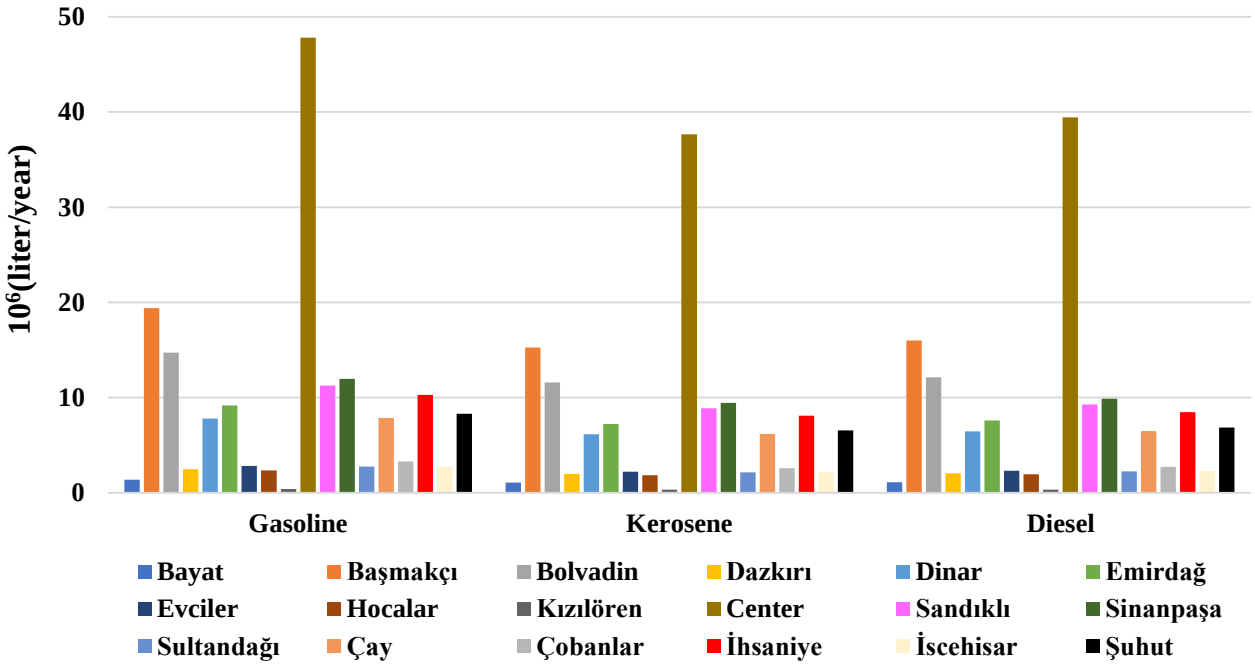


Figure 6. Gasoline, diesel, and kerosene equivalent of biogas for Afyonkarahisar

It is known that the share of natural gas consumed in residences in total consumption in Türkiye is close to 30%. 45% of the gas is consumed in industrial facilities, and transportation and 25% are used for electricity generation. As of the end of 2021, natural gas in Afyonkarahisar was 2.44 (TL/m^3) [40]. The natural gas and propane equivalents that can be obtained from biogas are given in Figure 6.

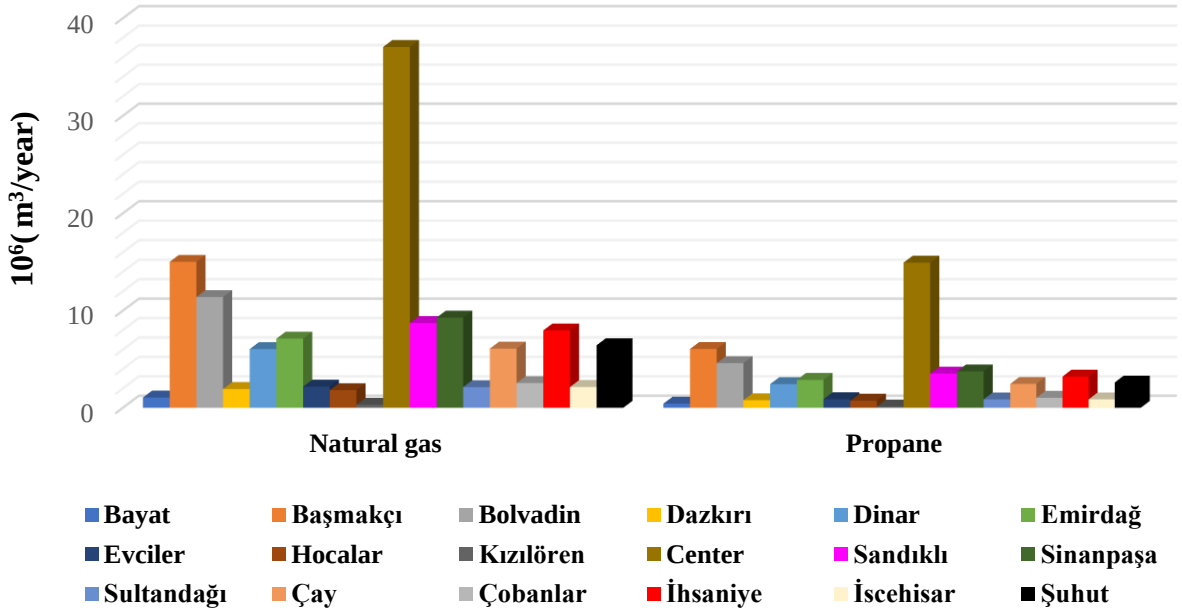


Figure 7. Natural gas and propane equivalent of biogas for Afyonkarahisar

When Figure 8 is examined, it is seen that biogas is equivalent to 129.230 Mm^3 of natural gas and 52.11 Mm^3 of propane in 2020. Afyonkarahisar's natural gas consumption amount in 2020 is 67562431.23 m^3 [41]. Considering the natural gas equivalent, depending on the biogas amount of Afyonkarahisar, an economic gain of 315321200 TL can be obtained.

Equivalents of fuel oil, liquefied petroleum gas, and butane that can be obtained from biogas are given in Figure 8. It is seen that there are 116.724 x 10^6 kg of fuel oil, 95.88 x 10^6 kg of liquefied petroleum gas, and 89.627 x 10^6 kg of butane equivalents for biogas in 2020. As of the end of 2021, the fuel oil price in Afyonkarahisar was 11.50 (TL/kg), and the price of liquefied petroleum gas was (9.67 TL/kg) [42]. Considering the fuel oil equivalent, 1342326000 TL income, and considering the liquefied petroleum gas price, 927159600 TL income can be obtained.

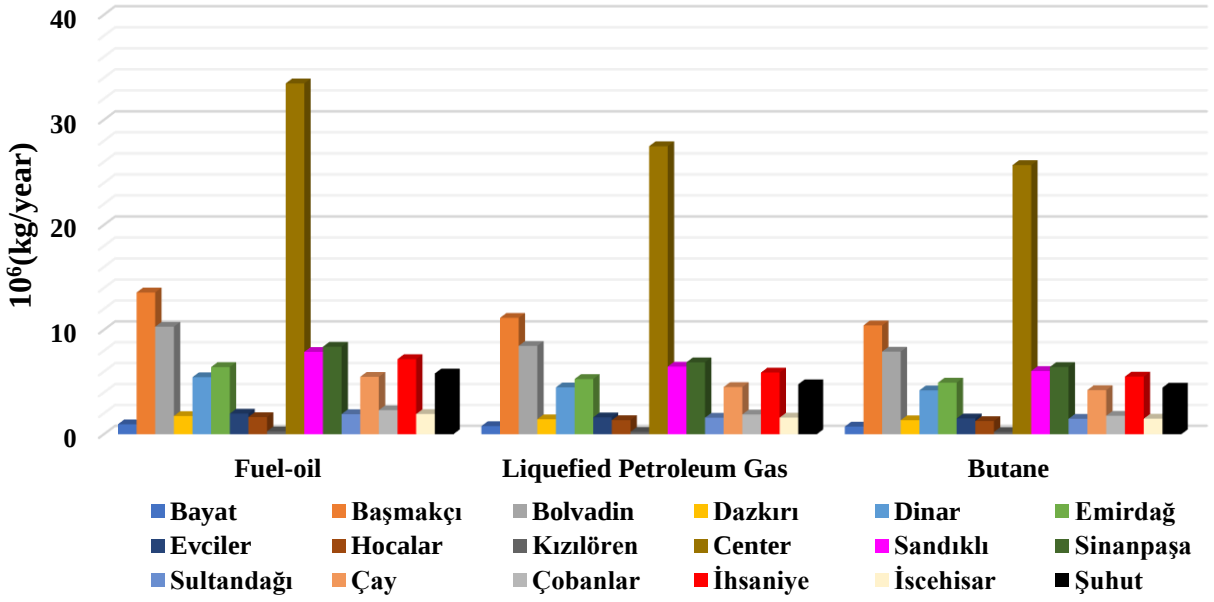


Figure 8. Fuel oil, liquefied petroleum gas, and butane equivalent of biogas for Afyonkarahisar

The increase in fuel prices in recent years has seriously affected the people in rural areas economically. It is known that heating needs are met by burning coal and wood. Especially in livestock facilities in rural areas, wood and coal are used as fuel for cooking and heating.

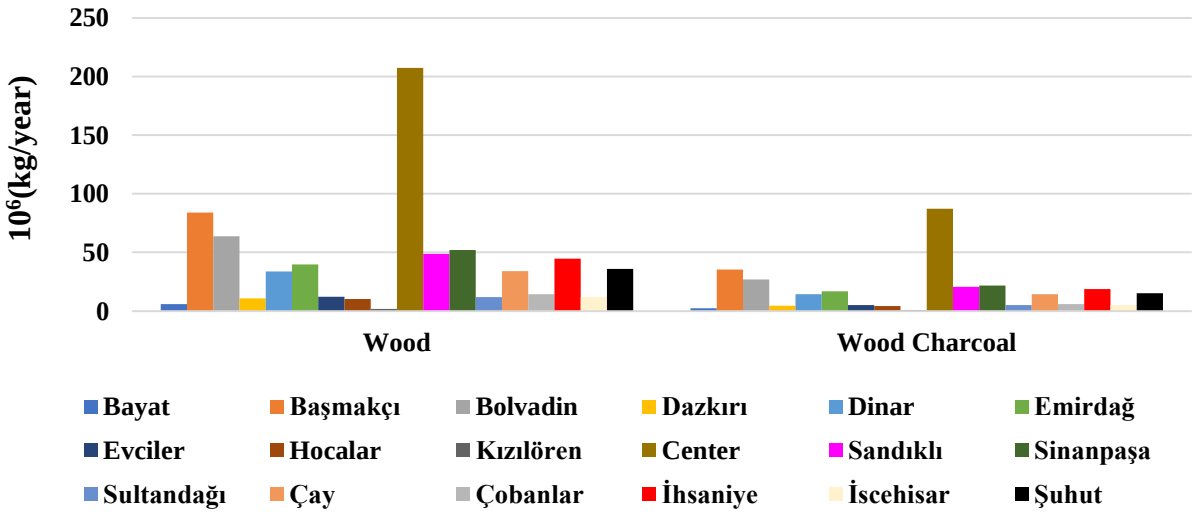


Figure 9. Wood and charcoal equivalents of biogas for Afyonkarahisar

Wood and charcoal equivalents that can be obtained from biogas are given in Figure 9. In 2020, it is seen that 304.317 x 10^6 kg of charcoal is equivalent to 723.274 x10^6 kg of wood from biogas. According to internet research, charcoal was 10 TL/kg, and wood was 1.2 TL/kg [43]. In the province, 867928800 TL can be obtained in terms of wood equivalent, and 3043170000 TL in terms of charcoal price equivalent.

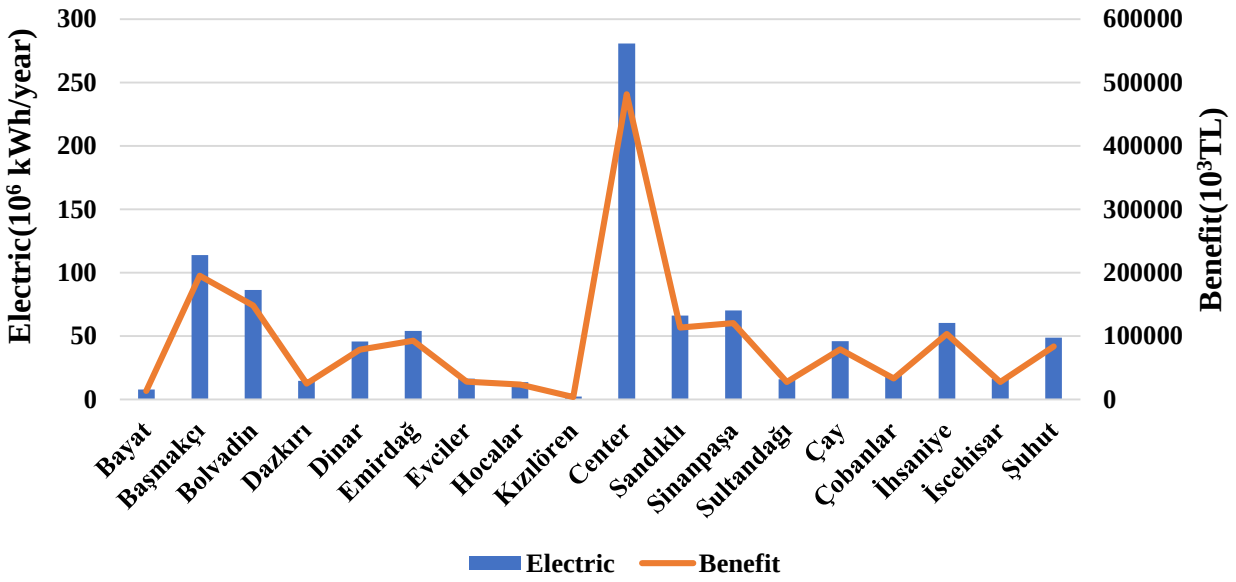


Figure 10. Biogas sourced electricity equivalent and benefit for Afyonkarahisar

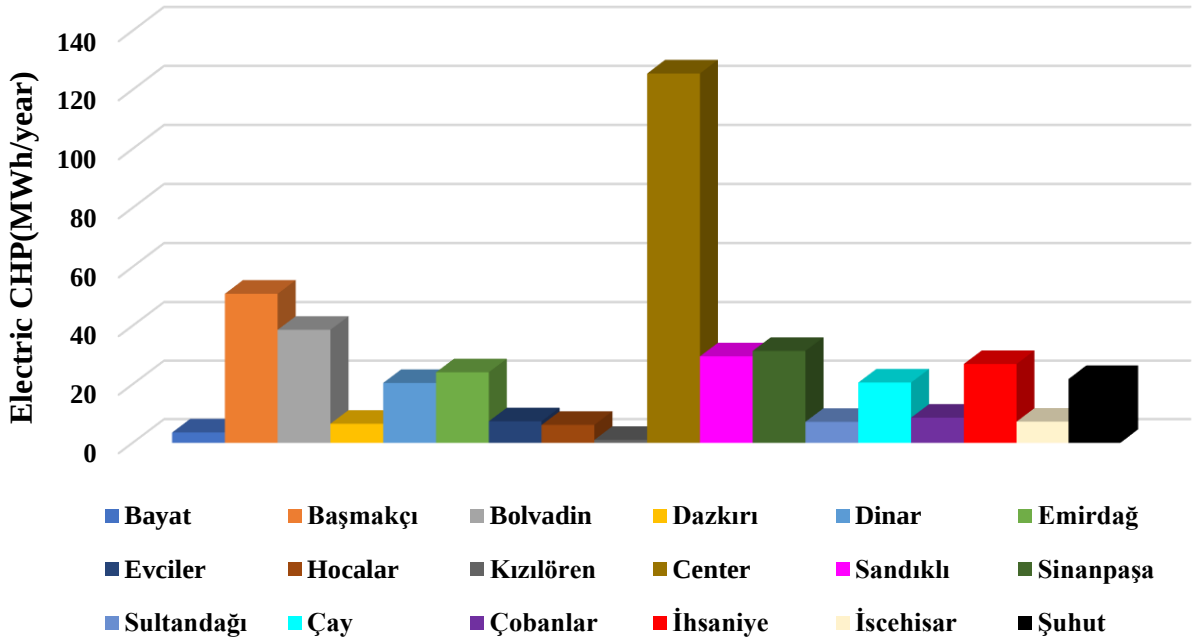


Figure 11. Electricity CHP equivalent to methane for Afyonkarahisar

The electrical energy equivalent that can be produced between the provinces and districts of Afyonkarahisar due to biogas production and the amount of benefit to be obtained are given in Figure 10. When the annual biogas production is used with the equivalent of 979.650 x 10^6 kWh electrical energy and the electricity unit price for the end of 2021, a benefit of 1680099750 TL will be provided (the end of 2021 pricing index is used). It has been determined that the district that contributes the most to the electricity equivalent value is the Center, which has the highest number of animals, and the district of Kızılören the least. According to the data of the TUIK, the electricity consumption per

capita in Afyonkarahisar in 2020 was 2529 kWh/year. The population of the province in 2020 was 736912. It has been calculated that the annual electricity needs of 388000 people can be met with electrical energy.

Ninety percent of the energy obtained from methane is converted into useful energy in CHP. 35% of this energy is converted into electrical energy [44]. CHP electrical energy equivalent for Afyonkarahisar is given in Figure 11. Approximately 437 MWh of electrical energy equivalent has been calculated from the annual methane production. The district that contributes the most to this value is the Center and the least is Kızılören.

CO_2 emissions that may arise from CHP electricity generation are given in Figure 12. Considering that 1 kWh of electricity savings corresponds to approximately 0.58 kg of CO_2 emissions, approximately 412 tons of CO_2 can be avoided per year.

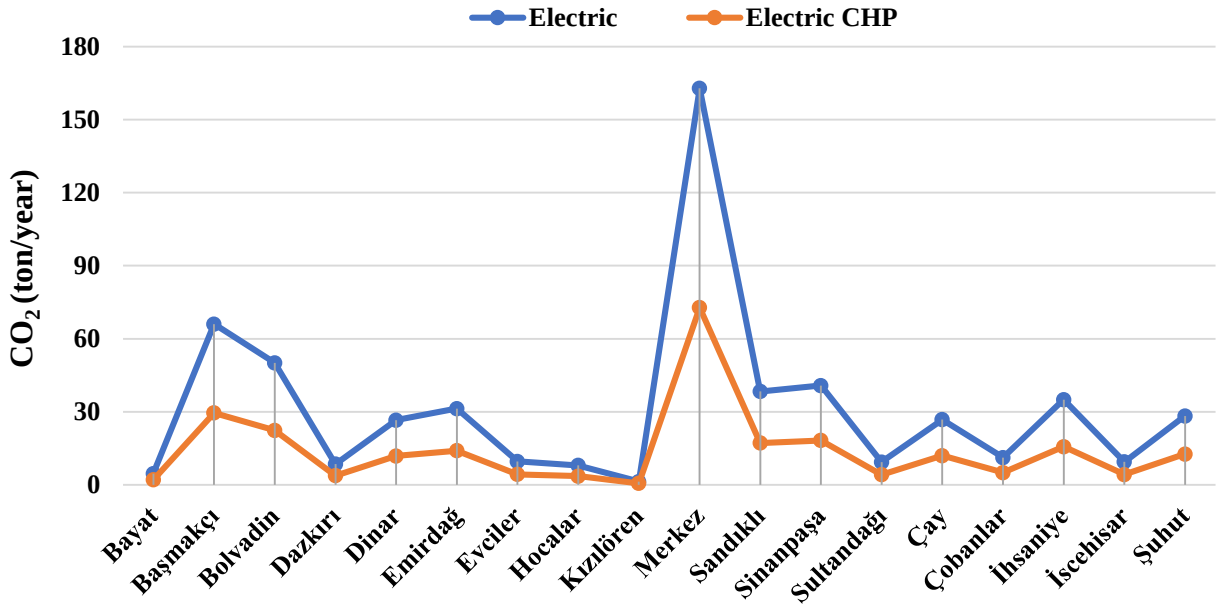


Figure 12. The effect of produced electrical energy on CO_2 emission for Afyonkarahisar

4. Conclusion

The livestock sector has an important place in providing rural development with its economic and social functions. More realistic and long-term plans should be made in the livestock sector in Türkiye to improve the current situation of animal breeders and to adapt them to innovations. In this study, the potential of animal waste, biogas, and methane to be obtained based on the TUIK 2020 animal statistical data of Afyonkarahisar, which is one of the important provinces of Türkiye in terms of livestock, and the energy equivalence of this potential was analyzed. According to TUIK 2020 different animal species statistical data, the theoretical amount of animal waste in the province has been calculated as 502786 tons/year. The amount of biogas generated from the collectible manure is 208.44 x 10^6 m^3 annually. The amount of methane that can be produced from collectible useful manure on a district basis is 125.092 x 10^6 m^3CH_4/year. The thermal energy equivalent of the methane amount is 4503342 GJ/year in total. The equivalent of CHP electrical energy originating from methane in the province was calculated as 437.82 MWh and it was determined that a total of 665.12 tons of CO_2 emission could be prevented. Türkiye has great potential in terms of renewable energy sources. However, the country imports most of its energy needs. Considering the economic and energy independence of the country, the use of renewable energy sources is very important. Since biogas is a sustainable, environmentally friendly, and domestic energy source, it can be considered

an important energy source for Afyonkarahisar. As a result, such studies can provide advantages in terms of energy and economy, as well as feasibility studies in biogas facilities planned to be established in the province or regionally. It can provide permanent job opportunities by creating new technologies and employment. It can enable steps to be taken to reduce climate change by reducing greenhouse gas emissions.

Authors' Contributions

KK contributes the idea of the study, contributes literature research, and the writing process of the article; AA contributes conceptualization and writing - review and editing. Both authors read and approved the final manuscript.

Competing Interests

The authors declare that they have no competing interests.

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