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Methane, Diesel Fuel, Electrical Energy, CO_2 Emissions and Economical Equavialent from Animal Manure of Tokat, Turkey

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Abstract

The animal husbandry sector is becoming a rapidly developing sector in Turkey and more waste is emerging in animal husbandry enterprises. It is necessary to dispose of these wastes that have a negative environmental impact. In search of new energy sources, it is becoming increasingly important to dispose of organic waste and use it in biogas production as an alternative energy source. Expanding the production of biogas will be very effective both in reducing external dependence on energy and in reducing the carbonG emissions that cause global warming. There are various studies in the literature on biogas potential calculations in Tokat province. In this study, animal species were given in detail, and district-based calculations were made and total biogas production potential was determined for Tokat, Turkey by taking into account different animal types according to 2020 Turkish Statistical Institute (TUIK) data. Different energy equivalent transformations that can be obtained depending on the biogas potential have been studied. The amount of benefits in TL that can be obtained for conversions has been determined. According to the total number of animals, the total amount of waste in the province was determined to be 249596 tons per year. The annual amount of biogas that can be obtained from waste is 49.92 x 10^6 m^3. It has been determined that this amount can be converted into 1133 x10^3 GJ thermal energy, 234.62 GWh electrical energy, and 32.95 x 10^6 liters. It has been calculated that 85636252 TL will be used for the conversion of biogas to electrical energy and 215822500 TL will be used for the conversion of diesel fuel.

Keywords:"Manure, Biogas, Methane, Diesel Fuel, Energy"

1. Introduction

Population growth and technological developments in the world increase the need for energy every day. Energy consumption worldwide is estimated to increase by approximately 49% from 2007 to 2035 [1]. Fossil-derived fuels can run out over time. In addition, limited fossil fuel resources make countries dependent on the outside. Too much use of fossil fuels poses significant threats to the future of the world. In addition to increasing greenhouse gas emissions due to fossil fuel use, the release of other pollutants has also increased [2,3]. Alternative energy sources have become very important in recent years because they do not pollute the environment and are environmentally friendly. Extensive research and investments have been made in recent years for the use of alternative energy sources [4,5]. Most developed countries carry out projects and research aimed at improving energy efficiency, sustainability of industrial production, and improving energy savings [6]. Furthermore, European Union member states have set their energy efficiency targets to reduce energy consumption by 2030. As in other countries, extensive investments and research are being carried out to evaluate alternative energy sources that exist in our country [7,8]. Among the targets for 2020, production from renewable energy sources in the world will be around 2.3-3.3 MTEP (million tons of oil equivalent) [9]. It is estimated that biomass energy, an important renewable energy source, can meet approximately 25% of global energy needs [10]. Biogas, which is an alternative energy source, stands out among these sources because it is cheap, environmentally friendly, and easily applicable in rural areas. As in other countries, increasing the energy deficit in Turkey is important for meeting the energy needs of biogas-producing facilities [11]. Biogas energy can be produced from microalgae, food and agricultural waste, animal fertilizers, poultry waste, municipal solid waste, industrial waste, forest waste, and various energy plants. These organic wastes are converted into biogas with 52% CH_4, 45% CO_2, 3% H_2S, O_2, N_2, H_2, and CO in an anaerobic environment by the effect of microbiological flora. CO_2 and other components, except CH_4 in the content of biogas, are removed, methane is purified and heat and electricity production is carried out [12].

Abdeshahian et al. (2016), investigated the biogas potential of Malaysia using waste from farm animals and determined that this energy value was approximately 4.6 billion m^3 and that the electrical energy obtained from biogas was 8 270 GWh [13]. Tasova (2017) found that in Tokat, Turkey average annual wet waste and biogas potential values of poultry in 2010-2014 were 6052.60 kg and 472095.60 m^3, respectively [14]. Doruk and Bozdeveci (2017) calculated the potential of biogas based on animal wastes occurring in Denizli, Turkey center and districts. According to 2014 data across Denizli, the total number of animals was 4 370 129, and the daily amount of fertilizer consists of 4 578 889 kg per day. The results showed that 70.16 m^3 of biogas can be produced

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from animal wastes in Denizli. The energy equivalent of the annual biogas potential from animal wastes was 46.30 million liters of diesel fuel, and the equivalent of electrical energy was 329 million kWh^{-1} [15]. Meyer et al (2018) examined the biomass and biogas energy potential of the member states of the European Union. They stressed that more technological developments need to be made to use biomass resources efficiently [16]. Kandemir and Açıkkalp (2019) determined the evolution of the number and waste of animals in Bilecik, Turkey between 2011 and 2017. Theoretical biogas from animal fertilizers and the equivalent of electrical energy that can be produced from biogas was found to be the most in 2017 with approximately 280.5 GWh [17]. Can (2020) examined the power generation capacity from municipal solid waste in Turkey. In the study, it was emphasized that the potential for renewable energy generation is high if landfill gases are used in Turkey [18]. Caglayan (2020) calculated the potential amount of waste that will consist of cattle and small animals of 14 provinces belonging to the Eastern Anatolia region of Turkey. In the study, biogas energy that can be produced from these wastes and the number of people who will benefit from this energy were determined. As a result of the study, about 95.4% of the population of the Central District of Ardahan province could meet its energy needs from biogas energy if the necessary facility was established [19]. Gençyilmaz and Seçkin (2020) determined the biogas energy potential of Çankırı, Turkey-based on animal waste. Biochemical methane production potential and its contribution to electricity production were calculated and energy analysis was made by creating a regional map for each district. In addition, electricity and CO_2 emissions from biogas production were calculated [9]. Ay and Kaya (2020) determined the theoretical biogas potential and electrical energy production of Kahramanmaraş, Turkey using five different models. As a result of the models used, it was calculated that the theoretical biogas potential of Kahramanmaraş province is in the range of 37.5 – 137 million m^3 [20]. Aslan et al. (2021) determined that the renewable energy resources potential of Adıyaman, Turkey is 251.252 MW/year from solar, wind, hydroelectric energy and 1.330 MW/year from biogas energy potential [21]. Kurnuc et al. (2021) calculated the energy potential of Erzincan, Turkey from animal waste. The results show that approximately 15.5 million m^3/year biogas potential can be produced from animal waste in Erzincan [22].

In this study, biogas production potential was determined for Tokat, which has many livestock enterprises. The details of the animal species were also included in the study. The possible use of these wastes in energy production and their contribution to the economy has been calculated. In Turkey, animal manure is generally stored in open areas and creates various environmental problems. Animal wastes can be used as fertilizer on agricultural lands, as well as for heating and cooking in rural areas. The energy obtained from direct combustion is relatively lower than the energy obtained by converting manure to biogas. The use of manure on agricultural lands is also more economical than directly burning it into energy. The reason why biogas facilities are not used sufficiently in rural areas is the lack of technical, economic, and sustainable facilities. In general, biogas plant design should take into account animal and plant waste potentials and geographical locations. Climatic and production conditions must be taken into account. In this study, these conditions were tried to be taken into account. low cost, high efficiency, easy to install, operate and maintain systems should be designed and built. There are various studies in the literature on biogas potential calculations in Tokat province [23-28]. However, in this study, animal species were given in detail, and district-based calculations were made. In addition, data for 2020 were used. Tokat livestock sector plays an important role in Tokat's provincial income. It is quite clear that the use of animal wastes depending on manure management techniques and calculations will make a positive contribution to the province of Tokat, both environmentally and economically. Calculations and estimations made in this study will contribute to sustainable waste management for the province of Tokat. Such calculations are also of great importance in terms of climate change, which is the biggest problem of today.

2. Materials and Method

Tokat is located in the interior of the Central Black Sea region of Turkey. Its area is 9958 km^2. It is between the latitudes of 39º 51' – 40º 55' north and the longitudes of 35º 27'- 37-39' East. There are 12 districts, including the Central District. 370,446 ha of agricultural land constitute 37% of its area. 30% of agricultural areas are irrigated agriculture. Tokat also has 67.398 agricultural enterprises. Most of the enterprises are in the form of small family enterprises, 44% of which are plant production and 56% of which are animal production. Its economy is based on agriculture, animal husbandry, industry, and trade. Large and small animal breeding is widely carried out. Cattle and buffalo are raised in lowland areas, sheep and goats are raised in mountainous areas. In addition, poultry and beekeeping are carried out, as well as fishing in the lakes. Four important animal products are obtained through dairy cattle, fattening cattle, beekeeping, and trout farming activities. In 2020, 128,326 tons of milk production and 2.6 million eggs were produced by small and cattle farming activities in the province. The share of milk obtained by dairy farming in Turkey is 1.5% [29]. According to statistics Turkey (TUIK) data for 2020, Tokat's total animal presence is 1016988 units. 31% of these animals are dairy cattle, meat cattle, and calves, 44.6% are sheep and goats, 23.9% are egg chickens, turkeys, geese, and ducks, 0.5% are horses, donkeys, and mules. Animal presence by county is given in Table 1 [30].

Table 1. Number of animals

District	Dairy Cattle	Meat Cattle	Calf	Sheep	Goat	Horse Donkey Mule	Egg Chicken	Turkey	Goose Duck
Almus	6715	894	4128	13445	860	254	6700	200	1050
Artova	6810	1685	3797	12183	1012	19	3575	340	835
Başçiftlik	3517	1011	1082	7705	13	32	0	0	0
Erbaa	23461	7180	7898	87779	8102	188	33421	182	1336
Center	45255	5423	15617	78404	28045	2097	42300	865	6050
Niksar	15170	4088	8310	37430	1875	635	11800	280	720
Pazar	8232	1659	4355	12000	1200	25	2300	200	1310
Reşadiye	7010	2366	4254	33096	1898	164	3165	8	318
Sulusaray	6593	1219	3358	7418	1455	82	5200	430	3060
Turhal	32485	11635	11390	48102	18850	426	62250	380	1140
Yeşilyurt	5103	1239	5126	8618	2185	16	18010	165	3525
Zile	24826	5836	16190	27776	14540	527	26000	1000	5500
Total	**185177**	**44235**	**85505**	**373956**	**80035**	**4465**	**214721**	**4050**	**24844**

In this study, the daily waste amounts and characteristics accepted in the livestock sector in Turkey were taken into account. Daily manure quantities depending on the type of animal wet manure formation per unit animal (kg/day-animal), solids ratio, volatile solids ratio, volatile solid contents, are given in Table 2. The formulas used in this study are given in equations (1-4). Symbols and abbreviations used in equations are shown in the nomenclature section [31].

Table 2. Admissions used in the study

Animal type	OAM x 365 (kg/day-animal))	RW (%)	PVS (%)	TVS (%)
Dairy Cattle	43.00	13.95	83.36	65
Meat Cattle	29.00	14.66	84.65	25
Calf	2.48	8.39	44.23	50
Sheep	2.40	27.50	83.63	13
Goat	2.05	31.71	73.06	13
Horse-Donkey-Mule	20.40	29.41	66.67	29
Egg Chicken	0.13	25.88	77.27	99
Turkey	0.38	25.53	75.83	68
Goose-Duck	0.33	28.18	61.28	68

$$TAM = OAM\ x\ AN \quad (1)$$
$$TWM = TAM\ x\ AVM \quad (2)$$
$$SM = TWM\ x\ RW \quad (3)$$
$$TVS = SM\ x\ PVS \quad (4)$$

The amount of biogas production was considered to be about 200 m^3 per unit ton of dry fertilizer. The heating value of biogas was taken into account as 22.7 MJ/m^3. The amount of heat provided by 1 m^3 of biogas is equivalent to 4.7 kWh of electricity and 0.66 diesel fuel [3]. 1m^3 biogas has 60% methane content, as well as 1 kWh of electricity savings equivalent to approximately 0.58 kg of CO_2 emissions [32,33]. According to the report of the Turkish Energy Market Regulatory Board dated 18.03.2021, the price of diesel fuel was accepted as 6.55 TL. As of 01.07.2020, the average residential electricity prices to be applied for the third quarter of 2020 were 0.366 TL [34,35]. The population distribution of Tokat province by the district in 2020 is given in Table 3 [36]. A family of five people is known as 0.15 m^3 daily use for one hour of lighting, daily cooking needs: 0.35 m^3 since it is used for 8 hours of lighting purposes daily, the total daily need is taken as about 3 m^3 days [19].

Table 3. Population of Tokat, Turkey

District	Population	District	Population
Center	203395	**Almus**	23825
Erbaa	98342	**Pazar**	13209
Turhal	79776	**Yeşilyurt**	8871
Niksar	61119	**Artova**	8132
Zile	54368	**Sulusaray**	7083
Reşadiye	34211	**Başçiftlik**	5530

3. Results and Discussion

Tokat is one of the important provinces of Turkey in terms of animal husbandry. For this reason, the amount of animal manure is quite high. According to TUIK 2020 data, the amount of manure calculated based on different animal numbers is determined at the district level and given in Figure 1. In the calculation, the coefficients and formulas given in Table 2 were used for animal type. The calculated amount of waste fertilizer was determined to be 249596 tons per year throughout the province. The amount of waste fertilizer calculated according to different types of animals was the largest number of animals in the Central District (59413 tons). This district is followed by Turhal (44441 tons), Zile (33024 tons), and Erbaa (32908 tons) districts. The county where the amount of waste fertilizer is the least is Başçiftlik (4738 tons) district.

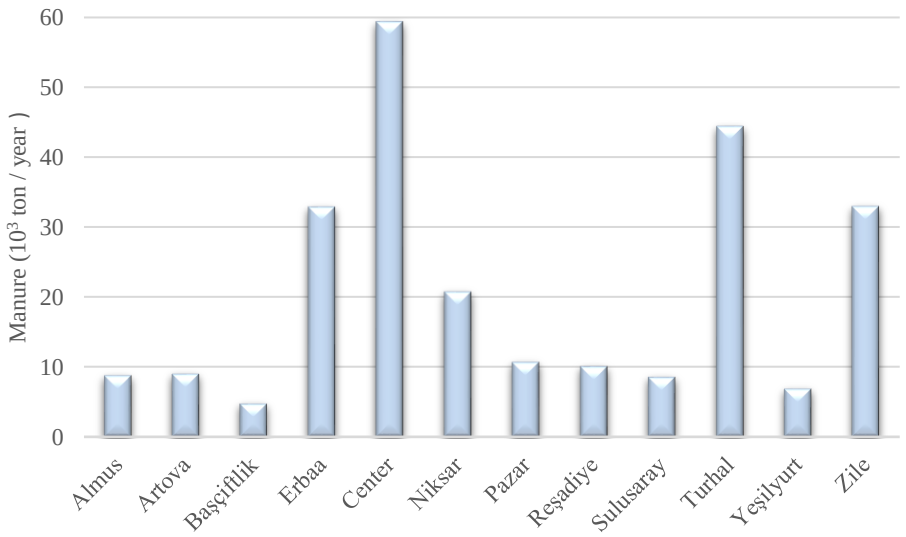

Figure 1. Animal Manure Quantity

Fertilizer formation amounts are potential production and in practice, only a certain part can be collected. The ability to collect animal manure is related to the time when animals are indoors and the ability to accumulate waste that occurs indoors. In Turkey, the amount of useful fertilizer that can be collected from animal manure has been defined as technical biogas potential. Depending on the type of animal, different coefficients are used in the literature with the duration of the animals ' stay in a closed environment. In this study, the coefficients and formulas in Table 2 were used in the calculation of the biogas potential. The theoretically calculated amount of biogas in Tokat province is 49.92 x 10^6 m^3 for 2020. According to the proportional distribution of this amount by district, 23.8% of the Center is accounted for, depending on the amount of waste. The district with the least proportion is Başçiftlik with 1.9%. Center is followed by Turhal with 17.8%, Zile with 13.2%, and Erbaa with 13.1% respectively.

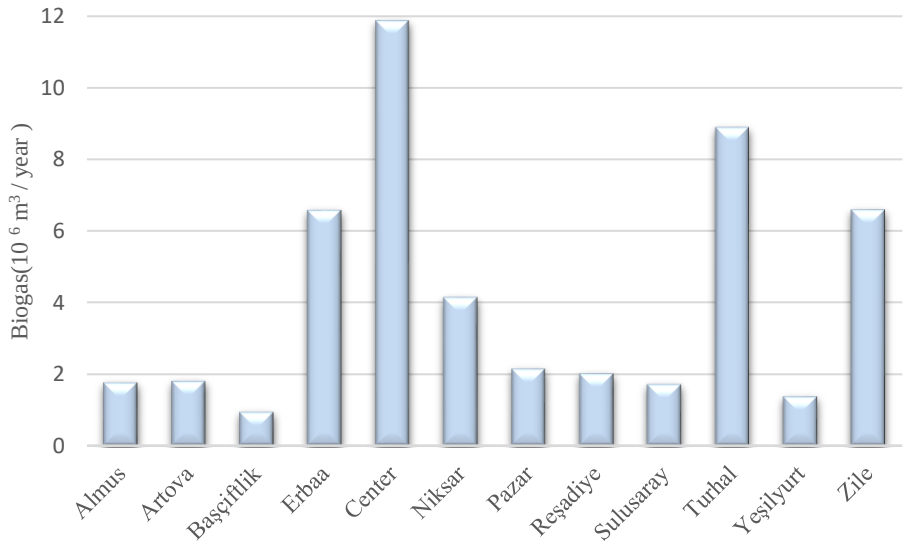

Figure 2. Biogas Amount

The degree of purity of the biogas produced is determined by the methane content. In a general approach, the gas produced by a biogas plant must have a methane content of at least 60% to run smoothly. Figure 3 shows that 29.95 x 10^6 m^3 of methane gas can be produced from a total annual amount of 49.92x10^6 m^3 of biogas. According to the distribution of methane gas by animal type, it consists of 94.4% (dairy cattle, meat cattle, and calves), 4.6% (sheep and goats), 0.02% (egg chicken, turkey, goose, and duck), 0.08% (horse, donkey, and mule). The Center district with 7.13x10^6 m^3 has the most methane production, while the Başçiftlik has the least methane production with 0.57 x10^6 m^3.

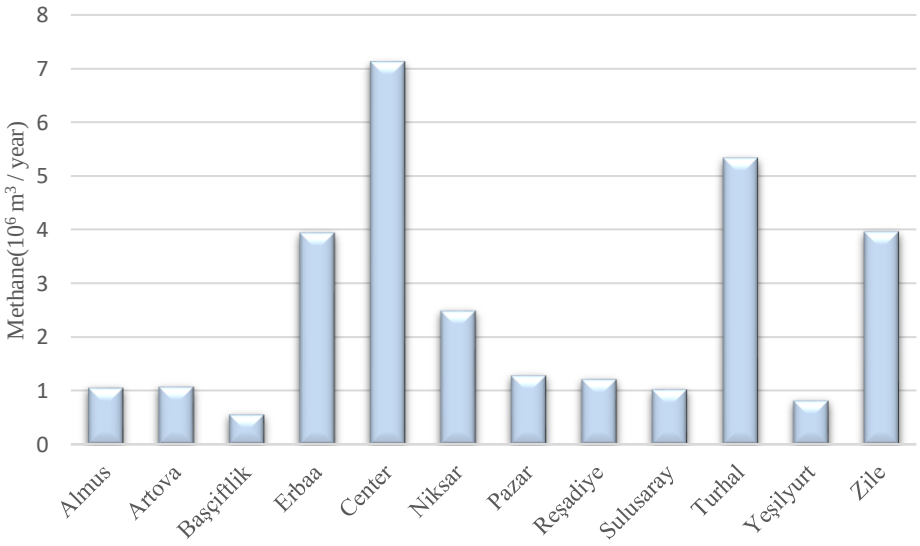

Figure 3. Amount of Methane

The equivalent value of heat energy that can be obtained depending on the amount of biogas in Tokat is given in Figure 4. Accordingly, 1133 x10^3 GJ thermal energy can be obtained from the total annual amount of biogas. Accordingly, when the thermal energy equivalent is examined based on districts, the energy potential is greater in the districts where the amount of biogas is greater, and in the districts where the amount of biogas is less. The districts where heat energy is the least of the districts are; Center, Turhal, Zile, Erbaa, Niksar, Pazar, Reşadiye, Artova, Almus, Sulusaray, Yeşilyurt and Başçiftlik respectively.

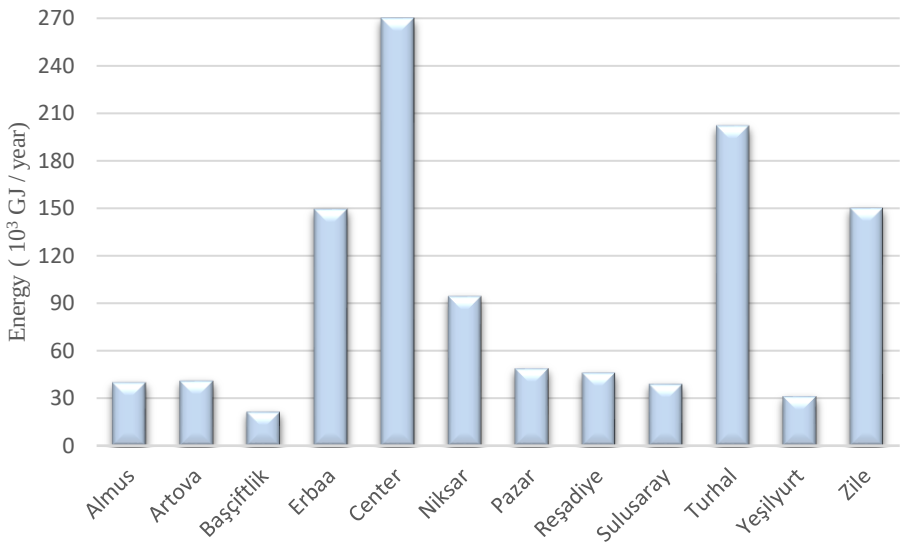

Figure 4. Energy Values

The equivalent value of electrical energy that can be obtained from biogas in Tokat is given in Figure 5. Accordingly, 234.62 GWh of electricity will be generated from biogas from 49.92×10^6 m^3, which can be produced annually. It is clear that this potential is directly proportional to the amount of biogas production. 55.85 GWh of electrical energy is obtained from 11.88×10^6 m^3 of biogas in Center, where biogas is the most abundant, while 4.45 GWh of electrical energy can be produced from 0.95×10^6 m^3 of biogas in Başçiftlik. Turhal, Zile, and Erbaa followed Center where the most electrical energy can be produced, respectively. According to Tokat's 2019 TUIK data, electricity consumption per capita was 1348 kWh, and total electricity consumption was 825.98 GWh. The population of Tokat as of 2020 was 597861 people. If electricity consumption per capita in 2020 was similar to 2019, the electricity needs of 29% of the total population can be met. In addition, if biogas is converted to electrical energy, 85636300 TL will be useful. It means that approximately 136079 tons of CO_2 per year can be prevented by obtaining biogas from animal waste.

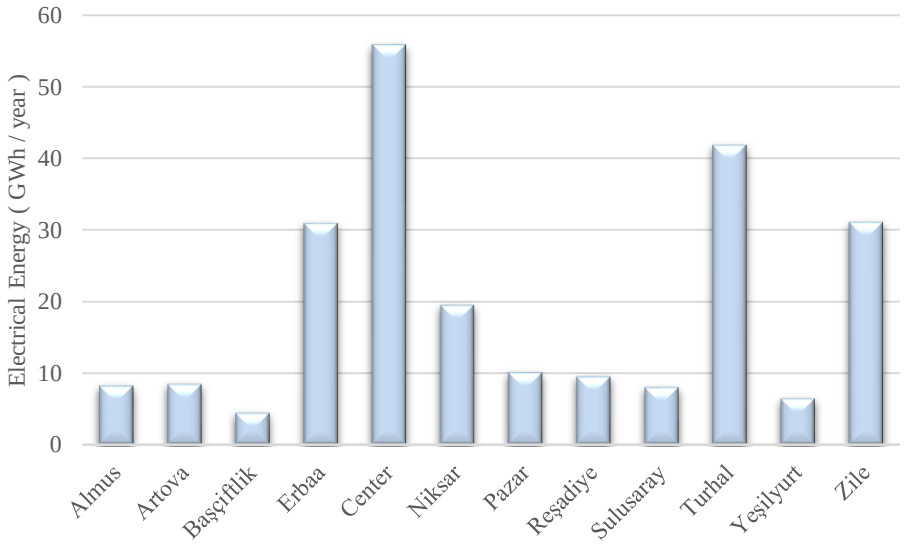

Figure 5. Electrical Energy Equivalent

The equivalent value of diesel fuel that can be obtained from biogas in Tokat is given in Figure 6. Accordingly, 32.95×10^6 liters of diesel fuel can be produced from biogas from 49.92×10^6 m^3, which can be produced annually, while the most diesel fuel production occurs in the central district, followed by Turhal, Zile, and Erbaa respectively. The least diesel fuel production was in Başçiftlik district, where the amount of biogas was the least. In the case of converting biogas to fuel approximately 215822500 TL of benefit will be provided.

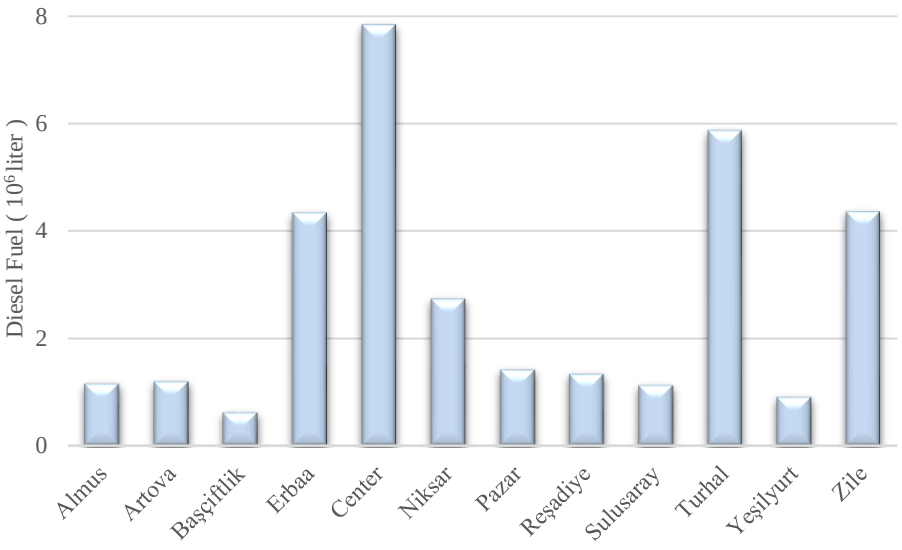

Figure 6. Diesel Fuel Equivalent

According to 2020 data, Tokat has a population of 597861 people. The number of people who can benefit from biogas production according to the district population and the benefit values that can be achieved by converting biogas to electricity and fuel energy is seen in Table 4. A total of 49.92×10^6 m^3 biogas can be obtained annually in the study. 45586 people will be able to benefit from this amount of biogas. This represents approximately 8% of the total population. By evaluating Tokat's biogas production potential of animal wastes, it will be possible to provide an annual benefit of 85636252 TL from electricity sources. In addition, depending on the amount of biogas production, its benefits in diesel equivalent and TL were calculated. Accordingly, the benefit that will be provided when the diesel equivalent value is accepted will be 215800362 TL.

Table 4. Benefits from biogas production

District	Biogas Benefits			Benefit from Electricity		Benefit from Diesel Fuel	
	Biogas Amount ($10^6 m^3$/year)	Population	References Number of People	Production (kWhe/year)	TL	Amount (lt)	TL
Almus	1.77	23825	1612	8298860	3029084	1165372	7633185
Artova	1.81	8132	1656	8523149	3110949	1196868	7839484
Başçiftlik	0.95	5530	865	4453859	1625659	625436	4096603
Erbaa	6.60	98342	6010	30933648	11290782	4343874	28452375
Center	11.89	203395	10851	55848644	20384755	7842576	51368870
Niksar	4.16	61119	3797	19540766	7132380	2744023	17973348
Pazar	2.15	13209	1965	10114222	3691691	1420295	9302932
Reşadiye	2.03	34211	1854	9539442	3481896	1339581	8774257
Sulusaray	1.72	7083	1570	8079452	2948999	1134561	7431376
Turhal	8.89	79776	8117	41775258	15247969	5866313	38424349
Yeşilyurt	1.38	8871	1257	6469993	2361547	908552	5951017
Zile	6.61	54368	6032	31042577	11330541	4359170	28552566

4. Conclusion

Many studies have been conducted to assess the potential for biogas production in Turkey on a regional or urban basis. These studies, it is aimed to determine the energy potential of various biogas sources. The biogas potential of Tokat province, one of the cities of its economy based on agriculture and animal husbandry, according to the number of animals and its conversion to other energy sources equivalent to this potential, were evaluated. As in similar studies in the literature, animal numbers were obtained from TUIK.

The total number of cattle (dairy cattle, meat cattle, and calves) in Tokat is 314917, the number of small animals (sheep and goats) is 453991, the number of animals with nails (horses, donkeys, and mules) is 4465 and the number of poultry is 243615. According to the theoretical calculation obtained in the study, the total amount of waste in Tokat was determined as 249596 tons/year. According to these waste amounts, the total biogas potential of Tokat was calculated as 49919121 m^3/year. The total annual electricity generation potential that can be generated from biogas is 214619871 kWh. In addition, 1133×10^3 GJ/year heat energy production can be achieved in the province by benefiting from the same source biogas production potential.

Considering the biogas potential of Tokat province, which has a total annual electricity generation potential of 234619871 kWhe, the energy to be produced will be able to meet the electricity needs of approximately 43500 households, considering a household of 4 people. In addition, 136079 tons of CO_2 emissions can be prevented by converting biogas to electricity. By evaluating the waste in Tokat province, it is seen that an annual benefit of 85636252 TL will be provided from electricity sources. The benefit to be provided when the diesel equivalent value is accepted will be 215800362 TL.

With the development of technology, the increase in the number of agricultural vehicles powered by biogas will reduce the dependence on diesel, which is the highest expenditure of the farmer. With the reduction of dependence on diesel, each farmer will be able to make his fuel and use it in agricultural production. The establishment of biogas facilities will not only develop an environmentally friendly system but will also play a key role in the development of our country's agriculture.

Nomenclature

OAM: Amount of manure an animal can produce in a year (kg/year-animal)
AN: Animal number
TWM: Total amount of wet manure that can be produced by animals in one year (kg/year)
TAM; Total amount of manure that can be produced by animals in one year (kg/year)
AVM: Available manure ratio
SM is the total amount of solids in the annually collected manure (kg/year),
RW is the ratio of solids in the wet manure (%).
TVS: The total amount of volatile solids per year in wet manure (kg/year),
PVS: The proportion of volatile solids in the number of solids

References

[1] Cheah, W. Y., Ling, T. C., Show, J.C., Juan, J.C., Chang, J. S., and Lee, D. J. (2016). Cultivation in wastewaters for energy: A microalgae platform. Applied Energy, 178, 609-625. https://doi.org/10.1016/j.apenergy.2016.07.015.

[2] Kligerman, D. C., & Bouwer, E.J. (2015). Prospects for biodiesel production from algae-based wastewater treatment in Brazil: A review. Renewable and Sustainable Energy Reviews, 52, 1834–1846. https://doi.org/10.1016/j.rser.2015.08.030.

[3] Seyitoğlu, S. S., & Avcıoğlu, E. (2021). An Investigation for the Potential of Biogas to be Produced from Animal Waste in Corum. Gazi University Journal of Science PART C: Design and Technology, 9(2), 246-261. https://doi.org/10.29109/gujsc.889846.

[4] Choi, W., Yoo, E., Seol, E., Kim, M., and Song, H. H. (2020). Greenhouse gas emissions of conventional and alternative vehicles: Predictions based on energy policy analysis in South Korea, Applied Energy, 265, 1, 114754, 1-17. https://doi.org/10.1016/j.apenergy.2020.114754.

[5] Stagnaro, C., Amenta, C., Di Croce, G., and Lavecchia, L. (2020). Managing the liberalization of Italy's retail electricity market: A policy proposal. Energy Policy, 137, 111150, 1-6. https://doi.org/10.1016/j.enpol.2019.111150.

[6] Safarzadeh, S., Rasti-Barzoki, M., and Hejazi, S.R. (2020). A review of optimal energy policy instruments on industrial energy efficiency programs, rebound effects, and government policies. Energy Policy, 139, 111342, 1-25. https://doi.org/10.1016/j.enpol.2020.111342.

[7] Austvik, O.G., & Rzayeva, G. (2017). Turkey in the geopolitics of energy. Energy Policy, 107, 539-547. https://doi.org/10.1016/j.enpol.2017.05.008.

[8] Kulińska, E., & Gruszka, M. D. (2019) Green cities- problems and solutions in Turkey. Transportation Research Procedia, 39, 242-251. https://doi.org/10.1016/j.trpro.2019.06.026.

[9] Gençyılmaz, O., & Seçkin, G. (2020). Determination of Animal Source Biogas Potential of Çankırı Province. International Journal of Life Sciences and Biotechnology, 3(3), 325-341. https://doi.org/10.38001/ijlsb.756288.

[10] Rawat, I., Ranjith Kumar, R., Mutanda, T., and Bux, F. (2011). Dual role of microalgae: Phycoremediation of domestic wastewater and biomass production for sustainable biofuels production. Applied Energy, 88(10), 3411-3424. https://doi.org/10.1016/j.apenergy.2010.11.025.

[11] Kumaş, K., Temiz, D., Akyüz, A. Ö., and Güngör, A. (2019). Biomass to Energy: The Potential of Biogas in Turkey and World, Mesleki Bilimler Dergisi, 8 (2), 64-69. https://dergipark.org.tr/tr/pub/mbd/issue/50202/568785.

[12] Zabed, H.M., Akter, S., Yun, J., Zhang, G., Zhang, Y., and Qi, X. (2020) Biogas from microalgae: Technologies, challenges and opportunities. Renewable and Sustainable Energy Reviews,117, 109503,1-21. https://doi.org/10.1016/j.rser.2019.109503.

[13] Abdeshahian, P., Lim, J. S., Ho, W. S., Hashim, H., and Lee, C.T. (2016). Potential of biogas production from farm animal waste in Malaysia. Renewable and Sustainable Energy Reviews, 60, 714–723. https://doi.org/10.1016/j.rser.2016.01.117.

[14] Taşova, M. (2017). Determination of Biogas Production Potential of Poultry Wastes: Tokat Province Example. Kafkas University Institute of Natural and Applied Science Journal, 10(2), 296-303. https://dergipark.org.tr/tr/pub/kujs/issue/33872/344577.

[15] Doruk, İ., & Bozdeveci, A. (2017). Determination of animal resource wastes from Biogas Potential in Rural Areas of Denizli. Iğdır Unıversity Journal of the Institute of Science and Technology, 7(3),181-186. https://dergipark.org.tr/tr/pub/jist/issue/34626/389934.

[16] Meyer, A.K.P., Ehimen, E.A., and Holm-Nielsen, J. B. (2018). Future European biogas: Animal manure, straw and grass potentials for a sustainable European biogas production. Biomass and Bioenergy, 111, 154–164. https://doi.org/10.1016/j.biombioe.2017.05.013.

[17] Kandemir, S.Y., & Açıkkalp, E. (2019) Investigation of Biogas Potential of Animal Wastes in Bilecik. BSEU Journal of Science, 6 (1),104-108. https://doi.org/10.35193/bseufbd.567938

[18] Can, A. (2020). The statistical modeling of potential biogas production capacity from solid waste disposal sites in Turkey. Journal of Cleaner Production, 243, 118501,1-13. https://doi.org/10.1016/j.jclepro.2019.11850.

[19] Çağlayan, G. H. (2020). Investigation of Biogas Potential of Cattle and Sheep Waste in Eastern Anatolia Region. Turkish Journal of Agricultural and Natural Sciences, 7(3), 672–681. https://doi.org/10.30910/turkjans.699879.

[20] Ay, Ö. F., & Kaya, A. (2020). Determination of Biogas Potential of Kahramanmaraş Province Using Different Models. Journal of Agricultural Faculty of Bursa Uludag University, 34(2), 351-364. https://dergipark.org.tr/tr/pub/bursauludagziraat/issue/57889/723957.

[21] Aslan, M., Ulum, T., and Türkmenler, H. (2021). An Evaluation on Dete rmination of Renewable Energy Potential of Adıyaman Province. Fırat Üniversitesi Müh. Bil. Dergisi, 33(1), 263-274. https://doi.org/10.35234/fumbd.791647.

[22] Kurnuç Seyhan, A., & Badem, A. (2021). Biogas plant scenarios for evaluating biogas potential from animal waste of Erzincan province Gümüşhane University Journal of Science and Technology Institute, 11 (1): 245-256. https://doi.org/10.17714/gumusfenbil.743724.

[23] Kizilaslan, H., & Onurlubas, H. E. (2010). Potential of production of biogas from animal origin waste in Turkey (Tokat Provincial Example). Journal of Animal and Veterinary Advances, 9(6), 1083-1087. https://doi.org/0.3923/javaa.2010.1083.1087

[24] Karaman, S., Avan, H., and Gökalp, Z., (2015). Livestock Waste-Based Biogas Energy Potential of Tokat Province and Possible Implementations. 2nd International Conference on Sustainable Agriculture and Environment (pp.1-7). Konya, Turkey

[25] Avan, H., & Karaman, S. (2016). Assessment of Biogas Production Potential of Livestock Wastes in Tokat Province by Geographic Information Systems (GIS) Technologies, Journal of Agricultural Faculty of Gaziosmanpasa University, 33 (1), 25-32. http://dx.doi.org/10.13002/jafag903

[26] Karaman, S., Avan, H., and Gökalp, Z. (2016). Tokat İlinin Hayvansal Atık Kaynaklı Biyogaz Enerjisi Potansiyeli ve Uygulanabilirliği. Bahri Dağdaş Hayvancılık Araştırma Dergisi, 4(2), 11-19. https://dergipark.org.tr/tr/pub/bdhad/issue/35005/388362

[27] Dilmaç, M., Özgüven, F.E., and Özgüven, M. M. (2015). Determination of Biogas and Electricity Generation Capacity in Tokat Domestic Wastewater Treatment Plant. Journal of Agricultural Faculty of Gaziosmanpasa University, 33 (2), 28-33. http://dx.doi.org/10.13002/jafag941

[28] Bayrak Işık, E.H., & Polat, F. (2018). The Biogas Potential That Can Be Obtained From The Animal Wastes of Tokat Province, Gaziosmanpasa Journal of Scientific Research,7(3), 93-100. https://dergipark.org.tr/tr/pub/gbad/issue/39083/402091

[29] Anonim2021a. https://tokat.csb.gov.tr/cografi-yapi-i-1211. (Accessed date: 25.06.2021).

[30] Türkiye İstatistik Kurumu, Hayvan İstatistik Raporu https://biruni.tuik.gov.tr/medas/?kn= 101&locale=tr (Accessed date: 25.06.2021).

[31] Ekinci, K., Kulcu, R., Kaya, D., Yaldız, O., Ertekin, C., and Ozturk, H.H. (2010). The Prospective of Potential Biogas Plants that can Utilize Animal Manure in Turkey. Energy Exploration & Exploitation, 28(3), 187-205. https://doi.org/10.1260/0144-5987.28.3.187.

[32] Yağlı H., & Koç, Y. (2019). Determination of Biogas Production Potential from Animal Manure: A Case Calculation for Adana Province. Çukurova University Journal of the Faculty of Engineering and Architecture, 34(3), 35-48. https://doi.org/10.21605/cukurovaummfd.637603.

[33] Kumaş, K., & Akyüz, A. (2021). Biogas Potential, CO_2 Emission and Electrical Energy Equivalent from Animal Waste in Burdur, Turkey. Academia Journal of Nature and Human Sciences, 7(1), 52-62. https://dergipark.org.tr/tr/pub/adibd/issue/60270/912682

[34] Anonim 2021b. https://www.epdk.gov.tr/Detay/Icerik/3-0-158/akaryak%C4%B1tfiyat (Accessed date: 25.06.2021)

[35] Anonim 2021c. https://www.enerjiportali.com/elektrik-fiyatlari-8/

[36] Türkiye İstatistik Kurumu Nüfus ve Demografi https://data.tuik.gov.tr/Kategori/GetKategori?p=nufus-ve-demografi-109&dil=1 (Accessed date: 25.06.2021)