IWEC 2024

4. International World Energy Conference

FULL TEXT BOOK

EDITORS
Mustafa Serdar GENÇ
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Şükrü Taner AZGIN
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December 06-08, 2024 / Kayseri, Türkiye

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İlgili makama;

4. ULUSLARASI DÜNYA ENERJİ KONGRESİ, 6-8 Aralık 2024 tarihleri arasında Kayseri'de 22 farklı ülkenin akademisyen/araştırmacılarının katılımıyla gerçekleşmiş, sözlü sunumları kongre kitaplarında yayınlanmıştır. Kongre 16 Ocak 2020 Akademik Teşvik Ödeneği Yönetmeliğine getirilen "Tebliğlerin sunulduğu yurt içinde veya yurt dışındaki etkinliğin uluslararası olarak nitelendirilebilmesi için Türkiye dışında en az beş farklı ülkeden sözlü tebliğ sunan konuşmacının katılım sağlaması ve tebliğlerin yarıdan fazlasının Türkiye dışından katılımcılar tarafından sunulması esastır." değişikliğine uygun düzenlenmiştir.

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08.12.2024 / Hall-2 / Online Session-3 / TSI Time - 15^{00}:17^{00}

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HEAD OF SESSION: Prof. Dr. Cengiz KARACA

Authors	Affiliation	Presentation title
Cemre YILMAZ **Prof. Dr. Dilek ERDİRENÇELEBİ**	Konya Technical University, Türkiye	A Physical Separation Methodology and its Effects on the Waste Animal Fat Content Prior to Biodiesel Production Process
Cemre YILMAZ **Prof. Dr. Dilek ERDİRENÇELEBİ**	Konya Technical University, Türkiye	The Effect of Reaction Time on Biodiesel Quality from Waste Animal Fat Using Ethanol
Assoc. Prof. Dr. Sedat BOYACI **Prof. Dr. Atılgan ATILGAN**	Kırşehir Ahi Evran University, Türkiye Alanya Alaaddin Keykubat University, Türkiye	Determination of Energy Potential of Plant Residues from Greenhouse Courgette Cultivation
Assoc. Prof. Dr. Sedat BOYACI **Prof. Dr. Atılgan ATILGAN**	Kırşehir Ahi Evran University, Türkiye Alanya Alaaddin Keykubat University, Türkiye	Investigation of the Effect of Energy Saving Measures on Heat Energy Requirement in Greenhouses
Mehmet Can ÖZTÜRK	Osmaniye Korkut Ata University, Türkiye	Effects of Wooden Structures on Energy Performance and Carbon Emissions
Yasir Tümay DOST **Assist. Prof. Dr. Cemil KOYUNOĞLU**	Yalova University, Türkiye	Biomass-Based Energy Production Plant Feasibility Study
Prof. Dr. Cengiz KARACA	Hatay Mustafa Kemal University, Türkiye	Energy Production Potential from Agricultural Residues in Kayseri Province
Prof. Dr. Cengiz KARACA	Hatay Mustafa Kemal University, Türkiye	The Potential of Biogas Production from Livestock Manure and Effects on Greenhouse Gas Reduction in Kayseri Province

THE POTENTIAL OF BIOGAS PRODUCTION FROM LIVESTOCK MANURE AND EFFECTS ON GREENHOUSE GAS REDUCTION IN KAYSERİ PROVINCE

Cengiz KARACA

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Abstract

The objective of this study is to determine the biogas amount and energy value of biogas produced from livestock manure in Kayseri province and its effects on greenhouse gas emissions (GHG). For this purpose, biogas potential was calculated considering the number of cattle, broiler chickens and laying hens in the province. According to 2023 data, there are approximately 433.3 thousand cattle, 220 thousand broiler chickens and 3.62 million laying hens in Kayseri province. These livestock in the province produce a total of 4.41 million tons of manure per year, including 4.31 million tons of cattle manure, 440 tons of broiler manure and 105.61 thousand tons of laying hen manure. From the usable amount of these manures, 76.4 Mm3 of biogas can be produced annually. The calorific value of the biogas produced from these manures is approximately 1,734.4 TJ and the amount of electricity that can be produced from this biogas is calculated as approximately 192.71 GWh_{el}. This value can supply 4.43% of the annual electricity consumption of Kayseri province (4,344 GWh_{el}). The calculated amount of manure and energy values are mapped by district. When the districts are ranked according to the amount of biogas production, the first three districts are Kocasinan (23.4%), Develi (13.1%) and Pınarbaşı (12.5%). Also, greenhouse gas emission reduction values were calculated to indicate the environmental benefits of biogas production from farm manure. It was determined that CO_2 equivalent emission reductions ranging between 902.62 - 1,285.82 thousand tons per year could be achieved by utilizing the calculated biogas potential.

Keywords: Biogas Potential, Livestock Manure, Greenhouse Gas Emission, Kayseri

KAYSERİ İLİNDE ÇİFTLİK GÜBRESİNDEN BİYOGAZ ÜRETİM POTANSİYELİ VE SERA GAZI AZALTIMINA ETKİLERİ

Özet

Bu çalışmanın amacı Kayseri ilinde çiftlik gübresinden üretilen biyogazın miktarını ve enerji değeri ile bunun sera gazı emisyonlarına (GHG) etkilerini belirlemektir. Bunun için ildeki sığır, et tavuğu ve yumurta tavuğu sayıları dikkate alınarak biyogaz potansiyeli hesaplanmıştır. Kayseri ilinde 2023 verilerine göre toplam yaklaşık 433.3 bin sığır, 220 bin et tavuğu ve 3.62 milyon yumurta tavuğu varlığı bulunmaktadır. İldeki bu hayvan varlığından yılda 4.31 milyon ton sığır gübresi, 440 ton et tavuğu gübresi ve 105.61 bin ton yumurta tavuğu gübresi olmak üzere toplam 4.41 milyon ton çiftlik gübresi elde edilmektedir. Bu gübrenin kullanılabilir miktarından yılda 76.4 Mm^3 biyogaz üretilebilir. Bu gübreden üretilen biyogazın ısıl değeri yaklaşık 1,734.4 TJ, bu biyogazdan üretilebilecek elektrik miktarı yaklaşık 192.71 GWh_{el} olarak hesaplanmıştır. Bu değerler Kayseri ilinin yıllık elektrik enerjisi tüketiminin (4,344 GWh_{el}) %4.43'ünü karşılayabilmektedir. Hesaplanan gübre miktarları ve enerji değerlerinin ilçelere göre dağılımı haritalanmıştır. Biyogaz üretim miktarına göre ilçeler sıralandığında ilk üç ilçe Kocasinan (%23.4), Develi (%13.1) ve Pınarbaşı (%12.5) şeklinde sıralanmıştır. Ayrıca çiftlik gübresinden biyogaz üretiminin çevresel faydalarını göstermek için sera gazı emisyon azaltımı değerleri hesaplanmıştır. Hesaplanan biyogaz potansiyelinin değerlendirilmesi ile yıllık 902.62-1,285.82 bin ton arasında değişen CO_2 eşdeğeri emisyon azaltımının sağlanabileceği belirlenmiştir.

Anahtar Kelimeler: Çiftlik Gübresi, Biyogaz Potansiyeli, Sera Gazı Emisyonu, Kayseri

INTRODUCTION

Energy plays an important role in the world's future. Energy is central to economic development, and there is a clear correlation between energy consumption and living standards. Energy sources are split into three categories: fossil fuels, renewable sources and nuclear sources (Karaca, 2015).

Increase in energy demand and the issues about current non-renewable energy resources led researchers to investigate alternative energy sources during the last two decades. Renewable energy resources draw attention all over the world because they are sustainable, improve the environmental quality and provide new job opportunities in rural areas (Isci and Demirer, 2007).

Biomass is a type of energy source with high carbon content. In fact, biomass is the only energy source that contains carbon within the renewable energy systems. Biomass can be either obtained directly from plants or indirectly from industrial, domestic, agricultural and animal wastes. To contribute to the energy demand of the country by using the national sources and to overcome the environmental problems, renewable energy sources should be considered as important inputs. Because biomass offers considerable flexibility in fuel supply in Turkey, due to the range and diversity of the fuels that can be produced, it should be considered as a renewable energy equivalent to fossil fuels. Biomass can be either used by direct combustion or mixed with an appropriate fossil fuel and be combusted or it can be converted into solid, liquid and gaseous fuels using conversion technologies such as fermentation to produce alcohols, bacterial digestion to produce biogas and gasification to produce a natural gas substitute (Dumanlı *et al*., 2007)

Biogas is a mixture of methane and carbon dioxide. It also has traces of hydrogen sulphide, ammonia, oxygen, hydrogen, water vapor etc., depending upon feed materials and other conditions. Biogas is generated by fermentation of cellulose rich organic matter under anaerobic conditions. In anaerobic conditions, the methane-producing bacteria become more active. Thus, the gas produced becomes rich in methane (NIIR, 2004).

Biogas is about 20 percent lighter than air and has an ignition temperature in the range of 650° to 750° C It is an odorless and colorless gas that burns with clear blue flame similar to that of LPG gas. Its calorific value is between 20-23 MJ/m^3 and burns with 60 percent efficiency in a conventional biogas stove (FAO, 1996).

Biogas is supplied to a variety of uses or markets, including electricity, heat and transportation fuels. In many countries, the gas is used for direct combustion in household stoves and gas lamps are increasingly common. However, producing electricity from biogas is still relatively rare in most developing countries. In industrialized countries, power generation is the main purpose of most biogas plants; conversion of biogas to electricity has become a standard technology. Leading countries in producing biogas include Germany, India and China (WEC, 2016).

The objective of this study was to determine the production potential of biogas from animal manure (cattle, broiler chicken and laying hens) and mapping in Kayseri with separate districts. For these purposes, biogas potential and its energy potential of animal manure were evaluated by ArcMap which is a geographical information system (GIS) program. The differences in data among the districts for seeing more clearly were created maps in GIS. A database was created within the GIS for Kayseri and its districts. The number of animals, calculated biogas potential, and its heating value in the province for the year 2023 were inputs to this database.

MATERIALS AND METHODS

Kayseri is a province of Turkey on the Central Anatolia Region. Kayseri province is divided into 16 districts, five of which are included in the municipality of central district. The districts of Kayseri province are Hacılar, İncesu, Kocasinan, Melikgazi, Talas, Akkışla, Bünyan, Develi, Felahiye, Özvatan, Pınarbaşı, Sarıoğlan, Sarız, Tomarza, Yahyalı and Yeşilhisar.

In the scope of this study, Turkish Statistical Institute's data on the number of livestock in 2023 were used. (TURKSTAT, 2024). The data used in the calculation of the biogas production potential were considered only cattle, broiler chicken and laying hen population. Because the attainability of animal manures, as determined by staying time in the barn, provides the highest value in a cattle farm (65%), broiler and laying hens farm (99%) (Başçetinçelik *et al*., 2006). Since the collectability and availability of manure from other livestock is very low, it was not used in the calculations.

Animal manure and biogas production calculation methods

The following methods were used to calculate the amount of animal manure and biogas production (Başçetinçelik *et al*., 2006; Karaca and Gürdil, 2019; Karaca, 2023).

$$AFM = NA \times MPPA/1000 \quad (1)$$

where;

AFM: amount of fresh manure per day (t/day)

NA: number of animals

MPPA: daily manure production per animal (kg/day)

The *MPPA* is 27.24 for cattle, 0.0476 for broiler and 0.08 for laying hens.

$$ASM = AFM \times SMR \quad (2)$$

where;

ASM: amount of daily solid manure (t/day)

SMR: solid manure ratio (%)

$$TSUM = ASM \times AOM \times AGP \quad (3)$$

where;

TUSM: annual total usable solid manure (t/year)

AOM: attainability of manure (%)

AGP: yearly growing period (day)

The AGP is 365 for dairy cattle and laying hens, 42 for broiler. Because, assuming that six cycles were produced in a year and that broilers are reared for up to six weeks of age, the yearly amount of broiler litter is calculated as 42 days.

$$AB = TSUM \times BCR_{SM} \quad (4)$$

where;

AB: amount of biogas (m^3/year)

BCR_{SM}*:* biogas conversion ratio of solid manure (200 m^3/t)

$$THV = AB \times HV \quad (5)$$

where:

THV: total heating value (MJ)

HV: heating value of unit biogas (22.7 MJ/m^3)

Electricity generation from biogas with a gas engine was calculated by the following equation:

$$EP = (THV \times EPE_{Net})/3.6 \quad (6)$$

where;

EP: electricity production (kWh_{el}/year)

EPE_{Net}*:* net electricity production efficiency of a biogas engine (40%) (Clarke Energy, 2021)

For each district, the calculated values, the total amount, the total biogas production, and the total energy potential of animal manures, were mapped using ArcMAP Software.

Calculation methods of GHG emission abatement from biogas system

GHG emission reduction effect of biogas production is based on two factors, ERMM (emission reduction by manure management) and ERES (emission reduction by energy substitution).

ERMM (emission reduction by manure management)

Under anaerobic conditions (in the absence of oxygen) the extrication of animal manure produces methane (CH_4) throughout storage. The most significant benefit of a biogas system is preventing the uncontrolled methane emissions. The following methods were used to calculate the CH_4 production from uncovered lagoon manure storage systems (IPCC, 2006; Guo Guo, 2010). This calculation was done according to annual average temperature.

$$CH_{4Manure} = EF_{(j)} \times N_{(j)} \quad (7)$$

where;

$CH_{4Manure}$: methane emissions from manure management (kg CH_4/year)

$EF_{(T)}$: emission factor for livestock category T, (kg CH_4/animal year)

$N_{(T)}$: the number of animal of livestock species/category T

T : species/category

$$EF_{(T)} = (VS_{(T)} \times 365) \times (B_{O(T)} \times 0.67) \times \left(\frac{MCF_{S,k}}{100}\right) \quad (8)$$

where;

$VS_{(T)}$: volatile solid for livestock category per day T, (kg dry matter/animal day)

$B_{o(T)}$: maximum methane production capacity (m^3/kg)

0.67 : conversion multiplier from m^3 CH_4 to kg CH_4

$MCF_{S,k}$: methane conversion parameters for manure management system S, by climate region k, (%)

$$ERMM_{CO_2} = CH_{4Manure} \times 27.2 \quad (9)$$

where;

$ERMM_{CO2}$: CO_2 emission reduction from manure management (kg CO_2 $year^{-1}$)

27.2 : Coefficient of the CO_2 equivalent of CH_4 (ERC Evolution, 2023).

ERES (emission reduction by energy substitution)

In rural regions biogas can use instead of solid fossil fuels and other biomass resources, because of high heat value (22.7 MJ/m^3). Therefore, the effect of CO_2 emission reduction of biogas system depends on the amount of fossil fuel replacement. The ERES is computed as GHG emissions produced by biogas-substituted fuel consumption. In this part, CO_2 emission reduction was calculated separately for each fossil fuel, which substituted instead of the estimated biogas potential. The following equations were used for this (Guo Guo, 2010)

$$ERES_{CO_2\,fuel} = FS \times CE_{fuel} \times EF_{CO_2\,fuel} \quad (10)$$

where;

$ERES_{CO2\,fuel}$: CO_2 emission reduction for substituted fuel, (kg/year)

FS : Fuel substitution value of biogas energy equivalent, (GJ/year)

CE_{fuel} : Combustion efficiency of fuels

$EF_{CO2\,fuel}$: CO_2 emission factors (kg/GJ)

$$FS = THV \times 0.6 \quad (11)$$

where;

THV : Total heating value of biogas potential (GJ/year)

0.6 : Combustion efficiency of biogas

FINDINGS AND DISCUSSION

Potential of animal manure, biogas production and energy value

Total animal manure potential of Kayseri in 2023 as a solid matter depending on the number of cattle, broiler and laying hens is presented in Table 1.

Table 1. Number of animals, and total amount of animal manure as fresh and solid matter

Animal	NA	AFM (t/year)	SMR (%)	ASM (t/year)	AOM (%)	TUSM (t/year)
Cattle	433,283	4,307,960	12.7	547,111	65	355,622
Broiler	220,000	440	12.7	264	65	261
Laying hens	3,616,779	105,610	25.0	26,402	99	26,138
TOTAL		**4,414,009**		**573,777**		**382,022**

According to Table 1, the total amount of usable solid manure, obtained from cattle, broiler and laying hens, is 382.02 thousand tons in 2023. Its distributions by the sources are cattle (93.09%), broiler (0.07%) and laying hens (6.84%).

The amount of biogas which can be obtained from the total animal manure as a solid matter along with the electricity generation from this biogas is presented in Table 2.

Table 2. The biogas potential and the energy potential of biogas in Kayseri

Animal	TUSM (t/year)	AB (m^3/year)	THV (GJ/ year)	EP (MWh_{el}/ year)
Cattle	355,622	71,124,412	1,614,524	179,392
Broiler	261	52,251	1,186	132
Laying hens	26,138	5,227,692	118,669	13,185
TOTAL	**382,022**	76,404,356	1,734,379	192,709

Table 2 shows that the total biogas potential of Kayseri is estimated at 76.40 million m^3/year. Furthermore, the heating value was calculated as 1,734.38 TJ/year. It has been determined that 192.71 GWh_{el} of electrical energy can be obtained annually by converting the whole biogas potential obtained from animal manure into electrical energy by means of a gas engine. These values can provide 4.43 % of Kayseri's annual electricity consumption (4,344 GWh_{el}).

Several studies carried out by Karaca (2016, 2017, 2018, 2019, 2023) in Afyonkarahisar, Hatay, Balıkesir, Adana, Ankara and Konya provinces, indicated that the total biogas derived from animal manure was 84.8, 14.5, 153.4, 26.3, 40.3 and 105.67 Mm^3/year respectively.

The potential of biogas from animal manure was determined in Samsun province. The total biogas potential was determined as 53.6 Mm^3/year in the province. (Karaca & Gürdil, 2019).

The biogas potential that can be obtained from animal fresh manure and solid manure, the calorific value of this biogas potential and the amount of electrical energy generated from this biogas are presented in Table 3 for the 16 districts of Kayseri for the year 2023.

Table 3. Amount of fresh manure, biogas potential and energy values in the districts of Kayseri

Districts	Fresh Manure (t/year)	Biogas Potential (m^3/year)	Heating Value (GJ/year)	Electrical Energy (MWh_{el})	Share in total (%)
Hacılar	64,625	1,069,186	24,271	2,697	1.4
İncesu	284,275	4,695,859	106,596	11,844	6.1
Kocasinan	917,197	17,871,685	405,687	45,076	23.4
Melikgazi	476,520	8,013,959	181,917	20,213	10.5
Talas	177,385	2,985,686	67,775	7,531	3.9
Akkışla	90,734	1,500,571	34,063	3,785	2.0
Bünyan	398,622	6,583,318	149,441	16,605	8.6
Develi	605,432	10,023,133	227,525	25,281	13.1
Felahiye	34,507	574,181	13,034	1,448	0.8
Özvatan	16,918	280,465	6,367	707	0.4
Pınarbaşı	578,857	9,557,560	216,957	24,106	12.5
Sarıoğlan	139,576	2,306,079	52,348	5,816	3.0
Sarız	102,823	1,702,421	38,645	4,294	2.2
Tomarza	262,915	4,340,824	98,537	10,949	5.7
Yahyalı	154,809	2,563,845	58,199	6,467	3.4
Yeşilhisar	108,816	2,335,583	53,018	5,891	3.1
TOTAL	**4,414,009**	**76,404,356**	**1,734,379**	**192,709**	**100**

Kocasinan districts have the highest potential with 17.87 Mm^3. This is followed by Develi, Pınarbaşı and Melikgazi districts with 10.02 Mm^3, 9.56 Mm^3 and 8.01 Mm^3, respectively.

The distribution of animal manure potentials in the provinces of Kayseri is given in Figure 1. In all districts, it is observed that in the majority of cattle manure. In addition, it has been determined that the amount of laying hens manure in Kocasinan and Yeşilhisar districts are higher than the other districts. It was determined that there was no broiler litter in all other provinces except Melikgazi (438.8 tons) district.

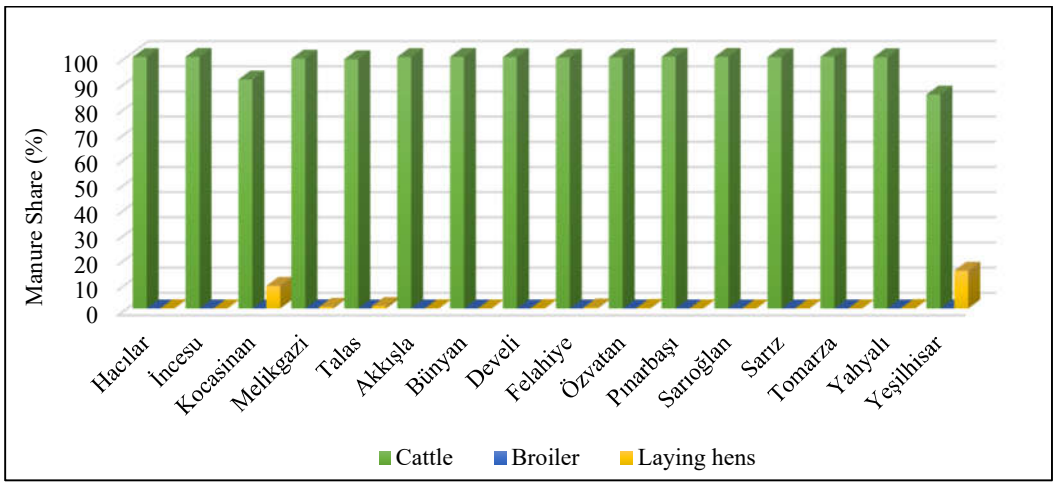


Figure 1. The distribution of animal manure potentials per district

The amount of biogas and their energy values were calculated separately for each district and were mapped. The distribution map of biogas potential and its energy values for 16 districts of Kayseri are given in Figures 2 and 3.

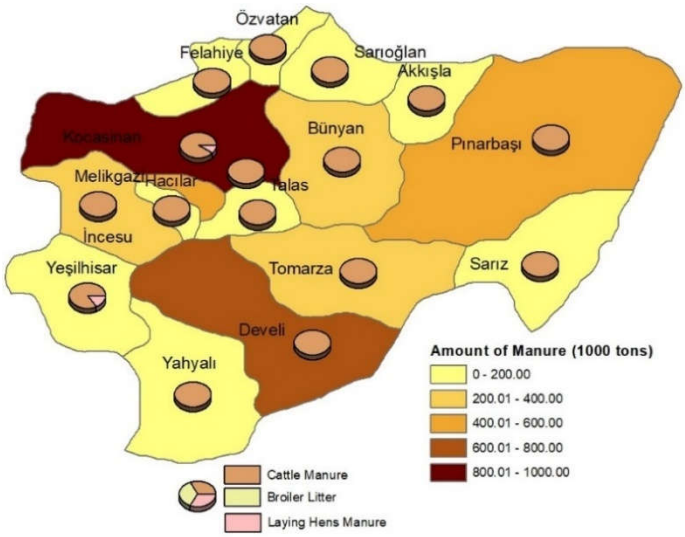


Figure 2. The distribution map of biogas potential in Kayseri

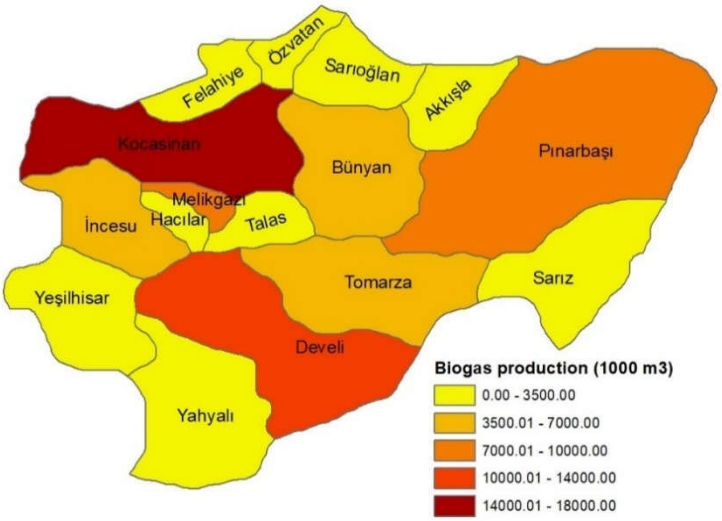


Figure 3. The biogas production potential map of Kayseri

These maps show that the biogas potential is concentrated in Kocasinan and Develi districts. This means that the biogas production plants can be established between these districts. This situation is an advantage in terms of raw material supply for biogas production plants.

GHG Emission Abatement from Biogas System

The result of this computation is called ERMM, which are shown in Table 4. The result of this computation can be observed as GHG emission reduction substituted by biogas, which is offered as $ERES_{CO2\ fuel}$ (Table 5). Total CO_2 emission abatement from manure biogas system is given in Table 7.

Table 4. CH_4 emission reduction from manure management in Kayseri

T	N	VS (kg/animal day)	B_o (m^3CH_4/kg)	MCF (%)	EF (kgCH_4/year)	CH_4 (kg/year)	$CO_{2\text{-eqv.}}$ (kg/year)
Cattle	433,283	2.8	0.13	76	67.6523	29,312,597	797,302,630
Broiler	220,000	0.01	0.36	1.5	0.0132	2,905	79,023
Laying hens	3,616,779	0.02	0.39	1.5	0.0286	103,485	2,814,780
Total						**29,418,987**	**800,196,433**

Methane emissions from manure are shown in Table 5. Cattle manures were the largest emitters of methane with 797,302 ton $CO_{2\text{-eqv}}$. It is seen that the cattle have the largest share of methane emission from farm manure in Kayseri with 99.6%.

Table 5. CO_2 emission reduction from energy substitution in Kayseri

Fuels	FS (GJ/year)	$EF_{CO2\ fuel}$ (kg/GJ)	CE_{fuel}	CO_2 emission (kg/year)
Firewood	1,040,627	112	0.24	485,626,085
Coal	1,040,627	94.6	0.40	246,108,362
Biogas	1,040,627	0	0.60	0
Natural gas	1,040,627	56.1	0.57	102,419,637

The CO_2 emissions from the conventional fuels that would be displaced by biogas were estimated. By replacing firewood with biogas, the total annual reduction of CO_2 emissions could reach 485.63 kt. Also, using this biogas as fuel eliminates methane emissions that would otherwise have come from the manure of cattle and poultry.

Table 6. Total CO_2 emission abatement from manure biogas system in Kayseri

ERMM $_{CO2\text{-eqv.}}$ (t/year)	Fuels	$ERES_{CO2\ fuel}$ (t/year)	Total CO_2 emission abatement (t/year)
800,196.43	Firewood	485,626.09	1,285,822.52
	Coal	246,108.36	1,046,304.80
	Natural Gas	102,419.64	902,616.07

GHG emission from manure can be reduced by 800.2 kt $CO_{2\text{-eqv}}$ by manure management with biogas systems. In addition, when fuel substitution is added, the total emission reduction can vary from 902.62 to 1,285.82 kt CO_2 equivalent according to the fuel to be substituted.

CONCLUSION AND RECOMMENDATIONS

In this study, it was detected that the biogas potential of Kayseri from cattle, broiler litter and laying hens manures was 76.4 Mm^3/year depending on the number of the animals in the years 2023.

Kocasinan districts have the greatest biogas potential. Develi, Pınarbaşı and Melikgazi districts follow this. If the whole biogas potential from animal manure is converted into electricity by means of a gas engine, approximately 192.71 GWh_{el}/year of electricity can be generated. This value can provide 4.43% of Kayseri's annual electric energy consumption (4,344 GWh_{el}).

At present in the province, there are 3 biogas plant investments with a total rate of 6 MW, which is under installation or newly operational. (Biyogazder, 2024). These biogas plants are BYZ Global and Mir Global with an installed capacity of 1.5 MW in Kocasinan district and Cod Enerji with an installed capacity of 3 MW in Pınarbaşı district. The installed power potential of biogas from animal manure in Kayseri province is around 27.5 MW. With the operation of the entire installed power potential of these three biogas plants, it is seen that almost all of the capacity (22%) can be utilized. This potential of Kayseri is not enough evaluated with the biogas plant currently installed.

The environmental benefits of biogas are often highlighted, as a valid and sustainable alternative to fossil fuels. Together with the reduction of greenhouse gas (GHG) emissions, biogas can enhance energy security, thanks to its high energetic potential. Catching and utilizing biogas is a powerful tool for GHG reduction, a major cause of human-induced climate change. GHG are reduced in two ways: first, the biogas produced is a source of renewable energy that can replace fossil fuels. Second, the capturing of biogas reduces methane, a very potent greenhouse gas that would otherwise be free to escape into the atmosphere.

In this study, the created maps were provided to visualize more clearly the differences of data from the districts. The mapping can raise public awareness and provide a reference point for policy makers and investors.

Turkey has a great potential in terms of renewable energy resources. The country needs to make more use of renewable energy sources in order to become energy independent. Therefore, biogas can be a very attractive choice for Turkey as it is a sustainable, environmentally friendly and domestic energy source.

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