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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Determination of Commercially Available Biogas Production Capacity and Effects on Methane Capture in Tekirdağ Province

Tekirdağ İlinde Ticari Olarak Kullanılabilir Biyogaz Üretim Kapasitesinin ve Metan Tutumuna Etkilerinin Saptanması

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Abstract

This research was carried out in farms which have 100 and more cows with commercial biogas production capacity, in 2019 in Tekirdağ. This is because it is stated that if the livestock enterprises have at least 100 animals, biogas production can be realized economically. The distribution and number of farms with this feature in districts were provided from Tekirdağ Food, Agriculture and Livestock Provincial Directorate. Biogas is generally used by converting it to heat and electrical energy. While it is used mostly for heating purposes in small farms, electricity and heat energy are provided in CHP units in large farms. Total methane production potential and energy value were calculated as 22 466 Nm^3day^{-1} and 81 756.4 $MWhyear^{-1}$, respectively. The highest methane production potential and energy value is in Muratlı district and the least is in Çerkezköy district. It was determined that 42 512.48 $MWhyear^{-1}$ useful heat energy and in CHP unit 28 614.17 $MWhyear^{-1}$ electricity energy and 19 784.65 $MWhyear^{-1}$additional heat energy could be obtained from methane produced by anaerobic fermentation. It is determined that 19 067.56 tons $CO_{2e}year^{-1}$ of methane will be released if the manure is stored outdoors. It was determined that methane emission could be reduced by 1 087.13 tons $CO_{2e}year^{-1}$ if the nitrogen was used in fermentation residues instead of the chemical fertilizer. Total methane retention in the use of methane for heat purposes will be 31 590.55 tons $CO_{2e}year^{-1}$. Methane emissions will be reduced by 12 522.99 tons $CO_{2e}year^{-1}$ when used for heat purposes, than the conditions in which the manure is stored outdoors. When methane is used in the CHP unit to provide electricity and heat energy, total methane retention is calculated as 38 467.6 tons $CO_{2e}year^{-1}$, and the decrease in methane emission is calculated as 19 400 tons $CO_{2e}year^{-1}$. In animal husbandry enterprises that are located in Tekirdağ and are commercially producing, evaluation of manure without long-term storage by means of anaerobic digestion is important in terms of meeting of the energy requirement and reducing methane emission and the government should encourage enterprises in this regard.

Keywords: Biogas, anaerobic digestion, methane emission, methane capture, emission factor

Özet

Bu araştırma, 2019 yılında Tekirdağ ilinde ticari anlamda biyogaz üretimi kapasitesine sahip 100 ve daha fazla büyükbaş hayvan bulunan işletmelerde yürütülmüştür. Bunun nedeni hayvancılık işletmelerinin en az 100 hayvana sahip olmaları durumunda, biyogaz üretiminin ekonomik olarak gerçekleşebileceğinin belirtilmesidir. Bu

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özellikteki işletmelerin ilçelere göre dağılımları ve sayıları, Tekirdağ Gıda Tarım ve Hayvancılık il müdürlüğünden sağlanmıştır. Biyogaz genel olarak ısı ve elektrik enerjisine dönüştürülerek kullanılmaktadır. Küçük işletmelerde daha çok ısı amaçlı kullanılırken büyük işletmelerde ise CHP ünitelerinde elektrik ve ısı enerjisi sağlanmaktadır. Toplam metan üretim potansiyeli ve enerji değeri sırasıyla 22 466 $Nm^3gün^{-1}$ ve 81 756.4 $MWhyıl^{-1}$ olarak hesaplanmıştır. En fazla metan üretim potansiyeli ve enerji değeri Muratlı ilçesinde, en az ise Çerkezköy ilçesindedir. Aneorobik fermantasyon ile üretilen metandan 42 512.48 $MWhyıl^{-1}$ yararlı ısı enerjisi, CHP ünitesinde 28 614.17 $MWhyıl^{-1}$ elektrik enerjisi ve 19 784.65 $MWhyıl^{-1}$ ek ısı enerjisi elde edilebileceği saptanmıştır. Gübrenin açıkta depolanması halinde 19 067.56 ton $CO_{2e}yıl^{-1}$ metan salınımı olacağı belirlenmiştir. Fermantasyon artıklarında bulunan azotun kimyasal gübre olarak kullanılması durumunda metan emisyonunun 1 087.13 ton $CO_{2e}yıl^{-1}$ azaltılabileceği tespit edilmiştir. Metanın ısı amaçlı kullanılmasında toplam metan tutumu 31 590.55 ton $CO_{2e}yıl^{-1}$ olacaktır. Metan emisyonu. ısı amaçlı kullanımda gübrenin açıkta depolandığı koşullara göre 12 522.99 ton $CO_{2e}yıl^{-1}$ azalacaktır. Metanın CHP ünitesinde elektrik ve ısı enerjisi sağlamak için kullanılması durumunda, toplam metan tutumu 38 467.6 ton $CO_{2e}yıl^{-1}$, metan salınımındaki azalma 19 400 ton $CO_{2e}yıl^{-1}$ olarak hesaplanmıştır. Tekirdağ'da bulunan ve ticari olarak üretim yapan hayvancılık işletmelerinde gübrenin uzun süre depolanmadan, anaerobik sindirim yoluyla değerlendirilmesi, hem enerji gereksiniminin bir kısmının karşılanması, hem de metan emisyonunun azaltılması açısından önemlidir ve devletin bu konuda işletmeleri teşvik etmesi gerekmektedir.

Anahtar Kelimeler: Biyogaz, anaerobik sindirim, metan salınım, metan tutumu, emisyon faktörü

1. Introduction

Biomass has an important potential as a renewable energy source. It can be converted into different types of energy by burning directly or by using thermo-chemical and biochemical conversion methods. Biogas is a combustible gas obtained by anaerobic digestion, which is one of the biochemical conversion methods, containing about 60% methane (CH_4) and about 40% CO_2. The specific energy value is between 5-7.5 $KWhNm^{-3}$ depending on the CH_4 ratio in the content of the biogas. The density of the biogas is about 1.22 $kgNm^{-3}$ (Rutz, 2015).

The energy value of biogas produced in the world in 2014 is around 352 780 GWh. The most biogas in the world is produced in China with an energy value of 91 490 $kWhyear^{-1}$. This country is followed by Germany with 86 460 $GWhyear^{-1}$, America with 73 830 $GWhyear^{-1}$ and Russia with 32 240 $GWhyear^{-1}$ (Anonymous, 2017). The energy value of biogas production in our country was around 2 706 $GWhyear^{-1}$ in 2014. Considering the production in the world, it is seen that the biogas production in our country is quite low. Only 10% of technical biogas potential of Turkey is evaluated (Anonymous, 2019a).

Especially, the emission of methane, which occurs as a result of animal production, is an important factor in the increase of greenhouse gas. Animal production causes 18% of the greenhouse gas emissions in the world. The production of animal manure and urine, which is the source of this emission, is around 13 billion tons per year in the world (Harkin, 1997). Capture of the methane of manure by biogas production plays an important role in the reduction of methane emissions from agricultural and urban wastes as well as energy recovery.

The simplest method of obtaining heat energy from biogas is to directly burn it in boiler systems. The efficiency of the biogas burning process varies between 75-85%. Boiler systems used to burn natural gas can also be used in biogas combustion by changing fuel-air mixture ratios. However, since biogas has lower energy content, higher flow rate is required. Therefore, the combustion unit also needs to be modified. Since low quality biogas is burned in boiler systems, the operating temperatures should be above the dew point to prevent condensation (Krich et al, 2005).

CHP (Cogeneration-combined Heat and Power) systems are used to obtain electricity and additional heat energy from biogas. While electrical energy is obtained with the generator connected to the gas engines used in these systems, the resulting heat energy is transferred to a fluid or air with the help of heat exchangers in the engine and exhaust outlet. In modern CHP units, heat losses are around 10-15%, electrical energy efficiency is 30-40%, and heat energy efficiency is around 40-50%. The overall efficiency of the CHP system can be 80% and above (Dueblein and Stainhauser, 2011). In addition, Recebli et al (2015) stated that if biogas is used for heat purposes, a gain of \$ 0.35/m^3 can be achieved compared to natural gas.

In recent years, it has become common to remove CO_2 from biogas and to obtain biomethane. In this improvement process, the energy value of the product is increased, and its transportation and storage become easier. In addition, it is possible to use it in gas engines or vehicles directly or with natural gas without any additional treatment. Biomethane is also used as a raw material in the chemical industry (Beil and Beyrich, 2013).

Biogas is a renewable energy source and is increasingly important in terms of providing sustainable energy. As a greenhouse gas, methane is 25 times stronger than CO_2. Therefore, in addition to the energy value of the biogas obtained in the biogas production process, methane capture is also important in terms of environmental effects. As a result of long-term storage of manure, 20-45% of the total methane potential is mixed into the atmosphere as a greenhouse gas emission (Dumont et al., 2013). If biomethane is used instead of fuel oil to obtain heat and electrical energy, 0.269 kg CO_2e/kWh and 0.454 kg CO_2e/kWh methane capture are provided, respectively. Also, 6.172 kg CO_2e/kg methane attitude can be achieved if nitrogen in fermentation wastes is used instead of chemical nitrogen fertilizer (DEEC, 2013; Frost and Gilkinson, 2010).

In a study conducted by Yaldız and Sözer (2005), it was understood that 100 animals for cattle, 150000 for chicken, 2000 for sheep and 5000 for turkey were economical size for biogas plants. In this study, it was aimed to determine the commercially biogas production potential from cattle manure in Tekirdağ province and to determine its effects on methane capture if this potential is used as an energy source.

2. Materials and Methods

2.1. Determination of the number of cattle farms in the region

25% of the gross production value of Tekirdağ province is due to animal production. There has been a significant increase in the number of bovine animals in the region in recent years (Anonymous, 2019b). The research was carried out by identifying bovine farms with 100 and more animals in Tekirdağ. 25% of the gross production value of Tekirdağ province is due to animal production.

2.2. Determination of methane production potential and energy value

The coefficients used to determine the methane production potential are given in *Table 1*. The value of *n* in *Table 1* means the number of animals.

Table 1. Coefficients used in the calculation of methane production potential (Lukahurst ve Bywater, 2015)

	Value	Unit
Production of Liquid cattle manure (PLM)	$55\ \frac{\text{kg}}{\text{day}-\text{animal}} * \text{n}$	kgday^{-1}
Total Solids (TS)	%13.9 PLM	kgday^{-1}
Volatile Solids (VS)	%11.62 PLM or %83 TS	kgday^{-1}
Methane Production (MP)	$0.15\ \frac{\text{Nm}^3}{\text{kg}-\text{VS}} * \text{VS}$	$\text{Nm}^3\text{day}^{-1}$
Specific Energy of Methane (SEM)	9.97	kWhNm^{-3}
Total Energy Value of Methane (TEV)	MP*SEM	kWhday^{-1}

2.3. Determination of useful heat energy that can be obtained from methane

It is assumed that 48% of the produced methane is used for heating the reactor, and the remaining 52% is used as useful energy (Lukahurst and Bywater, 2015). Useful potential for heat purposes of the methane was calculated with the help of the following equation:

$$EP_{heat} = 0.52 * TEV \qquad \text{(Eq.1).}$$

Where; EP_{heat}(kWhday^{-1}) is the useful heat energy potential of the methane.

2.4. Determination of the usage energy potential of the methane in the CHP unit

In use in the CHP unit, 90% of the energy obtained from methane turns into useful energy. It is accepted that 35% of this useful energy turns into electrical energy and 55% of it turns into heat energy (Rutz, 2015). It is assumed that 56% of the heat energy produced in the CHP unit is used for reactor heating (Lukahurst and Bywater, 2015).

The electrical energy potential of the methane is calculated with the formula below:

$$EP_{elk} = 0.35 * TEV \qquad \text{(Eq.2).}$$

Where; EP_{elk} (kWhday^{-1}) is the electrical energy potential of the methane in CHP unit.

The useful part of the heat energy generated in the CHP unit has been found with the help of the following equation:

$$EP_{CHP,heat} = 0.44 * (0.55 * TEV) \qquad \text{(Eq.3).}$$

Where; $EP_{CHP,heat}$ (kWhday^{-1}) is the useful heat energy potential of the methane in CHP unit.

2.5. Methane emission and CO_2 equivalent in long term storage of the manure

The methane emission and CO_2 equivalent occurring in long-term storage of the manure are calculated by taking into account the values given in *Table 2*.

Table 2. Methane release in long-term storage (Lukahurst ve Bywater, 2015)

	Value	Unit
Methane emission in long-term storage (MEL_v)	%13 MP	Nm^3day^{-1}
Methane release in long-term storage (MEL_m)	0.715474 kg/Nm^3* MEL_v	$kgday^{-1}$
CO_2 equivalent of methane emission in long-term storage ($MELCO_{2e}$)	25* MEL_m	kg $CO_{2e}day^{-1}$

2.6. Determination of the methane capture if methane is used instead of Fuel Oil

As a result of converting the methane into heat and electrical energy, emission factors of CO_2 equivalent of the methane capture are given in *Table 3*.

***Table 3. Emission reduction factors** (DECC, 2013)*

Usage	EF	Unit
Heat energy	0.269	kg $CO_{2e}kWh^{-1}$
Electrical energy	0.454	kg $CO_{2e}kWh^{-1}$

CO_2 equivalent of total methane capture when obtaining heat energy from the methane was found with the following formula:

$$MC_{heat} = EF_{heat} * EP_{heat} \quad \text{(Eq.4).}$$

Where; MC_{heat} (Kg $CO_{2e}kWh^{-1}$) is the methane capture for using as heat energy, EF_{heat} is the emission factor of methane capture for heat energy.

CO_2 equivalent of total methane capture when usage of the methane in CHP system was found with the following formula:

$$MC_{el} = EF_{el} * EP_{el} \quad \text{(Eq.5).}$$

$$MC_{CHP,heat} = EF_{heat} * EP_{CHP,heat} \quad \text{(Eq.6).}$$

Where; MC_{el} and $MC_{CHP,heat}$ (Kg $CO_{2e}day^{-1}$) are the methane capture for obtaining electrical energy and heat from the methane.

2.7. Determination of the methane capture if the digested material is used instead of mineral fertilizer

As a result of using digested materials as fertilizer, emission factors of CO_2 equivalent of the methane capture are given in *Table 4* (Frost and Gilkinson, 2010).

Table 4. Methane capture in using of digested material as fertilizer

	Value	Unit
The amount of nitrogen in the slurry (ANS)	$0.286 \frac{kg}{day - animal} * n$	$kgday^{-1}$
Usable amount of nitrogen (UN)	0.36 ANS	$kgday^{-1}$
Amount of nitrogen available as fertilizer in digested material (FAM)	0.20 UN	$kgday^{-1}$
CO_2 equivalent of the methane capture (MC_{fer})	$6.172 \frac{kg\ CO_{2e}}{kg} * FAM$	kg $CO_{2e}day^{-1}$

2.8. Determination of the total methane capture

The total methane capture in using of methane for obtaining heat energy was calculated as below:

$$\sum MC_{heat} = MC_{heat} + MC_{fer} + MELCO_{2e} \quad \text{(Eq.7).}$$

The total methane capture in using of methane in CHP unit was calculated as below:

$$\sum MC_{chp} = MC_{el} + MC_{CHP,heat} + MC_{fer} + MELCO_{2e} \quad \text{(Eq.8).}$$

3. Results and Discussion

3.1. Current status of farms with having 100 or more cattle in Tekirdağ province

The distribution of farms with 100 and more cattle number in Tekirdağ in early 2019 by districts is given in *Table 5*. There are 77 farms in the city. The highest number of farms is in Malkara district with 19 and the minimum number of farms is in Çerkezköy district with 4. The number of cattle is less than 200 in 55% of the farms (Tan, 2018). The total number of animals in these farmers is 23 435.

Table 5. Distribution of farms and cattle number with more than 100 animals in Tekirdağ by districts

DISTRICTS	**Cattle Number**				**FARM NUMBER**	**CATTLE NUMBER**
	100>= and <200	200>= and <300	300>= and <400	400<=		
Çerkezköy	4	0	0	0	4	631
Çorlu	4	4	0	1	9	1 913
Ergene	5	2	0	0	7	1 104
Hayrabolu	7	1	0	1	9	3 153
Kapaklı	6	0	1	0	7	1 036
Malkara	16	0	2	1	19	3 416
Marmaraereğlisi	3	0	1	1	5	1 214
Muratlı	4	0	0	1	5	7 909
Saray	4	2	0	0	6	1 061
Süleymanpaşa	2	1	2	1	6	1 998
TOTAL	**55**	**10**	**6**	**6**	**77**	**23 435**

3.2. Methane production potential and energy value

Distribution of liquid manure, organic solid and methane production potentials and energy values by districts are given in *Table 6*. There is a total of 1 288.9 tonsday^{-1} liquid fertilizer and 149.8 tonsday^{-1} organic solid matter productions in the city. The methane production potential was found to be 22 466 Nm^{3}day^{-1}. The energy value of the methane in biogas is 223.99 MWhday^{-1} (Tan,2018). It is observed that there is a potential to provide 81 756.4 MWh of energy in one year from the methane production in Tekirdağ province.

Table 6. Methane production potential and energy value

DISTRICT	PLM (tonsday^{-1})	VS (tonsday^{-1})	MP (Nm^{3}day^{-1})	TEV (MWhday^{-1})	TEV (MWhyear^{-1})
Çerkezköy	34.7	4.03	604.9	6.03	2 201.0
Çorlu	105.2	12.23	1 833.9	18.28	6 672.2
Ergene	60.7	7.06	1 058.3	10.55	3 850.8
Hayrabolu	173.4	20.15	3 022.6	30.14	11 001.1
Kapaklı	57.0	6.62	993.2	9.90	3 613.5
Malkara	187.9	21.83	3 274.7	32.65	11 917.3
Marmaraereğlisi	66.8	7.76	1 163.8	11.60	4 234.0
Muratlı	435.0	50.55	7 582.0	75.59	27 590.4
Saray	58.4	6.78	1 017.1	10.14	3 701.1
Süleymanpaşa	109.9	12.77	1 915.4	19.10	6 971.5
TOTAL	**1 288.9**	**149.77**	**22 466.0**	**223.99**	**81 756.4**

3.3. Useful energy potential in the use of methane for heat

The distribution of useful energy amounts to be obtained in the case of using methane to be produced with biogas produced in Tekirdağ for heat purposes is given in *Table 7*. There is a potential for 116.47 MWhday^{-1} of energy use throughout the province in use for heat purposes. The annual potential is 42 512.48 MWh.

Table 7. Useful heat energy potential of methane

DISTRICTS	EP_{heat} (MWhday^{-1})	EP_{heat} (MWhyear^{-1})
Çerkezköy	3.14	1 144.67
Çorlu	9.51	3 470.30
Ergene	5.49	2 002.72
Hayrabolu	15.67	5 719.73
Kapaklı	5.15	1 879.37
Malkara	16.98	6 196.83
Marmaraereğlisi	6.03	2 202.27
Muratlı	39.31	14 347.39
Saray	5.27	1 924.72
Süleymanpaşa	9.93	3 624.49
TOTAL	**116.47**	**42 512.48**

3.4. Useful energy potential in the use of methane in the CHP unit

In case the methane production potential is used to obtain electrical energy in the CHP unit, there is 28 614.17 MWhyear^{-1} electrical energy and 19 784.65 MWhyear^{-1} heat energy potential throughout the province. Total useful energy potential in the CHP unit is 48 398.82 MWhyear^{-1} (*Table 8*).

Table 8. Useful energy potential in the CHP unit

DISTRICTS	EP_{el} ($MWhday^{-1}$)	$EP_{CHP,heat}$ ($MWhday^{-1}$)	Total ($MWhday^{-1}$)	Total ($MWhday^{-1}$)
Çerkezköy	2.11	1.46	3.57	1 303.16
Çorlu	6.40	4.42	10.82	3 950.80
Ergene	3.69	2.55	6.25	2 280.02
Hayrabolu	10.55	7.29	17.84	6 511.69
Kapaklı	3.47	2.40	5.86	2 139.59
Malkara	11.43	7.90	19.33	7 054.85
Marmaraereğlisi	4.06	2.81	6.87	2 507.20
Muratlı	26.46	18.29	44.75	16 333.96
Saray	3.55	2.45	6.00	2 191.22
Süleymanpaşa	6.68	4.62	11.31	4 126.34
TOTAL	**78.39**	**54.20**	**132.60**	**48 398.82**

3.5. Methane release and CO_2 equivalents in long-term storage of manure

Methane emission values and their CO_2 equivalents are given in Table 9 if the manure is stored for a long period of time without being evaluated as biogas. 2 089.60 $kgday^{-1}$ of methane is emitted throughout the city and its CO_2 equivalent is 52.24 tons $CO_{2e}day^{-1}$. The CO_2 equivalent of the annual methane emission is 19 067.56 tons CO_{2e}.

Table 9. Methane release in long-term storage of manure

DISTRICTS	MEL_m ($kgday^{-1}$)	$MELCO_{2e}$ ($tonsday^{-1}$)	$MELCO_{2e}$ ($tonsyear^{-1}$)
Çerkezköy	56.26	1.41	513.40
Çorlu	170.57	4.26	1 556.49
Ergene	98.44	2.46	898.25
Hayrabolu	281.14	7.03	2 565.39
Kapaklı	92.38	2.31	842.93
Malkara	304.59	7.61	2 779.38
Marmaraereğlisi	108.25	2.71	987.75
Muratlı	705.21	17.63	6 435.05
Saray	94.60	2.37	863.27
Süleymanpaşa	178.15	4.45	1 625.64
TOTAL	**2 089.60**	**52.24**	**19 067.56**

3.6. Methane capture in using of digested materials instead of mineral fertilizer

If digested materials are evaluated as mineral fertilizers, CO_2 equivalents of methane capture are given in *Table 10.* The amount of nitrogen of the liquid fertilizer (ANS) that emerges in the farms is 6 702.4 $kgday^{-1}$. The amount of nitrogen (UN) suitable for use by bacteria in liquid fertilizer was calculated as 2 412.9 $kgday^{-1}$, and the amount of nitrogen that could be used as mineral fertilizer (FAM) was 482.6 $kgday^{-1}$. If digested materials are evaluated as the mineral fertilizer, 2 978.4 kg $CO_{2e}day^{-1}$ and 1 087.13 tons $CO_{2e}year^{-1}$ methane capture will be provided.

Table 10. Methane capture in using of digested materials instead of mineral fertilizer

DISTRICTS	ANS ($kgday^{-1}$)	UN ($kgday^{-1}$)	FAM ($kgday^{-1}$)	MC_{fer} ($kg\ CO_{2e}day^{-1}$)	MC_{fer} ($tons\ CO_{2e}year^{-1}$)
Çerkezköy	180.5	65.0	13.0	80.2	29.27
Çorlu	547.1	197.0	39.4	243.1	88.74
Ergene	315.7	113.7	22.7	140.3	51.21
Hayrabolu	901.8	324.6	64.9	400.7	146.27
Kapaklı	296.3	106.7	21.3	131.7	48.06
Malkara	977.0	351.7	70.3	434.2	158.47
Marmaraereğlisi	347.2	125.0	25.0	154.3	56.32
Muratlı	2 262.0	814.3	162.9	1005.2	366.89
Saray	303.4	109.2	21.8	134.8	49.22
Süleymanpaşa	571.4	205.7	41.1	253.9	92.69
TOTAL	**6 702.4**	**2 412.9**	**482.6**	**2 978.4**	**1 087.13**

3.7. Total methane capture in the use of methane for heat

The methane capture that will be provided if the methane in the biogas produced in the farms is used only for the purpose of obtaining heat energy is given in *Table 11*. In the conversion of methane to useful heat energy, a total of 86.55 tons $CO_{2e}day^{-1}$ and 31 590.55 tons $CO_{2e}year^{-1}$ of methane capture are provided. In case the manure is not the long-term storage and converted into biogas in order to obtain heat energy by using instead of fuel oil, in addition to preventing the release of methane due to long-term storage, an additional 12 522.99 tons $CO_{2e}year^{-1}$ of methane capture will be provided.

Table 11. Total methane capture in using of the methane in order to obtain the useful heat energy

DISTRICTS	MC_{heat} ($tons\ CO_{2e}\ day^{-1}$)	MC_{fer} ($tons\ CO_{2e}\ day^{-1}$)	$MELCO_{2e}$ ($tons\ CO_{2e}\ day^{-1}$)	TOTAL ($tons\ CO_{2e}\ day^{-1}$)	TOTAL ($tons\ CO_{2e}\ year^{-1}$)
Çerkezköy	0.84	0.08	1.41	2.33	850.59
Çorlu	2.56	0.24	4.26	7.07	2 578.74
Ergene	1.48	0.14	2.46	4.08	1 488.20
Hayrabolu	4.22	0.40	7.03	11.64	4 250.27
Kapaklı	1.39	0.13	2.31	3.83	1 396.54
Malkara	4.57	0.43	7.61	12.62	4 604.79
Marmaraereğlisi	1.62	0.15	2.71	4.48	1 636.48
Muratlı	10.57	1.01	17.63	29.21	10 661.39
Saray	1.42	0.13	2.37	3.92	1 430.24
Süleymanpaşa	2.67	0.25	4.45	7.38	2 693.32
TOTAL	**31.33**	**2.98**	**52.24**	**86.55**	**31 590.55**

3.8. Total methane capture when using methane in the CHP unit

In the case of using methane produced in the biogas unit in order to obtain electrical energy and additional heat in the CHP unit, a total of 35.59 tons $CO_{2e}day^{-1}$ methane capture for electrical energy and 14.58 tons $CO_{2e}day^{-1}$ methane capture at additional heat recovery can be provided (*Table 12*). Total methane capture in the CHP unit has been calculated as 105.39 tons $CO_{2e}day^{-1}$ and 38 467.6 tons $CO_{2e}year^{-1}$. In addition to preventing the release of methane due to long-term storage, an additional 19 400 tons $CO_{2e}year^{-1}$ of methane capture will be provided in the CHP unit.

Table 12. Total methane capture in using of the methane in the CHP unit

DISTRICTS	MC_{el} (tons CO_{2e} day^{-1})	$MC_{CHP,heat}$ (tons CO_{2e} day^{-1})	MC_{fer} (tons CO_{2e} day^{-1})	$MELCO_{2e}$ (tons CO_{2e} day^{-1})	TOTAL (tons CO_{2e} day^{-1})	TOTAL (tons CO_{2e} $year^{-1}$)
Çerkezköy	0.96	0.39	0.08	1.41	2.84	1 035.8
Çorlu	2.91	1.19	0.24	4.26	8.60	3 140.1
Ergene	1.68	0.69	0.14	2.46	4.96	1 812.2
Hayrabolu	4.79	1.96	0.40	7.03	14.18	5 175.5
Kapaklı	1.57	0.64	0.13	2.31	4.66	1 700.6
Malkara	5.19	2.13	0.43	7.61	15.36	5 607.2
Marmaraereğlisi	1.84	0.76	0.15	2.71	5.46	1 992.7
Muratlı	12.01	4.92	1.01	17.63	35.57	12 982.3
Saray	1.61	0.66	0.13	2.37	4.77	1 741.6
Süleymanpaşa	3.03	1.24	0.25	4.45	8.99	3 279.6
TOTAL	**35.59**	**14.58**	**2.98**	**52.24**	**105.39**	**38 467.6**

4. Conclusions

This research has been carried out by considering 100 or more cattle capacity farms with commercial biogas production potential in Tekirdağ province. It is possible to summarize the results obtained in the research as follows;

- There are 77 farms with more than 100 cattle capacity in Tekirdağ province. There are 23 435 cattle in these farms. The number of animals in approximately 71% of these farms is below 200.
- In these farms, a total of 470 457.6 $tonsyear^{-1}$ liquid manure and 54 667.2 $tonsyear^{-1}$ organic solid materials are produced. Methane production capacity of these manure has been calculated as 22 466 Nm^3day^{-1}. Energy value of this methane is 223.99 $MWhday^{-1}$ and 81 756.4 $MWhyear^{-1}$.
- If methane is used for heat purposes, 42 512.48 $MWhyear^{-1}$ of useful heat energy will be provided. When using methane in the CHP unit, 28 614.2 MWh_eyear^{-1} of electrical energy and 19 784.7 $MWhyear^{-1}$ of additional heat will be provided.
- Instead of long-term storage of manure, 12 525.6 tons $CO_{2e}year^{-1}$ less methane emission will be achieved in the use of methane production for heat purposes and 19 400 tons $CO_{2e}year^{-1}$ when used in the CHP unit.

As seen in this research, it is determined that if biogas is obtained from the cattle manure that occurs in the farms in Tekirdağ province, there will be a significant amount of energy gain and the methane emission will decrease significantly. Many countries, especially Germany, are supporting farmers to turn to biogas production regardless of farm size, taking into account the important contributions of anaerobic fermentation to the methane attitude rather than obtaining energy from biogas. In our country, only 10% of the technical biogas potential is used (Yaldız and Sezer, 2005; Tan, 2018). In our country, which is in an energy bottleneck, in order to spread biogas, which is a renewable energy source, the government must provide the support to enable enterprises to turn to biogas production without considering economic concerns. Considering the environmental contributions of biogas production, the importance of these supports increases.

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