



Araştırma Makalesi/Research Article

## An Assessment of Biogas Production Potential from Animal Manures in Çanakkale

Sakine Özpınar<sup>1\*</sup>

<sup>1</sup>Agriculture Faculty, Çanakkale Onsekiz Mart University, Çanakkale, 17020 Turkey.

\*Corresponding author: sozpinar@comu.edu.tr

Geliş Tarihi: 08.10.2018

Kabul Tarihi: 23.10.2018

### Abstract

Population growth and technological advancement mean that human activities are now consuming increasingly higher levels of energy. This causes serious problems, such as depletion of fossil fuel resources. Renewable energy resources and technologies is a good solution to these problems. Livestock manure can be a viable alternative source of energy and is the best way to obtain sustainable biogas energy. This study reports on biogas production from livestock manure and considers the evaluation of the districts in Çanakkale province. Data were collected from available databases relating to district livestock farms and using statistical data on the number of livestock, the amount of produced manure and the volume of created biogas per kilogram of animal manure. The biogas production was calculated using a theoretical method. By using the livestock numbers from the last agricultural census (2017), biogas potential from the available livestock manure was  $1.77 \cdot 10^7 \text{ m}^3$  per year, 30.5% of which was obtained from heavy livestock (cattle, horse), 26.8% of it from light or small livestock (sheep, goat), and only 42.7% from poultry. Biga district had the greatest biogas production with 7.83 million  $\text{m}^3$ . The centre district had 1.64 million  $\text{m}^3$  biogas, followed by Yenice, Ezine, Lapseki and other districts (7-district) with 1.34, 1.30, 1.11 and 4.51 million  $\text{m}^3$ , respectively. Annually, biogas energy equivalence was approximately 425.3 million MJ and  $8.33 \cdot 10^7 \text{ kWh}$  electricity generation in all districts using livestock manure. The findings of this study indicate that the manure to produce biogas can be used as a source of sustainable renewable energy.

**Keywords:** Biomass production, Biogas, Livestock manure, Çanakkale.

### Çanakkale'de Hayvan Gübresinden Biyogaz Üretim Potansiyelinin Değerlendirilmesi

#### Öz

İnsan nüfusundaki artış ve teknolojiye olan gelişmelerle birlikte insan yaşamında oldukça yüksek bir enerji tüketimine gereksinim olduğu görülmektedir. İhtiyaç duyulan bu enerji özellikle sonlu enerji kaynağı olan fosil yakıtların tüketimi artırmakta ve bunların tükenmesine yol açmaktadır. Dolayısıyla sonlu enerji kaynağı olan fosil yakıtların yerini alacak ve onlardan sağlanan enerjiyi karşılayacak yenilenebilir enerji kaynakları önemli bir kaynağı temsil etmektedir. Bu anlamda hayvan gübresi önemli bir yenilenebilir enerji kaynağı olup, özellikle fosil kaynaklardan üretilen enerjilerin yerine alabilecek özelliğe sahiptir. Bu çalışmada Çanakkale ilinde önemli bir üretim potansiyeline sahip büyükbaş, küçükbaş ve kümes hayvanlarının varlığı ve bunların gübre atıklarından elde edilecek biyogaz ve enerji değeri teorik hesaplama yöntemlerinden yararlanılarak belirlenmiştir. Sonuç olarak, ilde yılda yaklaşık olarak biyogaz potansiyel varlığının  $1.77 \cdot 10^7 \text{ m}^3$  olduğu, bunun yaklaşık %30.5'nin at dahil olmak üzere büyükbaş hayvan gübresinden, %26.8'nin küçükbaş ve %42.7'sinin ise kümes hayvanlarından karşılandığı ve 7.83 milyon  $\text{m}^3$  ile Biga ilçesinin ilk sırada yer aldığı saptanmıştır. Bu durum merkez ilçede 1.64 milyon  $\text{m}^3$  ve bunu 1.34 ile Yenice, 1.30 ile Ezine, 1.11 ile Lapseki ve 4.51 milyon  $\text{m}^3$  ile diğer yedi ilçenin izlediği ortaya konulmuştur. İl bazında yıllık olarak elde edilen biyogazın enerji eşdeğerinin 425.3 milyon MJ ve bunda elektrik üretim eşdeğerinin ise  $8.33 \cdot 10^7 \text{ kWh}$  olduğu saptanmıştır. Dolayısıyla bu sonuçlar ele alındığında; hayvan üretim potansiyelinin yüksek olduğu Çanakkale ilinde hayvan gübresinden elde edilecek biyogazın sürdürülebilir enerji kaynağı bakımından önemli bir yere sahip olduğu kanısı ortaya çıkmıştır.

**Anahtar Kelimeler:** Biokütle üretimi, Biyogaz, Hayvan gübresi, Çanakkale.

### Introduction

Global energy resource has been continuously dominated by fossil fuels over the years with 81.0% of the world's energy resource being met through fossils (Anonymous, 2018). World's energy requirement is anticipated to further increase because of increasing population, economic and technologic development. The limitation of fossil fuel resources needs special attention to be paid to reduction of fossil energy use. Renewable energy sources have attracted the attention of researchers and consumers because of the exponential increase in energy requirement and concern to reduce the



environmental pollutants generated from fossil fuels. Developments in renewable energy technologies have begun to make these sources a real alternative because of their lower investment and delivery costs as well as more efficient utilization of these resources. The energy requirement in our country is also increasing rapidly by increasing the population and their lifestyle. On the other hand, the renewable energy does not have wide application either in the country because of technological and economic factors although the development of industrial and residential areas has caused a high requirement of electrical power. The total electric production reached approximately 824 GWh at the beginning of 2018 while 68.70% is provided from fossil sources such as natural gas, coal. However, wind sources are a promising alternative energy which is lies in northern and western part of country, at locations along the Aegean and Marmara Sea coasts. Çanakkale is one of the provinces that are located in Coast of Marmara Sea. It has a geographical area suitable for wind, geothermal, solar and hydro energy investments with 47 active power plants which are 33-wind, 8-coal, 2-geothermal, 2-hydroelectric, 2-solar (Table 1). The total installed capacity of these plants is 6282 MW, meets country 11.36% (55320 MW) of the total energy production from renewable sources (Anonymous, 2018) (Table 1). First wind project of 10.20 MW was installed in 2000 Bozcaada island and now 9 wind power projects with a cumulative capacity of 249 MW are operational in wind corridors in Çanakkale. 13 wind power projects are under construction with an expected Commercial Operation Date (COD) in 2018 with 138 MW. Along with that 32 wind projects with a cumulative capacity of 1012 MW in province are at different stages of project development and expected to obtain COD in 2018-2019. There are 41 geothermal resources in 14-different area with 23-96.2 °C surface temperature range in Çanakkale, but two of them are operated in Tuzla village in Ayvacık district with 7.5 MW and 8.0 MW installed power, 96.2 and 174 °C surface and deep temperature, respectively. Biogas is one of source within renewable energy and produced from agriculture biomass. It is the first energy form applied by man and is still the most important heat supplier in developing countries as well as in our country. It can be produced and used in many countries, especially in rural areas to meet daily necessities. In our country, biogas is not exactly used although it has actually high agriculture potential. The use of waste in the production of heat by burning is more common and energy produced from crop residues and animal manure are still used in rural parts of in the country to meet the energy requirement like developing countries. In addition, the crop residues and animal wastes such as manure that are not used in biogas production are mostly either directly burned or given as manure fertilizer to agricultural land. The benefit of increasing animal waste, especially manure, directly in the field is stated to be 2.66 times higher, while the benefit of obtaining biogas and bio-fertilizer will be 4.15 times higher. Livestock manure (heavy and small livestock) is one of the main sources available for biogas production potential 518 billion m<sup>3</sup> per year in our country (Anonymous, 2018) while poultry has become the most common growing stock of livestock in the last 15 years.

In Çanakkale, livestock farming has received increasing interest from farmers due to growing demands for animal products by 30% population growing. The increased population of the livestock in the province has caused an enhanced production of farm animal manure, resulting in the difficulty with the disposal of a large amount of manure. Considering the distribution of the number of the animals by districts, the poultry has high population, especially in Biga district (Table 3). Similarly, cattle breeding is high in Biga and Yenice while sheep and goat are in Ezine, Gökçeada and Ayvacık. However, no study has so far been carried out to evaluate the potential of production using manure obtained from animals in Çanakkale. Due to growing animal husbandry and the enormous production of animal manure per year, it is necessary to make the recommendation of the appropriate management for the livestock manures. The study aims to evaluate the potential of biogas energy generation and its energy equivalent from the livestock manure produced from livestock in all districts of province.



Table 1. Current renewable power plants and their capacity at different stages of development in Çanakkale

Type	Plants	Location	Project	Çanakkale (MW)	Turkey (MW)	(%)**		
Wind	Installed	Bozcaada	Bozcaada RES	10.2				
		Biga	İÇDAŞ Biga RES	60				
		Merkez	İntepe RES	30.4				
		Lapseki	Koru RES	50.0				
		Ezine	-	30.0				
		Merkez	SaRES	27.5				
		Ezine	Çamseki RES	20.8				
		Gelibolu	Burgaz RES	14.9				
		Ayvacık	AyRes	5.4				
		Total		249.2				
	Under construction	Gökçeada	Çahan RES	0.9				
		Gökçeada	Gökçe RES	0.9				
		Ezine	Kıvam RES	0.5				
		Merkez	Hasanoba RES	51				
		Gelibolu	G RES	5.0				
		Ezine	Yeşil RES	3.0				
		Çan	Tezyaparlar RES	2.0				
		Lapseki	Gelibolu 1 ve 2 RES	1.8				
		Lapseki	Nilüfer Belediyesi RES	0.9				
		Ezine	Kumburun RES	0.8				
		Lapseki	BHT RES	0.8				
		Ayvacık	Polante RES	0.8				
		Lapseki	Lapseki Belediyesi RES	0.5				
		Total		68.9				
	Licensed	Gelibolu	Saros RES	138.0				
		Lapseki	Üçpınar RES	99.0				
		Gelibolu	Gazi 9 RES	51.0				
		Gelibolu	Yeniköy RES	48.0				
		Merkez	Kocalar RES	26.0				
		Gelibolu	Maslaktepe RES	20.0				
		Gelibolu	Yeniköy RES	15.0				
		Ayvacık	Göztepe	3.0				
	Total		400.0					
	Pre-licensed	Merkez	Çanakkale RES	260.0				
		Ayvacık	Gülpınar RES	25.0				
		Gelibolu	Gelibolu RES	8.8				
		Total		293.8				
	Total			1012 (16.11)*			6927	14.61
	Coal			5240 (83.41)			17907	29.26
	Geothermal			15.5(0.25)			1028	1.51
	Hydro			13.5 (0.21)			27212	0.05
	Solar			1.2(0.02)			2246	0.05
	Total (general)			6282 (100.00)			55320	11.36

\*: Values in parentheses represent the share of province in total energy. \*\*: Share of total in Turkey to Çanakkale.

### Materials and Methods

The province of Çanakkale located in the northwest part of Turkey with latitude of 39° 30'N and longitude of 26° 80'E (10 m above sea level). It lies on both sides of the Dardanelles which connects the Marmara Sea to the Aegean Sea. Its shores touch both Europe (with the Gelibolu Peninsula) and Asia (with the Biga Peninsula). Annual rainfall average is 629 mm and average temperature is 15 °C while minimum and maximum is -5.8 °C and +38.8 °C, respectively. The rainiest months are November, December and January where the least rainy months are July, August and September. The rains are generally fallen 46% in winter, 25% in autumn, 22% spring and 7% in summer. There are generally windy most of the year with rate of humidity 72.6%. The total area for the wind energy plants that can be installed in Çanakkale province is about 2603 km<sup>2</sup>, with a wind



speed  $7.0 \text{ m s}^{-1}$  at a 50 m anemometer height (GMKA, 2017), but the wind speed is very high in Gallipoli peninsula, Bozcaada and Gökçeada with  $8\text{-}8.5 \text{ m s}^{-1}$  in west part. Province has annually 2836-hour year<sup>-1</sup> radiation time which is more than the country with 2741 hour. In province, total solar energy is  $1364.7 \text{ kWh m}^{-2}$  per year, but it is above Marmara region with  $1168 \text{ kWh m}^{-2}$  per year. Sunshine duration is 12-hour in the area per day while it is 10-hour in the Marmara region. The population socio-economic structure of the province is mainly based the agriculture and livestock farming as well as fishing and tourism. The livestock farming has considerable potential as an important part of agricultural and economy. In the province, total area is 993318 hectares with 33.4% (331633 hectares) arable area, 3.2% (31665 hectares) meadow-grassland, 52.9% (525580 hectares) forest and shrubbery 10.5% (104440 hectares) others such as settlement and unsuitable agriculture. The cereals cover the widest percentage (77.3%) in the total arable area under rainfed conditions. Cereals are mainly wheat (53.1%), barley (17.6%), sunflower (10.8%), rice (7.3%), oats (6.6%), maize (2.2%), rye (1.8%) and triticale (0.6%), and which are mainly cultivated in Bayramiç, Biga, Çan, and Yenice. Other leading agriculture crops are tomatoes, olives, and grapes. Olive is one of the main income which are grown in the coastal villages of Ayvacik and Ezine. Biga district is one of the most rapidly developing in terms of dairy farming followed by Yenice and Çan while Ezine, Bayramiç, Centre and Ayvacik are small livestock. The approach of this study is to consider the energy potential of livestock manure in the province, converting biogas to electricity using standard combustion system. With this purpose, information about the number of livestock (Table 2 and 3) was collected from the Statistical Institute of Turkey (TUIK, 2017), Food, Agriculture and Livestock Ministry of Turkey and previous literature. The retrieved information was categorized based on livestock's types, i.e. heavy (cattle, horse) and small (sheep and goat) livestock, poultry (chicken, turkey, duck, goose) per district for the year 2017. The total amount of the livestock manure can be calculated by multiplying the manure mass on the basis of effective livestock population, the rate of the annual animal manure to animal weight ( $RAW_i$ ) and the rate of collectable animal manure ( $RC_i$ ) those are taken from different sources in the scientific literature (Table 4) (ASABE, 2005; Daniel-Gromke et al., 2016; Matheri et al., 2018). The value of electric energy was taken as  $4.70 \text{ kWh per m}^3$  of biogas production (Acaroglu, 2007). It was used an equation (Abdeshahian et al., 2016) to obtain the amount of manure produced from each animal type (Table 2 and 3).

$$TM_i = \sum NA_i \times AW_i \times RAW_i \times RC_i \times DMC_i \quad (1)$$

where  $TM_i$  is the annual total dry manure (kg),  $NA_i$  is the number of animals for type animal  $i$  (Table 1, 2),  $AW_i$  is animal weight (kg) for type animal  $i$ ,  $i$  is the type of the animal and  $RAW_i$  is the coefficient of manure production related to weight of animal,  $RC_i$  is the rate of collectable manure for type animal  $i$ ,  $DMC_i$  is the rate of dry manure content (%). Total theoretical biogas potential from available animal manure has been calculated for each district of province (Table 4) according to equation 2 per year by using the biogas potential.

$$TBP_i = \sum TM_i \times BY_i \quad (2)$$

where  $TBP_i$  is the theoretical biogas production potential of livestock manure ( $\text{m}^3 \text{ year}^{-1}$ ),  $BY_i$  is the specific biogas production ( $\text{m}^3 \text{ tons}^{-1}$ ) ( $33, 58$  and  $78 \text{ m}^3 \text{ ton}^{-1}$  for cattle, small ruminants and poultry, respectively).

The amount of energy produced from biogas ( $\text{MJ year}^{-1}$ ) was calculated based on Equation 3:

$$E_{\text{biogas}} = \sum TBP_i \times ECB_i \quad (3)$$

where  $TBP_i$  represents the theoretical biogas production of livestock manure ( $\text{m}^3 \text{ year}^{-1}$ ),  $ECB_i$  is the coefficient of biogas content ( $\text{MJ m}^{-3}$ ) that is consider to be equal to  $24 \text{ MJ year}^{-1}$ .



Table 2. The number of heavy and small livestock in the study area

District	Cattle (*1000)	Horse (*1000)	Total		Sheep (*1000)	Goat (*1000)	Total	
			(*1000)	(%)			(*1000)	(%)
Centre	10575	124	10699	5.17	30695	34940	65635	9.42
Ayvacık	13810	261	14071	6.81	70350	26700	97050	13.93
Bayramiç	13600	213	13813	6.68	37520	33575	71095	10.20
Biga	61276	202	61478	29.74	59371	20370	79741	11.44
Bozcaada	11	6	17	0.01	825	399	1224	0.18
Çan	27531	59	27590	13.34	33225	12450	45675	6.55
Eceabat	872	22	894	0.43	10035	6004	16039	2.30
Ezine	13935	103	14038	6.79	74964	21634	96598	13.86
Gelibolu	9130	161	9291	4.49	33500	29975	63475	9.11
Gökçeada	1200	58	1258	0.61	53760	21780	75540	10.84
Lapseki	13192	35	13227	6.40	25150	20630	45780	6.57
Yenice	40228	147	40375	19.53	28855	10133	38988	5.59
Total	205360	1391	206751	100.00	458250	238590	696840	100.00
Rate (%)		2.96				9.98		

Table 3. The number of poultry in the study area

District	Chicken (egg+broiler) (*1000)	Turkey (*1000)	Duck (*1000)	Goose (*1000)	Total		General Total	
					(*1000)	(%)	(*1000)	(%)
Centre	724600	1740	1410	1520	729270	12.00	805604	11.54
Ayvacık	13550	648	371	214	14783	0.24	125904	1.80
Bayramiç	123637	244	261	198	124340	2.05	209248	3.00
Biga	4487850	410	4280	2260	4494800	73.94	4636019	66.40
Bozcaada	465	40	15	35	555	0.01	1796	0.03
Çan	58280	145	150	44	58619	0.96	131884	1.89
Eceabat	9400	300	160	65	9925	0.16	26858	0.38
Ezine	222450	560	570	500	224080	3.69	334716	4.79
Gelibolu	27650	390	850	470	29360	0.48	102126	1.46
Gökçeada	3050	2120	60	540	5770	0.09	82568	1.18
Lapseki	363700	186	140	145	364171	5.99	423178	6.06
Yenice	21174	1450	290	195	23109	0.38	102472	1.47
Total	6055806	8233	8557	6186	6078782	100.00	6982373	100.00
Rate (%)			87.06				100.00	

Table 4. Weight and manure production coefficient for different animals

Animal type	Animal weight (AW <sub>i</sub> ) (kg)	The rate of the annual animal manure to animal weight (RAW <sub>i</sub> )	Manure production of one animal per year (kg)	The ratio of collectable animal manure (RC <sub>i</sub> )	The rate of dry manure content (DMC <sub>i</sub> ) (%)	The amount of biogas producibile from 1 tons of manure (m <sup>3</sup> year <sup>-1</sup> )
Cattle	500-720 (610.0)	2.6	1586	0.50	13.95	33
Horse	410	2.6	1066	0.50	27.50	33
Sheep	50-90 (70.0)	3.36	235.20	0.50	31.71	58
Goat	50-90 (70.0)	3.36	235.20	0.50	29.41	58
Poultry (egg)	2.0	4.4	8.80	0.99	25.00	78
Poultry (broiler)	3.8	4.4	16.50	0.99	25.88	78
Turkey	3.5	3.32	11.62	0.26	25.53	78
Ducks and goose	6.5	4.4	28.60	0.22	28.18	78

## Results and Discussion

The amount of collectable wet and dry manure by livestock according to 2017 data are given in Table 4 and 5. Biogas heating and electricity generation of livestock manure are given in Table 6, 7, 8,



respectively. In annual, the majority of wet manure includes heavy livestock (cattle and horse) with  $163592 \times 10^3$  tons (47.75%) related to the highest population, followed by poultry with  $97066 \times 10^3$  tons (28.33%) and small livestock with  $81948 \times 10^3$  (23.92%) tons (Table 4). The highest dry manure was found for small livestock with  $25340 \times 10^3$  tons (34.54%) followed poultry with  $25,103 \times 10^3$  tons (34.22%), heavy livestock (cattle and horse) with  $22922 \times 10^3$  tons (31.24%) (Table 5) because of the rate of dry manure content (Table 3). In contrast, it indicated that by Özcan et al. (2015) heavy livestock (cattle and buffalo) contributed to 79.8% of animal manure followed by contribution of small livestock and poultry with 6.6% and 13.6%, respectively. In this study, poultry have significantly higher contribution to biogas production by 42.72% than cattle by 30.46% and small livestock by 26.82% (Table 6), which is due to the highest unit manure coefficient with 25.88 in poultry comparing to cattle manure coefficient by 13.95 (Table 3). This indicates the poultry wealth should be supported not only for the economic development of the province but also biogas utilization of its manure as a renewable energy source. Horse is not generally included in the most of the biogas potential studies, is another noteworthy biogas source in the province, although its population is not as high as cattle, even less than small livestock and poultry. These indicate horse manure should also be taken into consideration as biogas source with the rate of dry manure content by 27.50 (Table 3). In a study concluded that the potential of biogas produced from cattle manure contributed to 68% of total biogas whereas small livestock and poultry accounted as 5% and 27%, respectively (Avcioglu and Türker, 2016). They found the distribution of animal waste biogas is 95%, 4% and 1% cattle, small livestock and poultry, respectively. Total biogas is calculated about  $1.77 \times 10^7 \text{ m}^3$  per year (Table 6) and generates an electrical energy of 83 GWh per year (Table 8).

Table 4. Annual total collectable wet livestock manure according to the data in 2017

District	Heavy livestock (cattle+horse)		Small livestock (sheep+goat)		Poultry (chicken+turkey+duck+goose)		Total	
	(1000 tons)	(%)	(1000 ton)	(%)	(1000 tons)	(%)	(1000 tons)	(%)
Centre	8452	30.35	7719	27.72	11674	41.93	27845	100.00
Ayvacık	11090	49.01	11413	50.44	124	0.55	22627	100.00
Bayramiç	10898	51.55	8361	39.55	1881	8.90	21140	100.00
Biga	48700	37.22	9378	7.17	72758	55.61	130835	100.00
Bozcaada	12	7.43	144	89.77	4	2.80	160	100.00
Çan	21864	78.17	5371	19.20	734	2.63	27969	100.00
Eceabat	703	26.30	1886	70.55	84	3.15	2674	100.00
Ezine	11105	42.69	11360	43.67	3547	13.64	26013	100.00
Gelibolu	7326	48.71	7465	49.63	250	1.66	15041	100.00
Gökçeada	983	9.92	8884	89.71	37	0.37	9903	100.00
Lapseki	10480	48.42	5384	24.87	5780	26.71	21644	100.00
Yenice	31979	87.00	4585	12.47	192	0.52	36756	100.00
Total/Rate (%)	163592	47.75	81948	23.92	97066	28.33	342607	100.00

Table 5. Annual total collectable dry livestock manure according to the data in 2017

District	Heavy livestock (cattle+horse)		Small livestock (sheep+goat)		Poultry (chicken+turkey+duck+goose)		Total	
	(1000 tons)	(%)	(1000 tons)	(%)	(1000 tons)	(%)	(1000 tons)	(%)
Centre	1188	18.11	2353	35.87	3020	46.03	6561	100.00
Ayvacık	1566	30.44	3547	68.95	31	0.60	5144	100.00
Bayramiç	1536	33.52	2560	55.88	486	10.60	4582	100.00
Biga	6808	23.85	2919	10.22	18825	65.93	28551	100.00
Bozcaada	2	4.39	45	93.24	1	2.37	48	100.00
Çan	3054	62.18	1670	33.99	188	3.82	4912	100.00
Eceabat	100	14.19	582	82.81	21	3.00	703	100.00
Ezine	1557	25.87	3544	58.89	917	15.24	6018	100.00
Gelibolu	1034	30.56	2286	67.58	63	1.86	3382	100.00
Gökçeada	141	4.86	2758	94.82	9	0.32	2909	100.00
Lapseki	1464	31.77	1651	35.82	1494	32.41	4610	100.00
Yenice	4472	75.20	1426	23.99	48	0.81	5946	100.00
Total/Rate (%)	22922	31.24	25340	34.54	25103	34.22	73365	100.00



Table 6. Annual total biogas potential from livestock manure base on collectable wet manure

District	Heavy livestock (cattle+horse)		Small livestock (sheep+goat)		Poultry (chicken+turkey+duck+goose)		Total	
	(1000 m <sup>3</sup> )	(%)	(1000 m <sup>3</sup> )	(%)	(1000 m <sup>3</sup> )	(%)	(1000 m <sup>3</sup> )	(%)
Centre	278,918	17.04	447,683	27.34	910,575	55.62	1,637,176	100.00
Ayvacık	365,985	35.27	661,959	63.80	9,648	0.93	1,037,591	100.00
Bayramiç	359,645	36.28	484,925	48.92	146,731	14.80	991,301	100.00
Biga	1,607,085	20.53	543,897	6.95	5,675,121	72.52	7,826,104	100.00
Bozcaada	393	4.33	8,349	91.82	350	3.85	9,092	100.00
Çan	721,496	66.17	311,540	28.57	57,273	5.25	1,090,310	100.00
Eceabat	23,206	16.67	109,399	78.61	6,569	4.72	139,174	100.00
Ezine	366,477	28.15	658,876	50.60	276,685	21.25	1,302,037	100.00
Gelibolu	241,755	34.82	432,950	62.36	19,529	2.81	694,234	100.00
Gökçeada	32,423	5.89	515,243	93.59	2,867	0.52	550,533	100.00
Lapseki	345,837	31.19	312,256	28.16	450,860	40.66	1,108,954	100.00
Yenice	1,055,312	78.98	265,929	19.90	14,968	1.12	1,336,210	100.00
Total/Rate (%)	5,398,532	30.46	4,753,006	26.82	7,571,175	42.72	17,722,714	100.00

Table 7. Biogas heating capacity values per year base on collectable wet manure

District	Heavy livestock (cattle+horse)		Small livestock (sheep+goat)		Poultry (chicken+turkey+duck+goose)		Total	
	(1000 MJ)	(%)	(1000 MJ)	(%)	(1000 MJ)	(%)	(1000 MJ)	(%)
Centre	6694037	17.04	10744397	27.34	21853788	55.62	39292222	100.00
Ayvacık	8783631	35.27	15887007	63.80	231540	0.93	24902179	100.00
Bayramiç	8631477	36.28	11638195	48.92	3521542	14.80	23791213	100.00
Biga	38570031	20.53	13053538	6.95	136202915	72.52	187826484	100.00
Bozcaada	9441	4.33	200368	91.82	8399	3.85	218208	100.00
Çan	17315916	66.17	7476961	28.57	1374558	5.25	26167435	100.00
Eceabat	556952	16.67	2625571	78.61	157650	4.72	3340174	100.00
Ezine	8795440	28.15	15813015	50.60	6640431	21.25	31248887	100.00
Gelibolu	5802115	34.82	10390807	62.36	468694	2.81	16661615	100.00
Gökçeada	778151	5.89	12365838	93.59	68799	0.52	13212788	100.00
Lapseki	8300090	31.19	7494149	28.16	10820651	40.66	26614890	100.00
Yenice	25327491	78.98	6382304	19.90	359237	1.12	32069032	100.00
Total/Rate (%)	129564771	30.46	114072151	26.82	181708206	42.72	425345128	100.00

Table 8. Biogas electrical capacity values per year base on collectable wet manure

District	Heavy livestock (cattle+horse)		Small livestock (sheep+goat)		Poultry (chicken+turkey+duck+goose)		Total	
	(1000 kWh)	(%)	(1000 kWh)	(%)	(1000 kWh)	(%)	(1000 kWh)	(%)
Centre	1310916	17.04	2104111	27.34	4279700	55.62	7694727	100.00
Ayvacık	1720128	35.27	3111206	63.80	45343	0.93	4876677	100.00
Bayramiç	1690331	36.28	2279146	48.92	689635	14.80	4659113	100.00
Biga	7553298	20.53	2556318	6.95	26673071	72.52	36782686	100.00
Bozcaada	1849	4.33	39239	91.82	1645	3.85	42732	100.00
Çan	3391034	66.17	1464238	28.57	269184	5.25	5124456	100.00
Eceabat	109070	16.67	514174	78.61	30873	4.72	654117	100.00
Ezine	1722440	28.15	3096716	50.60	1300418	21.25	6119574	100.00
Gelibolu	1136248	34.82	2034866	62.36	91786	2.81	3262900	100.00
Gökçeada	152388	5.89	2421643	93.59	13473	0.52	2587504	100.00
Lapseki	1625434	31.19	1467604	28.16	2119044	40.66	5212083	100.00
Yenice	4959967	78.98	1249868	19.90	70351	1.12	6280186	100.00
Total/Rate (%)	25373101	30.46	22339129	26.82	35584524	42.72	83296754	100.00

## Conclusion

In this study, the opportunity of converting organic waste including animal manure into biogas for potential electricity generation of districts of Çanakkale province is studied using statistical data of 2017. It was considered particularly livestock manure with collection ratios and were based on the unit biogas potential per districts of the province. As a result, total biogas potential was calculated about 18 million m<sup>3</sup> per year, which has net energy equivalence of 83 GWh per year. These results indicated that converting animal manure to biogas has significant contributions for managing disposal of waste.



Animal manure source of biogas are easily accessible and available because the livestock farming is one of the main occupation for the socio-economic structure of the province. Additionally, biogas energy produced from animal manure will be a good opportunity to be able use renewable energy in the area instead of fossil energy. Moreover, the results of the study will also contribute the development and improvement of the province animal husbandry and sustainable in the province development through the increasing use of renewable energy sources such as organic waste including animal manure as well as protection of environment.

### References

- Abdeshahian, P., Lim, J.S., Ho, W.S., Hashim, H., Lee, C.T., 2016. Potential of biogas production from farm animal waste in Malaysia. *Renew Sustain Energy Rev.* 60:714-723.
- Acaroglu, M., 2007. *Alternatif Enerji Kaynakları. 2. Baskı*, ISBN: 978-605395-047-9. 2007.
- Anonymous, 2018. Republic of Turkey Ministry of Energy and Natural Resources. 2015-2019 Strategic Plan.37 (<http://www.enerji.gov.tr>: date of access: December, 2017).
- ASABE, 2005. Manure production and characteristics. ASAE standard D384.2. St. Joseph, Michigan, USA: American Society of Agricultural and Biological Engineers.
- Avcioglu, A.O., Türker, U., 2012. Status and potential of biogas energy from animal wastes in Turkey. *Renew Sustain Energy Rev.* 16:1557-1561.
- Daniel-Gromke, J., Erte, F.C., Kittler, K., Gökgöz, F., Neubauer, P., Stinner, W., 2016. Analyses of Regional Biogas Potentials in Turkey, *EurAsia Waste Management Symposium, 2-4 May 2016*, YTU 2010 Congress Center, İstanbul, Türkiye.
- GMKA, 2017. South Marmara Development Agency. Çanakkale Investment Support and Promotion Strategy (2017-2023). 2017 Year Action Plan. pp.42.
- Matheri, A.N., Sethunya, V.L., Belaid, M., Muzend, E., 2018. Analysis of the biogas productivity from dry anaerobic digestion of organic fraction of municipal solid waste. *Renewable and Sustainable Energy Reviews.* 81:2328-2334.
- Ozcan, M., Oztürk, S., Oğuz, Y., 2015. Potential evaluation of biomass-based energy sources for Turkey. *Eng Sci Technol. Int J.* 18:178-184.
- TUIK, 2017. Turkish Statistic Institute, Ankara. (<http://www.tuik.gov.tr>).