BIOGAS PRODUCTION POTENTIAL FROM ANIMAL MANURE IN SAMSUN PROVINCE OF TURKEY

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The aim of this study was to determine biogas amount and the energy value produced from animal manure in Samsun province, Turkey. For this purpose, biogas potential was calculated considering the number of cattle, buffalo and laying hens in the province. Samsun has a total of about 300 thousand cattle, 18 thousand buffalo, and 1.4 million laying hens. From these animals in the province, 2.95 million t of cattle manure, 178 thousand t of buffalo manure, and 40 thousand t of laying hens manure, including the total of 3.2 Mt of manure per year is obtained. Annually, 53.6 Mm^3 of biogas can be produced from the usable amount of this manure. The heating value of biogas produced from this manure is about 1.22 PJ. The electricity production from this biogas is about 135 GWh_{el}. These values can provide 4.96% of Samsun's annual electrical energy consumption (2720 GWh_{el}). The distribution of these calculated amounts by districts was mapped. When districts are listed according to the biogas production amount, the top seven Samsun districts are Bafra (16.2%), Center (16.0%), Carsamba (12.1%), Vezirkopru (11.0%), Terme (7.6%), Alacam (7.4%) and Havza (7.0%).

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INTRODUCTION

Energy plays an important role in the world's development. Energy is essential for 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).

The 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, Demirer, 2007).

Biomass is a type of energy source with a high carbon content. 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 desirable 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 (Dumanli et al., 2007).

Animal husbandry is one of the main means of living. Thus a significant amount of animal wastes is produced annually. In Turkey, most of the animal based biomass studies have been done in the area of biogas research and development projects since the 1960s (Dumanli et al., 2007).

Biogas is a mixture of methane and carbon dioxide. It also has traces of hydrogen sulphide, ammonia, oxygen, hydrogen, water vapour etc., depending upon feed materials and other conditions. Biogas is generated by fermentation of cellulose rich organic matter under anaerobic conditions. In anaerobic conditions,

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

Animal	NA	AFM (t day^{-1})	SMR (%)	ASM (t day^{-1})	AOM (%)	TUSM (t year^{-1})
Cattle	296 454	8 075	12.7	1 026	65	243 418
Buffalo	17 944	489	12.7	62	65	14 710
Laying hens	1 378 525	110	25	28	99	9 963
Total		8 674		1 115		268 008

NA = number of animals, AFM = amount of fresh manure per day (t day^{-1}), SMR = solid manure ratio (%), ASM = amount of daily solid manure (t day^{-1}), AOM = attainability of manure (%), TUSM = annual total usable solid manure (t year^{-1})

the methane-producing bacteria become more active. Thus, the gas produced becomes rich in methane (NIIR, 2004).

Biogas is about 20% lighter than air and has an ignition temperature in the range of 650–750° C. It is an odourless and colourless gas that burns with clear blue flame similar to that of LPG gas. Its heating value is between 20–23 MJm^{-3} and burns with 60% 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).

Renewable energy accounted for 15.7 Mtoe or 12.1% of Turkey's total primary energy supply (TPES) in 2015. Renewables include biofuels and waste (3.3 Mtoe or 2.5% of TPES), hydropower (5.8 Mtoe or 4.4%), geothermal energy (4.8 Mtoe or 3.7%), solar (1 Mtoe or 0.7%) and wind power (1 Mtoe or 0.8%). Electricity from renewable sources amounted to 83.8 TWh in 2015, or 32.3% of total generation. Renewables in electricity generation include hydropower (66.9 TWh or 25.8% of total electricity generation), wind power (11.6 TWh or 4.4%), geothermal energy (3.4 TWh or 1.3%), biofuels and waste (1.5 TWh or 0.6%) and solar power (0.4 TWh or 0.2%). Among the International Energy Agency member countries, Turkey has the thirteenth-highest share of renewables in electricity generation (median level), with the third-highest geothermal share, the seventh-highest hydro share, and the fourth- and seventh-lowest share of biofuels and waste and solar (IEA, 2016).

The objective of this study was to determine the production potential of biogas from animal manure (only cattle, buffalo and laying hens) and to map the calculated values for each district in Samsun. For this purpose, animal manure biogas potential and its energy potential were evaluated by ArcMap, a geographical information system (GIS) program. The differences in data among the districts for seeing more clearly were mapped by GIS. A database was created within the GIS for Samsun and its districts. The number of animals, calculated biogas potential, and its heating value in the province for the year 2016 were inputs to this database.

MATERIAL AND METHODS

Samsun province in Turkey is located between 41°17′25″ N latitude and 36°20′1″E longitude, covering an area of 9 352 km^2. Samsun province is divided into 17 districts, four of which (Ilkadım, Canik, Atakum and Tekkekoy) are included in the municipality of Samsun city (Center). Other districts are Alacam, Asarcik, Ayvacik, Bafra, Carsamba, Havza, Kavak, Ladik, Ondokuzmayis, Salipazari, Terme, Vezirkopru and Yakakent.

Within the scope of this study, animal statistical data provided by TSI (2016) have been used as material. The data used in the calculation of the biogas production potential were considered only for cattle, buffalo and laying hen population because the attainability of animal manures, as determined by staying time in the barn, (65%) and laying hen farms (99%) (Bascetincelik et al., 2005). Buffalo is only in few provinces like Samsun in Turkey. (ruminant, horse, donkey, meat hen, turkey, duck, goose) were not used for calculations.

The following equations were used to calculate the amount of animal manure and biogas production (Bascetincelik et al., 2006; Ayhan, 2015; Ozsoy, Alibas, 2015):

$$AFM = NA \times MPPA/1000 \quad \text{(Eq. 1)}$$

where:

AFM = amount of fresh manure per day (t day^{-1})

NA = number of animals

MPPA = daily manure production per animal (kg day^{-1})

The MPPA is 27.24 kg day^{-1} for cattle and 0.08 kg day^{-1} for laying hens.

$$ASM = AFM \times SMR \quad \text{(Eq. 2)}$$

where:

ASM = amount of daily solid manure (t day^{-1})

SMR = solid manure ratio (%)

$$TSUM = ASM \times AOM \times 365 \quad \text{(Eq. 3)}$$

Table 2. Biogas potential and energy potential of biogas in Samsun

Animal	TUSM (t year^{-1})	AB (m^3 year^{-1})	THV (GJ year^{-1})	EP (MWh$_{el}$ year^{-1})
Cattle	243 418	48 663 614	1 104 664	122 740
Buffalo	14 710	2 945 549	66 864	7 429
Laying hens	9 963	1 992 520	45 230	5 026
Total	268 091	53 601 683	1 216 758	135 195

TUSM = annual total usable solid manure (t year^{-1}), AB = amount of biogas (m^3 year^{-1}), THV = total heating value (MJ), EP = electricity production (MWh$_{el}$ year^{-1})

where:
TUSM = annual total usable solid manure (t year^{-1})
AOM = attainability of manure (%)

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

where:
AB = amount of biogas (m^3 year^{-1})
BCR_{SM} = biogas conversion ratio of solid manure (200 m^3 t^{-1})

$$THV = AB \times HV \quad \text{(Eq. 5)}$$

where:
THV = total heating value (MJ)
HV = heating value of unit biogas (22.7 MJ m^{-1})
Electricity generation from biogas with a gas engine was calculated by the following equation:

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

where:
EP = electricity production (MWh$_{el}$ year^{-1})
EPE_{Net} = net electricity production efficiency of a biogas engine (40%) (C E , 2016)

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

RESULTS

Despite the fact that the number of animals in the year 2016 was used in the study, it was observed that there was not much change in animal numbers between 2012 and 2015. The average number of animals between these years was determined as 322 thousand of cattle, 15.5 thousand of buffalo and 1.37 thousand of laying hens (T S I , 2012, 2013, 2014, 2015). Total animal manure potential of Samsun in 2016 as a solid matter depending on the number of cattle, buffalo and laying hens is presented in Table 1. According to Table 1, the total amount of usable solid manure, obtained from cattle, buffalo and laying hens, is 268 thousand t in 2016.

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 shows the calculated value for the total biogas potential of Samsun – 53.6 Mm^3.year^{-1}. Besides, its heating value was calculated to be 1 217 TJ year^{-1}. It was determined that 135.2 GWh$_{el}$ year^{-1} energy can be obtained by the conversion of all the biogas potential from animal manure into electrical energy by means of a gas engine.

Table 3 provides calculations for the fourteen districts of Samsun province for the year 2016 concerning animal fresh manure, biogas potential obtainable from solid manure, the heating value of this biogas potential, and the electrical energy produced from this biogas. Bafra and Center provinces have the highest potential with 8.71 and 8.56 Mm^3.year^{-1}, respectively. These are followed by Carsamba, Vezirkopru, Terme, Alacam and Havza districts with 6.5, 5.9, 4.08, 3.94, and 3.75 Mm^3.year^{-1}, respectively.

The share of cattle, buffalo, and laying hens manure on the manure total amount is 93.1, 5.6, and 1.3%, respectively. The distribution of animal manure potentials in the provinces of Samsun is given in Fig. 1. In all districts, the prevalence of cattle manure can be observed. Bafra, Ondokuzmayis, Alacam, Vezirkopru and Terme districts display higher values for the buffalo than for the other manures. The laying hens manure share is low in all the districts.

The amount of biogas and its energy values were calculated separately for each district and were mapped using ArcMAP Software. The distribution map of bi-

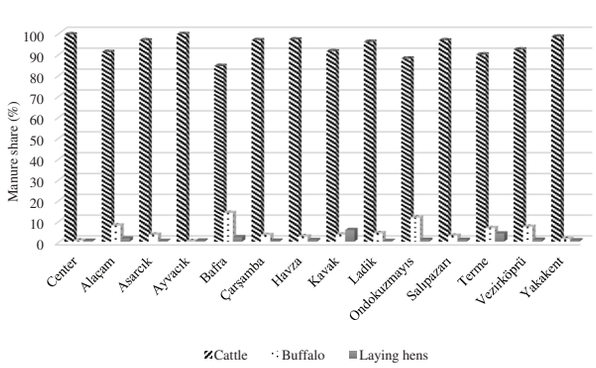

Fig. 1. Distribution of animal manure potentials per district

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

Districts	AFM (t year^{-1})	AB (m^3 year^{-1})	THV (GJ year^{-1})	EP (MWh$_{el}$)	Share in total biogas (%)
Center	515 419	8 563 179	194 384	21 598	16.0
Alacam	232 009	3 940 279	89 444	9 938	7.4
Asarcik	99 947	1 658 800	37 655	4 184	3.1
Ayvacik	83 689	1 394 223	31 649	3 517	2.6
Bafra	506 379	8 707 113	197 651	21 961	16.2
Carsamba	390 447	6 497 819	147 500	16 389	12.1
Havza	224 062	3 749 652	85 117	9 457	7.0
Kavak	126 256	2 313 275	52 511	5 835	4.3
Ladik	113 153	1 876 255	42 591	4 732	3.5
Ondokuzmayis	138 457	2 321 572	52 700	5 856	4.3
Salipazari	91 400	1 532 886	34 797	3 866	2.9
Terme	229 521	4 079 536	92 605	10 289	7.6
Vezirköprü	351 110	5 893 154	133 775	14 864	11.0
Yakakent	64 337	1 073 940	24 378	2 709	2.0
Total	3 166 186	53 601 683	1 216 758	135 195	

AFM = amount of fresh manure per day (t day^{-1}), AB = amount of biogas (m^3 year^{-1}), THV = total heating value (MJ), EP = electricity production (MWh$_{el}$ year^{-1})

ogas potential and its energy values for 14 districts of Samsun are given in Figs. 2 and 3. These maps show that the biogas potential is concentrated in Bafra and Center districts.

DISCUSSION

The distribution of the total amount of usable solid manure by the sources is as follows: cattle (90.8%), buffalo (5.5%) and laying hens (3.7%). The percentage for cattle reflects that in this region cattle is bred more commonly than other animals. 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 53.6 Mm^3 year^{-1}. It was determined that 135.2 GWh$_{el}$ year^{-1} energy can be obtained by the conversion of all the biogas potential from animal manure into electrical energy by means of a gas engine. These values can provide 5% of Samsun's annual electrical energy consumption (2720 GWh$_{el}$). A study carried out by K i z i l a s l a n , O n u r l u b a s

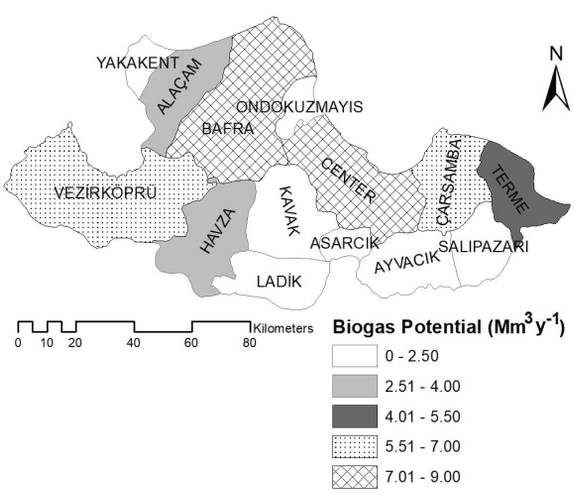

Fig. 2. Distribution map of biogas potential in Samsun

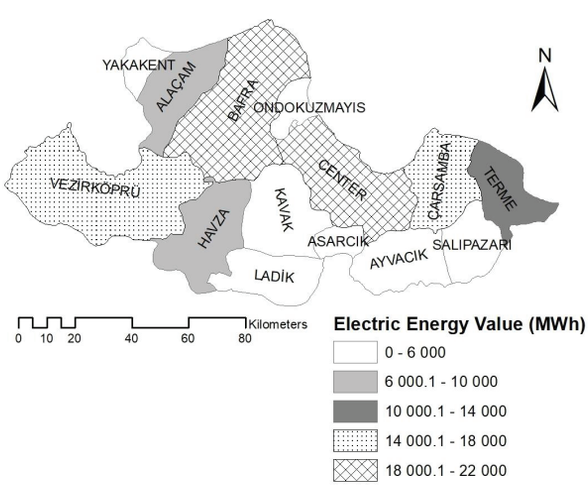

Fig. 3. Distribution map of electricity generation from biogas in Samsun

(2010) in Tokat province, Turkey indicated that the total biogas derived from animal manure was 37.9 Mm^3 $year^{-1}$ Ozsoy, Alibas (2015) reported the amount of biogas production from animal manure in Bursa was about 52 Mm^3 $year^{-1}$, equivalent to about 100.1 GWh_{el}. The potential of biogas from animal manure was determined in Yozgat province, Turkey. The total biogas potential was determined as 45 Mm^3 $year^{-1}$ in the province (Eryilmaz et al., 2015). A study carried out by Karaca (2016) in Afyonkarahisar province indicated that the total biogas derived from manure of cattle, buffalo and laying hens was 84.8 Mm^3 $year^{-1}$.

As a result, the biogas potential of Samsun province just considering the amount of manure from cattle, buffalo and laying hens, is greater than the potential in Bursa, Tokat and Yozgat provinces, and lower than the potential in Afyonkarahisar.

The distribution map of biogas potential and its energy values show that the biogas potential is concentrated in Bafra and Center districts. This means that the biogas production plants can be established between Bafra and Center districts. This situation is an advantage in terms of raw material supply for biogas production plants.

Samsun province has a good potential for biogas production, however still inadequately assessed. At present, one biogas plant is under construction with 1.04 MW_{el} capacity in Bafra (ED, 2015). This plant will cover only a third of the biogas potential of the district.

CONCLUSION

The present study showed that Samsun's biogas potential from cattle, buffalo and laying hen manures was 53.6 Mm^3 $year^{-1}$ depending on the number of animals in 2016. Bafra and Center districts have the greatest biogas potential, followed by Carsamba and Vezirkopru. If all the biogas potential from animal manure would be converted into electricity by means of a gas engine, the electrical energy output should make almost 135.2 GWh_{el} per year. This value could cover 4.96% of Samsun's annual electrical energy consumption (2720 GWh_{el}).

The presented maps visualize more clearly the differences in data from the districts. Hopefully this mapping will contribute to the rise of public awareness and policy-makers' reference on this issue.

Turkey has a great potential of renewable energy sources. Unfortunately, it is an energy-importing country. The country needs to use more of its renewable energy sources in order to be independent with regards to energy. Therefore, biogas can be a very attractive choice because it is sustainable, environmentally friendly and a native energy source for Turkey.

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