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Research Article

Determination of animal, agricultural, urban and treatment sludge waste potential and calculation of total combustion energy values of Uşak, Turkey

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Abstract

In order to ensure a sustainable quality of life, an applicable energy system needs to be created. Energy sources of fossil origin are not infinite. Therefore, the search for alternative sources for these resources has intensified in recent years. Animal, agricultural, urban organic and treatment sludge from these sources are organic waste or residues. Energy is obtained by burning these wastes. In this study, animal, agricultural, urban organic and treatment sludge wastes and combustion energy values of different years were calculated for Uşak, Turkey. The total annual energy values were determined as 2342215 GJ of animal origin, 6302240 GJ of agricultural waste, 1294897 GJ of urban organic waste and 291 GJ of treatment sludge waste.

Keywords
Manure
Agricultural Waste
Urban Waste
Sludge Waste
Biomass
Combustion

Uşak ilinin hayvansal, tarımsal, kentsel ve arıtma çamuru atık potansiyelinin belirlenmesi ve toplam yanma enerjisi değerlerinin hesaplanması

Özet

Sürdürülebilir bir yaşam kalitesinin sağlanması için uygun bir enerji sisteminin oluşturulması gerekmektedir. Fosil kökenli enerji kaynakları sonsuz değildir. Bu nedenle, bu kaynaklar için alternatif arayışlar son yıllarda yoğunlaşmıştır. Bu kaynaklardan elde edilen hayvansal, tarımsal, kentsel organik ve arıtma çamuru organik atık veya artıklardır. Bu atıkların yakılmasıyla enerji elde edilir. Bu çalışmada Uşak, Türkiye için farklı yıllara ait hayvansal, tarımsal, kentsel organik ve arıtma çamuru atıkları ile yanma enerjisi değerleri hesaplanmıştır.
Toplam yıllık enerji değerleri hayvansal kaynaklılar için 2342215 GJ, tarımsal atıklar için 6302240 GJ, kentsel organik atıklar için 1294897 GJ ve arıtma çamuru atığı için 291 GJ olarak belirlenmiştir.

Anahtar Kelimeler
Gübre
Tarımsal Atık
Kentsel Atık
Çamur Atığı
Biyokütle
Yanma

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INTRODUCTION

Energy is one of the locomotives of a country's social and economic development. In the development of energy policies that reduce external dependence of countries, the use of domestic and renewable energy sources that they have is very important. Energy production technologies based on renewable energy sources are environmentally sensitive technologies. Wind, solar, geothermal, wave, hydropower, biomass, landfill gas, wastewater treatment plant gas and biogas are defined as renewable energy sources. Biomass among these resources has attracted the attention of researchers in recent years in terms of its potential and species diversity [1]. Biomass is a biological energy source that is widely used in nature and is produced by various physical, chemical, and biological methods of existing agricultural products and whose specific properties are standardized [2]. Biomass can be defined as organic substances formed by renewable, plant waste, animal residues, forest product and urban waste [3]. Since the limited depleted energy resources such as oil, natural gas, coal, and the damage these resources cause to the environment, energy production with the use of biomass is becoming increasingly important. Biomass can be produced anywhere, and it can also help socioeconomic development, especially for out-of-town areas [4]. The installed power, which is progressing faster than planned due to the energy supply in Turkey, was 4.4 MW in 1979 and reached 91.3 MW according to 2019 year-end data. Turkey's total installed capacity has increased to 92 MW according to the data for early of 2020. In line with the targets set, biomass installed capacity is expected to be 1000 MW in 2023 [5]. The share of biomass energy in the amount of installed power that rising is low. Its share in total installed capacity has been around 1,195 MW. The energy equivalent of this power corresponds to 3,500 GWh in annual production. With this value, the daily energy needs of an average of 0.9 million people can be met. According to 2020 data, 12 of the 18 new energy production licenses issued by the EPDK were biomass production plants. According to 2020 data, there are 183 plants registered in Turkey. For this reason, biomass is predicted to become self-reliant in energy production. Some power plants and fuel types with the most installed power are given in Table 1 [6].

Callejón-Ferre et al., (2011) determined that the total annual residual amount for tomatoes, peppers, eggplants, pumpkins, beans, melons and watermelons grown in Spain/Almeria was 250 thousand tons and has an energy value of 3.6 PJ [7]. Bilgin et al. (2012) stated that a total of 252.8 thousand tons of biomass waste, including 204 thousand tons of tomatoes, 35 thousand tons of peppers and 14 thousand tons of eggplant waste,was formed from greenhouses in Turkey on a dry basis per year, and the energy value is 3.99 PJ [8]. Külcü (2016) investigated the potential of agricultural biomass for Afyonkarahisar/Turkey and that it has been possible to produce 1 490 451 tons of compost from 2 838 954 tons of vegetable waste (20% moisture content) [9]. Karaca (2017) determined that 202.53 thousand tons of biomass waste was obtained from tomato pepper and eggplant plants grown under cover in Antalya on a dry basis and that the total thermal value of the waste was 3.19 PJ.

Table 1. Power plants and fuel types with the most installed power [6].

Power Plant	City	Installed Power (MW)	Waste Type
Odayeri	İstanbul	34	Urban
Toros Tarım	Samsun	31	Heat
Mutlular	Balıkesir	30	Forest
Mamak	Ankara	25	Urban

Çadırtepe	Ankara	23	Urban
Sofulu	Adana	16	Urban

It was also stated that 13 combined heat and power plants with capacity of 23 MW could be installed from these wastes [10]. Mutlu et al. (2019) have calculated the total annual amount of usable waste of wheat, barley, corn and cotton for the Southeast Anatolia Project region as 5 572 419 tons and the thermal value as approximately 34 million MWh [11]. Karabaş (2019) determined the biomass and energy potential of Sakarya, Turkey. The amount of biomass for field crops was 974 990.8 tons/year and the total thermal capacity was 618 419 362 GJ/year, the dry biomass potential of pruning waste for fruit trees was 28 304 823.6 tons/year and the total thermal capacity was 566 096 472 GJ/year [12]. Polat (2020) determined the biomass potential and energy value of the provinces of Afyonkarahisar, Bilecik, Burdur, Bursa, Denizli, Eskisehir, Isparta, Kocaeli, Kütahya, Sakarya, Uşak and Yalova. In the study, wheat, barley, maize, sunflower and sugar beet were used most commonly. As a result, it was calculated that the energy potential of agricultural waste for 2018 was 6185.33 GWh [13]. Diken and Kayışoğlu (2020) examined the biomass potential and the amount of energy derived from field plant residues in Tekirdağ, Turkey. Wheat, barley, rye, sunflower, corn, Paddy, oats and triticale were used as field wastes in determining biomass potential. In 2019, 735.74 kton - 3 049.88 GWh were found to be usable agricultural waste and the energy value [14]. Gurel (2020) determined the waste amounts of animal, agricultural, urban organic, timber, industrial wood production, wood-based panel and treatment sludge for Turkey and calculated the combustion energy values of the waste. As a result, the combustion energy value of total biomass wastes in 2018 was calculated as 184.647 PJ [15].

Uşak is one of the important provinces of Turkey in terms of biomass. A plant for biomass and energy production will be put into operation at Uşak Deri Karma OSB. It is stated that the plant will produce 108 MW of electricity per year and will also contribute to the environment by converting waste into electricity. At the plant, electricity will be generated by drying and burning 150 tons of treatment sludge daily. The plant has an average dry substance of 30.44% and the upper thermal calorific value on a dry basis is approximately 3976 kcal/kg. With an installed power of 4.7 MWT, it is estimated that the gross amount of electrical energy that the plant can produce will be 8 GWh per year [16].

In this study, the biomass waste potential of Uşak, Turkey was determined and the total energy values that can be obtained by burning the waste were determined. Energy amounts were calculated separately according to each waste potential. In combustion technology, it has been determined which biomass wastes have the greater potential to be used as fuel.

MATERIAL AND METHOD

In this study, animal, agricultural, urban organic, and treatment sludge waste quantities of Uşak were determined and the total energy values that can be obtained by burning the waste were calculated. In determining the waste potentials, annual waste statistics values were obtained from the Turkish Statistical Institute (TUIK). The total number of animals in Uşak for the years 2019 and 2020 are given in Table 2. The number of animals for the years 2019 and 2020 were 11135342 and 14988949, respectively. Approximately 95% of the total number of animals was poultry, 3% was small ruminats and 2% was cattle. In 2020, approximately 96% of the total number of animals consists of poultry, 3% of small ruminants and 1% of cattle. In 2020, compared to 2019, the number of poultry and small animals increased, while the number of cattle decreased [17].

Table 2. Animal numbers[17].

Year	Cattle	Small Ruminants	Poultry
2019	149809	365874	10619659
2020	145124	422507	14421318

In the determination of combustion energy values caused by animal wastes, the values given in Table 3 were used. The ratio of dry fertilizer was considered to be 12.7% for cattle and 25% for small cattle and poultry. The availability ratio was selected for cattle (65%), small cattle (13%) and poultry (99%). The total combustion energy value of animal waste was calculated using equations in Table 3. [18]. Some agricultural waste amounts, waste product ratio, availability and thermal values for 2019 - 2020 in Uşak and formulas are given in Table 4 [14,17].

The amount of municipal waste collected in Uşak for the years 2014, 2016, and 2018 are given in Table 5 [17]. Data for 2014, 2016 and 2018 were used because data for other years were not available. The ratioof organic waste in municipal waste was taken as 54% and the thermal value of organic waste (1435 kcal/kg) [19] and the formula given at the bottom of the table was used in determining the total combustion energy potential of municipal waste [15].

Table 3. Assumptions and equations used in the determination of combustion energy [18]

Animal type	Manure per animal (tons/year)	Dry manure per animal (tons/year)	Available dry manure (tons/year)	Obtainable biogas (tons/m^3)	Calorific Value (MJ/m^3)
Cattle	9.95	1.26	0.82	200	22.7
Small ruminants	0.82	0.21	0.03	200	22.7
Poultry	0.03	0.01	0.01	200	22.7
Total manure = Available dry manure x Animal number Total combustion potential = Total manure x Obtainable biogas x Calorific value					

Table 4. Agricultural waste amount, waste product ratio availability values and heat values [14,17]

Product	Year	Waste type	Production (tons/year)	Waste / Product ratio (kg waste/kg product)	Availability (%)	Thermal Value (MJ/kg)
Wheat	2019	Straw	144660	0.98	15	17.9
	2020	Straw	172825			
Barley	2019	Straw	169221	0.95	15	17.5
	2020	Straw	147576			
Corn	2019	Cob	93925	2.10	60	18.5
	2020	Cob	93777			
Rye	2019	Straw	4506	0.78	15	17.5
	2020	Straw	3549			

Oat	2019	Straw	7049	0.75	15	17.4
	2020	Straw	9368			
Sunflower	2019	Cob	1117	2.80	60	14.2
	2020	Cob	1309			
Triticale	2019	Straw	6725	1.10	60	17.8
	2020	Straw	9873			
Waste amount = Production x (Waste / product ratio) x Availability Total combustion potential = Waste amount x Thermal value						

The amount of wastewater per person for the years 2014, 2016, and 2018 are given in Table 6. Data for 2014, 2016, and 2018 were used because data after 2018 were not available. The total combustion energy value of organic waste was calculated by accepting the thermal value of organic waste in treatment sludge (5.5 MJ/kg) from the formula in the table. The population of Uşak province was 349459 in 2014, 358736 in 2016 and 367514 in 2018[15,17,19].

Table 5. Urban Waste [17]

Year	**Amount of collected municipal waste (tons)**
2014	110021
2016	143733
2018	145370
Total combustion potential = Amount of waste x Thermal value x Waste ratio	

Table 6. Treatment Sludge Waste [17]

Year	**Treatment sludge waste (liter / person-day)**
2014	148
2016	134
2018	122
Total combustion potential = Amount of waste x Thermal value x Number of people	

RESULT AND DISCUSSION

The annual amount of waste potentials depending on the number of animals in Uşak are given in Figure 1. Given the amount of waste, the total waste for the three animal species for 2019 was determined as 240016.19 tons/year. In 2020, this value was 275890.02 tons/year. In 2019, the highest waste value was in cattle, and in 2020 it was in poultry. Given two years, the most waste was obtained from poultry, and the least waste was obtained from small ruminants. Energy values obtained from animal waste are given in Figure 2.

As seen in figure 2, the energy value is 1089674 GJ/year in 2019 and 1252541 GJ/year in 2020. The most energy have come from cattle in 2019 and poultry in 2020. There has been a 15% increase in the value of combustion energy in 2020 compared to 2019. The total combustion energy value is 2342214.42 GJ / year. When the total energy value is evaluated according to the type of animal, 46.8% is cattle, 48.5% is poultry and 4.7% is small animals

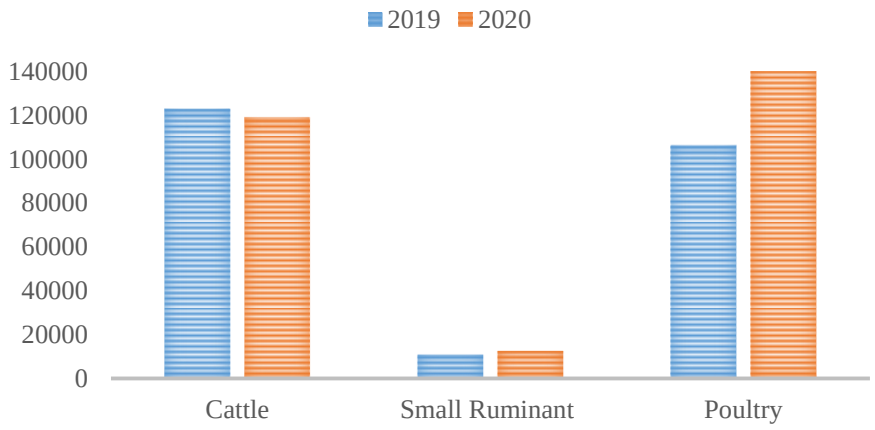

Figure 1. Amount of waste by animal type(tons/year)

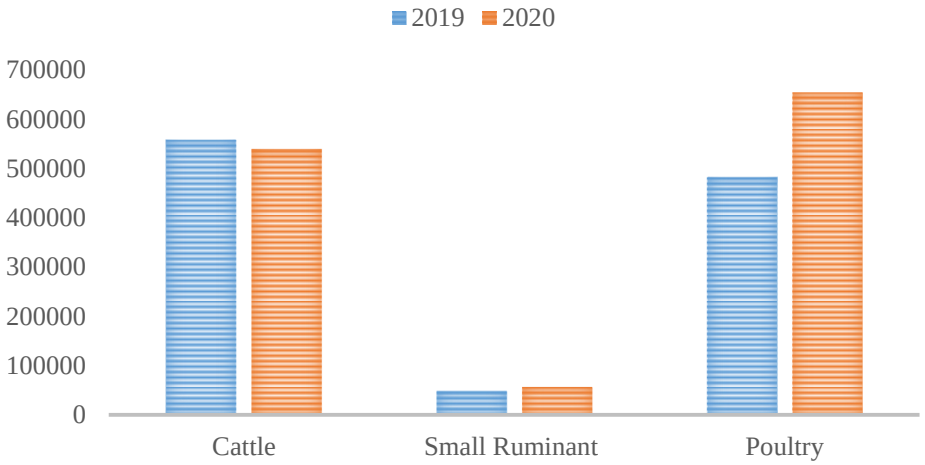

Figure 2. Energy value of animal waste combustion (GJ /year)

The amount of waste that can be obtained from agricultural waste is given in Figure 3. The total amount of usable agricultural waste in 2019 is 171360 tons, while in 2020 it is 174778 tons. In 2019 and 2020, the most usable waste was obtained from corn and the least from Rye. Looking at the percentage change of 2020 compared to 2019, it is seen that there is an increase of approximately 2%. Agricultural products that cause this increase have been wheat, triticale, sunflower and oats, respectively. Other products have decreased.

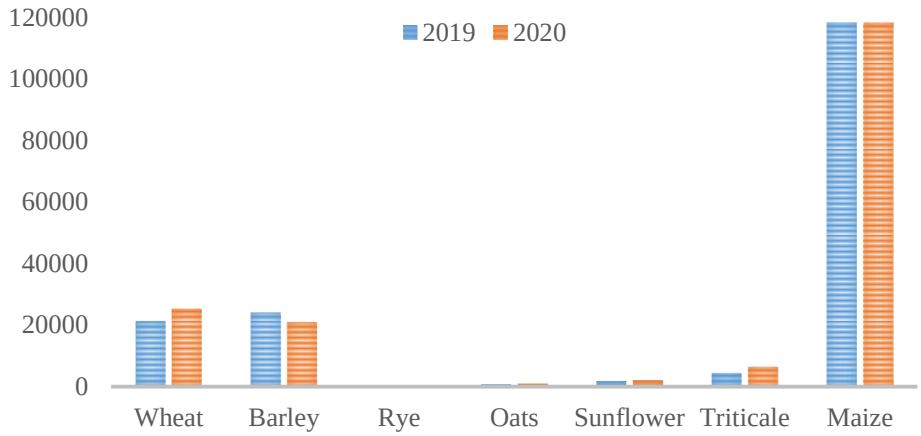

Figure 3. Amount of available agricultural waste (tons / year)

The combustion energy values of the available agricultural waste are given in Figure 4. Figure 4 shows that energy values are 3120707GJ in 2019 and 3181533 GJ in 2020. There is a 1.9% increase in total energy value in 2020 compared to 2019. In 2020, wheat, oats, sunflower, and triticale products increased, while barley, rye and corn decreased. Burning or gasification of agricultural waste is a good option in terms of energy production.

The amount of urban organic waste collected from municipalities for the years 2014, 2016, and 2018 is given in Figure 5. It is 59411 tons in 2014, 77615 tons in 2016 and 78500 tons in 2018. The total amount of organic waste is 215527 tons. From 2014 to 2018, the amount of organic waste increased by approximately 33%.

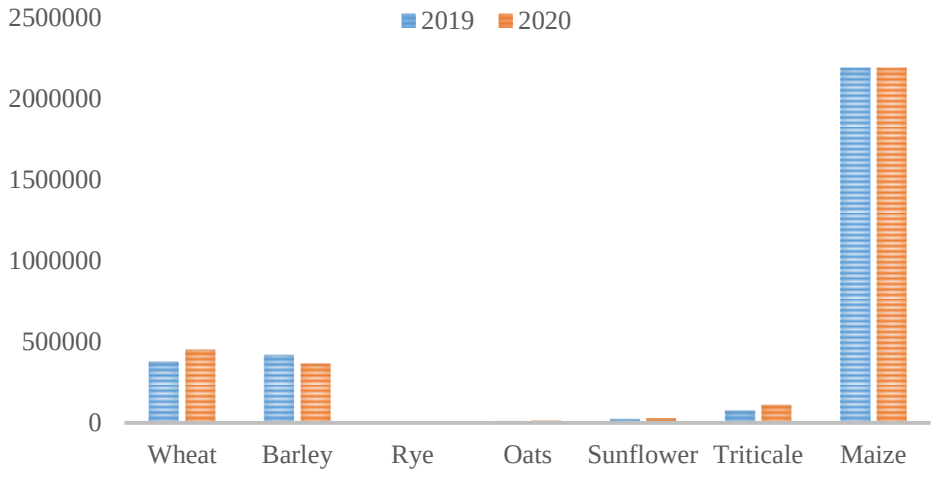

Figure 4. Combustion energy value of agricultural waste (GJ/year)

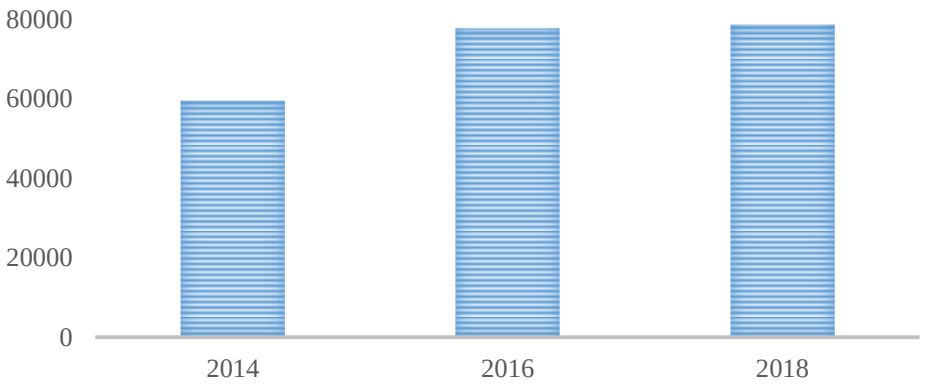

Figure 5. Amount of organic waste (tons/year)

The total energy value obtained from the burning of organic waste is given in Figure 6. It was 356946 GJ in 2014, 466320 GJ in 2016 and 471631 GJ in 2018. According to figure 6, the combustion energy values calculated between 2014 and 2018 are increasing. Compared to 2014, the energy value increased by 30.65% in 2016 and 32.12% in 2018. Electricity generation from methane gas generated by municipalities from urban organic waste at the warehouse site has not been taken into account in general combustion energy calculations, where it is more advantageous than the alternative of generating energy by burning. It may be more accurate to calculate biogas production from urban organic waste

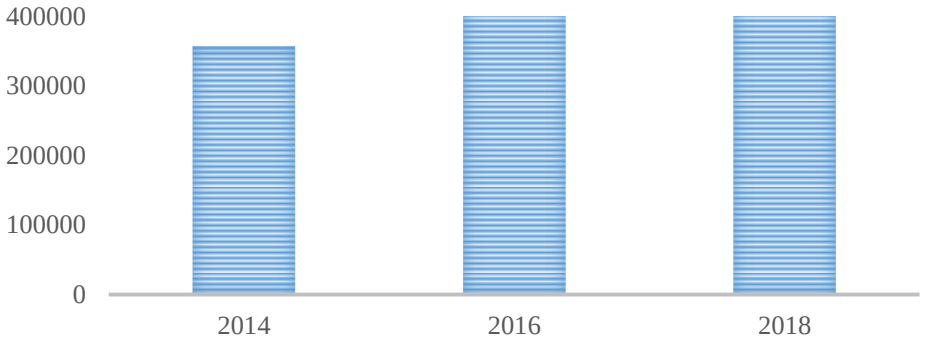

Figure 6. Combustion energy values of organic waste (GJ / year)

The amount of treatment sludge organic waste for the years 2014, 2016, and 2018 is given in Figure 7. It is 18877.77 tons in 2014, 17545.77 tons in 2016 and 16365.39 tons in 2018. The total amount of organic waste is 52788.95 tons. In 2016, the amount of waste decreased by 7% compared to 2014. From 2014 to 2018, there is approximately a 13.30% reduction in the amount of organic waste.

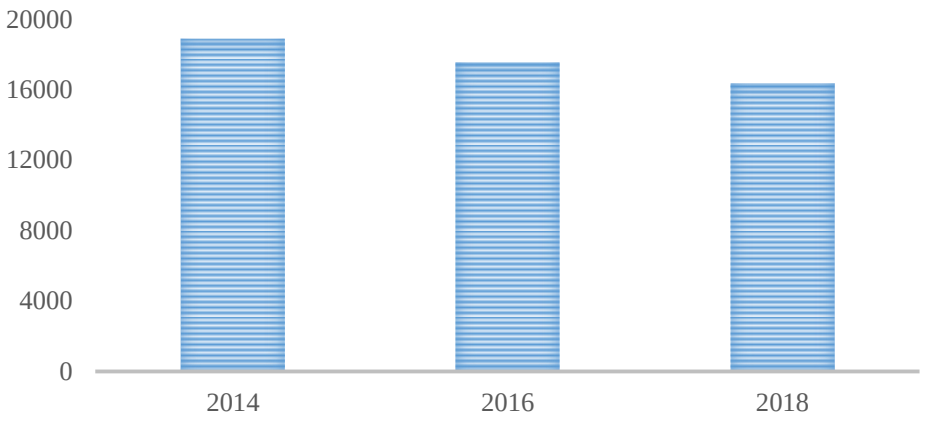

Figure 7. Treatment sludge waste (tons/year)

The total thermal values obtained by burning domestic treatment sludge in 2014, 2016, and 2018 are given in Figure 8. It is 103.88 GJ in 2014, 96.50 GJ in 2016 and 90.00 GJ in 2018. Over time, the amount and organic content of the sludge produced in the treatment plants decreased. When the percentage change was examined by year, there was a decrease of 7% in 2016 and 13.3% in 2018 compared to 2014. For this reason, the combustion energy value that can be obtained by burning waste has also decreased. Burning or gasification of domestic treatment sludge waste is an important option for energy production. For this reason, the combustion energy values of treatment sludge wastes were taken into account in the general combustion energy calculations of the wastes.

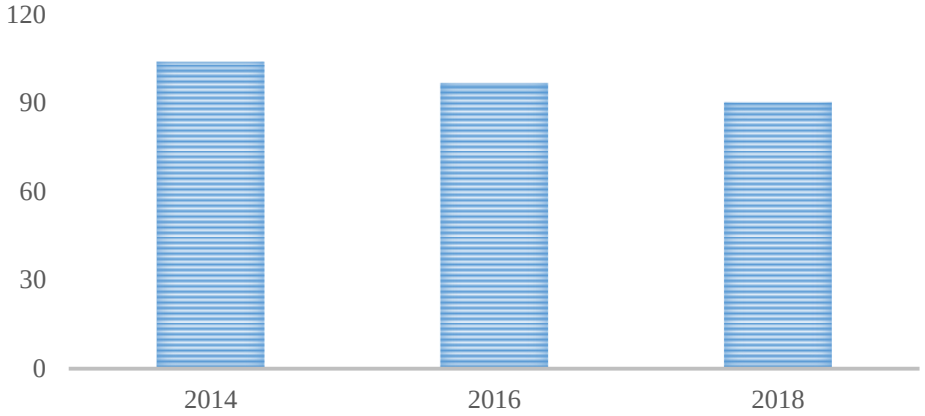

Figure 8. Combustion energy values of organic waste (GJ/year)

CONCLUSION

The main goal of energy policies should be clean, reliable and cheap energy supply. In addition to efficient use of energy, it is very important to ensure a variety of resources. Recycling and zero waste targets have become very important today. From this point of view, biomass energy is remarkable. In this study, combustion energy values were calculated according to the amount of animal, agricultural, urban organic and treatment sludge waste in Uşak. Data for 2014, 2016, and 2018 were used because data after 2018 were not available. Accordingly, the total amount of cattle, small cattle and poultry for the years 2019 and 2020 is 11135342 and 14988949, respectively. Depending on the number of animals, the total waste for the three animal species for the year is 240016 tons/year, while in 2020 this value is 275890 tons/year. The combustion energy value that can be obtained from waste is 1089674

GJ/year in 2019 and 1252541 GJ/year in 2020. For 2019 and 2020, the total amount of usable agricultural waste for wheat, barley, rye, oats, sunflower, triticale, corn products is 171360 tons and 174778 tons, respectively. The combustion energy values of these waste amounts were calculated as 3120707GJ in 2019 and 3181533 GJ in 2020. The amounts of urban organic waste collected from municipalities for the years 2014, 2016 and 2018 are 59411 tons, 77615 tons and 78500 tons respectively. The combustion energy value that can be obtained due to these wastes was 356946 GJ in 2014, 466320 GJ in 2016 and 471631 GJ in 2018. The amount of sewage sludge waste is 18878 tons in 2014, 17546 tons in 2016 and 16365 tons in 2018. The total combustion energy value obtained by burning domestic treatment sludge is 104 GJ, 97 GJ and 90 GJ respectively

REFERENCES

[1] Kumaş, K., Akyüz, A.Ö., Temiz, D., Güngör, A. (2019). Biomass to Energy: The Potential of Biogas in Turkey and World. Mesleki Bilimler Dergisi (MBD), 8 (2), 70-77.

[2] Horuz A., Korkmaz, A., Akınoğlu, G. (2015). Biofuel Plants and Technology, Toprak Bilimi ve Bitki Besleme Dergisi 3(2), 69-81.

[3] Ertürk,O.,Erdinç Ertürk,A.(2018). The Effect of Renewable Energy Sources on Power Generation and Current Account Deficit in Turkey, 4 th SCF International Conference on "Economic and Social Nevsehir Impacts of Globalization" and "Future of Turkey-EU Relations, 26th -28th April, Nevşehir, 103-113.

[4] Karayılmazlar,S., Saraçoğlu, N., Çabuk, Y., Kurt, R. (2011). Utilizations of Biomass as An Energy Source in Türkey, Bartın Orman Fakültesi Dergisi, 13, 19, 63-75.

[5] Anonim, 2020a TSKB Aylık Enerji Bülteni Mayıs 2020 http://www.tskb.com.tr/i/assets/document/pdf/enerji-bulteni-mayis-2020.pdf

[6] Anonim,2020b. https://icci.com.tr/2020de-18-onlisansin-12-adeti-biyokutle-santral-projelerine-verildi/

[7] Callejón-Ferre AJ, Velázquez-Martí B, López-Martínez JA, Manzano-Agugliaro F (2011) Greenhouse crop residues: Energy potential and models for the prediction of their higher heating value. Renewable and Sustainable Energy Reviews 15: 948–955.

[8] Bilgin S, Ertekin C, Kürklü A (2012) Türkiye'deki sera bitkisel biyokütle atık miktarının belirlenmesi. 27. Tarımsal Mekanizasyon Ulusal Kongresi Bildiri Kitabı, Samsun, s. 499-508.

[9] Külcü, R. 2016. Afyonkarahisar ilinin tarımsal biyokütle potansiyelinin incelenmesi. Akademia Mühendislik ve Fen Bilimleri Dergisi, 1(2): 1-9.

[10] Karaca, C. (2017). The mapping of greenhouse biomass residues potential and their usage for energy production potential in Antalya. Mediterranean Agricultural Sciences, 30(1), 21-25.

[11] Mutlu, N., Tolay, M., Karaca, C., Öztürk, H. H. (2019) Agricultural Biomass Potential of the Southeastern Anatolia Project (GAP) Region, Journal of Agricultural Machinery Science, 15 (3), 77-81.

[12] Karabaş, H. (2019). Investigation of Waste Amount and Energy Potential of Sakarya Province by Vegetative Biomass, Ulusal Çevre Bilimleri Araştırma Dergisi, 2(1), 35-43.

[13] Polat, M. (2020). Determination of Agricultural Residues Biomass Energy Potential of Transitional Zone Research Institute Responsibility Provinces, Eskişehir Technical University Journal of Science and Technology B- Theoretical Sciences, 8(1), 133-142.

[14] Diken, B., Kayışoğlu, B. (2020). Determination of Biomass Potential From Field Products Waste in Tekirdağ Province, Journal of Agricultural Machinery Science, 16(3),12-17.

[15] Gürel, B. (2020). Determination of Current Biomass Potential in Turkey and Calculation of Sectoral and Total Combustion Energy Values for Wastes Which are A Good Alternative for Energy Production by Combustion, Journal of Engineering Sciences and Design, 8(2), 407 – 416.
[16] Anonim 2021a. https://www.enerjigunlugu.net/usakta-atik-camurlar-elektrige-donusecek-30471h.htm (Erişim Tarihi:05.06.2021).
[17] Anonim 2021b. TÜİK, Veritabanları, Tarım. http://www.tuik.gov.tr/PreTabloArama.do.(Erişim Tarihi:05.06.2021).
[18] Öztürk, H., Başçetinçelik, A. (2006). Energy Exploitation of Agricultural Biomass Potential in Turkey. Energy Exploration and Exploitation, 24(9), 313-330.
[19] Yildiz, S., Yaman, C., Demir, G., Ozcan, H. K., Coban, A., Okten, H. E., Goren, S. (2013). Characterization of municipal solid waste in Istanbul, Turkey. Environmental Progress & Sustainable Energy, 32(3), 734-739.