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The Potential of Energy Production and Greenhouse Gases Emission Reduction from Households Organic Waste in Bandar Lampung, Indonesia

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Abstract. Households Organic Waste (HOW) is the type of waste dominantly found in the Bakung landfill, Bandar Lampung. It is because HOW from the settlements is only collected and transported to the landfill without any recycling treatment. A study was carried out to determine the potential of biogas generation and greenhouse gases (GHG) emission reduction related to the rate of generation waste, composition, and characteristics of HOW in Bandar Lampung city. The method for collecting sample and analysis procedure in this work was following into SNI 19-3964-1994. From the data results of sampling and measurement, it was known that the average HOW generation rate was 0.11 kg/person/day, which consists of 26.39% of vegetable scraps, 44.83% of fruit scraps, and 28.79% ripe food scraps. The Total Solids (TS) of HOW was 6.70%. Utilization of HOW to produce biogas was conducted through crushing the HOW in the crusher by adding water with ratio water, and HOW was 3:1. Based on estimation production data of HOW in 2020, it was estimated that Bandar Lampung city could produce about 1.40 million m^3 of CH_4/year, which is equivalent to 1.07 million kg of LPG. Meanwhile, converting HOW to produce biogas, it was estimated will reduce 21.09 million kg of CO_2-eq/year of GHG emissions.

1. Introduction

Population growth and urbanization in developing countries created new environmental problems, one of which is increasing municipal solid waste (MSW) production [1-3]. The types of MSW that are often found include food waste, paper, glass, textile, and others [4,5]. MSW in surrounding Bandar Lampung city usually transported from home and then it gathered to Bakung Landfill [6]. The Bakung Landfill is operated on open dumping [5,6] as a result the rooting process of the garbage produces an unpleasant odor, destroys environmental scenery, and so on [3,7,8]. In addition, the decomposition process of garbage is commonly produced leachate, which can contaminate soil and water. This problem commonly occurs due to not any sorting process of MSW. Thus, the mixed composition of garbage leads the landfill overcapacity [9].

In Indonesia, especially in Bandar Lampung city, household waste is only collected and then transported to the landfill without any prior separation. Household organic waste (HOW) usually consists of vegetable scraps, fruit scraps, and ripe food scraps. Therefore, the type of MSW that was mostly found in Bakung Landfill was food waste which reached 61.96% as presented in Table 1. [5]. Food waste is organic MSW that is produced due to the handling, storage, sale, cooking and serving of food [10]. The main source of food waste is household activities, hotels, canteens, and others [11]. The high water content makes organic waste difficult to burn, process, or recycle [10].

Table 1. Composition of waste from Bakung Landfill, Bandar Lampung [5]

No	Type of waste	Composition (%)
1	Food waste	61.96
2	Paperboard	4.65
3	Nappies	4.19
4	Garden waste	2.81
5	Wood	0.94
6	Rubber and leather	0.07
7	Fabrics / textiles	6.77
8	Plastic	14.47
9	Metal	0.78
10	Glass	3.36

The waste-to-energy concept is an economical and sustainable way of processing MSW to solve waste and environmental problems [12,13]. Organic waste has a high calorific value [14,15] so that it can be converted into energy [15,16]. Anaerobic digestion is a method of organic waste management that is widely used to produce energy in the form of biogas [17, 18]. Biogas can be used as fuel and generators of electricity [19]. The benefits of applying biogas technology include generating energy and reducing waste [11], which also reduces greenhouse gases (GHG) emissions [18]. The biogas components are shown in Table 2.

Table 2. Biogas composition [13]

No	Component	Chemical Formulas	Composition (%)
1	Methane	CH_4	50-75
2	Carbon dioxide	CO_2	25-50
3	Nitrogen	N_2	0-10
4	Hydrogen	H_2	0-1
5	Hydrogen sulphide	H_2S	0-3
6	Oxygen	O_2	0

The gases collected from the anaerobic conversion of waste in landfills are included in the GHG group [5]. GHG produced in the landfill in the form of CH_4 gas, and N_2O gas is equivalent to the emission of 25 kg CO_2-eq/kg CH_4 and 298 kg CO_2-eq/kg N_2O [20]. In anaerobic digestion, CH_4 gas can be converted into energy, and N_2O gas is not produced [21]. Therefore, compared to anaerobic conversion in landfills, anaerobic digestion will contribute better to reducing GHG emissions [22].

Rasyid et al. (2015) [23] has researched the potential of organic waste from traditional markets in Bandar Lampung as compost and biogas. On the other hand, Iryani et al. (2019) [5] have also researched the estimation of GHG emissions in Bakung Landfill, Bandar Lampung. However, no study has been found on the energy potential and reduction of GHG emissions from household organic waste in Bandar Lampung. Therefore, this research will focus on analyzing the potential of energy production and greenhouse gases emission reduction from household organic waste in Bandar Lampung. This is based on the increasing amount of waste generated in the Bakung landfill, reaching

750-800 tons/day [24]. With this study, it is hoped that it can become a reference in managing household organic waste so that it does not accumulate in landfills and cause environmental problems.

2. Research Methods

2.1. HOW sampling method
The sampling method in this study refers to the standard SNI 19-3964-1994 to determine the rate of generation and composition of HOW. HOW samples were taken from 10 households in Kali Balau Kencana Village, Bandar Lampung City. Then HOW is classified into 3 categories, namely vegetable waste, fruit waste, and ripe food waste. Each waste category is then weighed and the percentage calculated based on equation 1 [5] below:

$$W_i(\%) = \frac{Weight\ HOW\ type\ i}{HOW\ total\ weight} \times 100\% \quad (1)$$

2.2. Laboratory analysis methods
Laboratory analysis was carried out on HOW samples that had been crushed using a crusher with a ratio of water to HOW of 3: 1. The parameters tested include temperature, pH, chemical oxygen demand (COD), total solids (TS), and C/N ratio.

2.2.1. Temperature testing. Temperature testing was carried out using the APHA AWWA WEF 23rd Edition 2017 [25] Part 2550 B. The thermometer was immersed in the sample until the thermometer showed a stable value and then recorded the temperature reading.

2.2.2. pH testing. The pH test was carried out using the APHA AWWA WEF 23rd Edition 2017 [25] Part 4500 - H + B method. The electrodes on the pH meter were rinsed with distilled water three times and dried with a tissue. Immerse the electrode in the sample until the pH meter shows a steady reading and then record the pH reading.

2.2.3. COD testing. COD testing was carried out using the APHA AWWA WEF 23rd Edition 2017 [25] Part 5220 D. Take a sample of 2.5 ml, then add 1.5 ml of digestion solution and 3.5 ml of sulfuric acid reagent. The sample and reagent mixture reflux at a temperature of 150^{o}C for 2 hours. Cool to room temperature and test using a spectrophotometer at a wavelength of 420 nm.

2.2.4. TS testing. TS testing was conducted on household organic waste and juice household organic waste samples. TS testing was performed using the APHA AWWA WEF 23rd Edition 2017 [25] Part 2540 B. Take a number of homogenized samples and pour them into a plate with a known weight. Weigh it to find the wet sample + plate weight. Then dry the sample + plate using the oven for ≥ 1 hour at 103-105^{o}C until dry. Cool and weigh dry sample + plate.

The TS calculation is based on equation 2 as follows:

$$TS(\%) = \frac{(A - C)}{(B - C)} \times 100\% \quad (2)$$

Where,
A = dry sample weight + plate (mg)
B = wet sample weight + plate(mg)
C = the weight of the plate (mg)

2.2.5. Ultimate analysis. The contents of C, H, N, and O were tested by placing a sample of 20 mg TS analysis results on thin foil then put into the Elementar Analyzer at a temperature of 1200°C for 30 seconds.

2.3. The method of calculating the estimated rate of HOW generation

The amount of HOW disposed of by one resident is obtained from the sampling result data in the form of calculating the average HOW generation rate. Then the number of HOWs in Bandar Lampung City can be calculated by equation 3 [5] as follows:

$$R = Population \times rate\ of\ HOW\ generation \tag{3}$$

2.4. The method of calculating the estimated energy potential

The amount of potential energy in the form of biogas from HOW is calculated based on equation 4 [26] as follows:

$$TBP = AOM \times C \times ER \tag{4}$$

where,
TBP = total biogas potential (m^3/year)
AOM = annual organic matter
C = number of people
ER = experimental results (m^3/ton)

2.5. The method of calculating the estimated greenhouse gases reduction

The calculation of GHG emissions in MSW processing is biologically influenced by CH_4 and N_2O emissions. However, in anaerobic digestion, N_2O emission is assumed to be absent [21]. Then the estimated GHG reduction is calculated based on the CH_4 emission factor according to equation 5 as follows:

$$CH_4\ Emission\ (kg\ CO_{2\,eq}) = weight\ of\ CH_4 \times 21 \tag{5}$$

3. Results and Discussion

3.1. Generation rate and composition of HOW

Based on the data obtained in this study, the rate of generation and composition of HOW varies depending on the type of waste found in each household. After sampling and calculation, the rate of HOW generation is presented in Figure 1 with an average AOM = 0.11 kg HOW/person/day. Meanwhile, the composition of HOW is divided into 3 types, namely food scraps, fruit scraps, and vegetable scraps, as shown in Figure 2.

If it is known that the population data for the population of Bandar Lampung City in 2020, C = 1,068,982 people [27], the estimated rate of HOW generation in 2020 can be calculated using equation 3, which is 42,396.79 tonnes HOW/year. If processed using anaerobic digestion technology, this large amount of HOW will produce energy and reduce environmental pollution due to waste. In addition, anaerobic digestion technology also produces digestates used as organic liquid fertilizers.

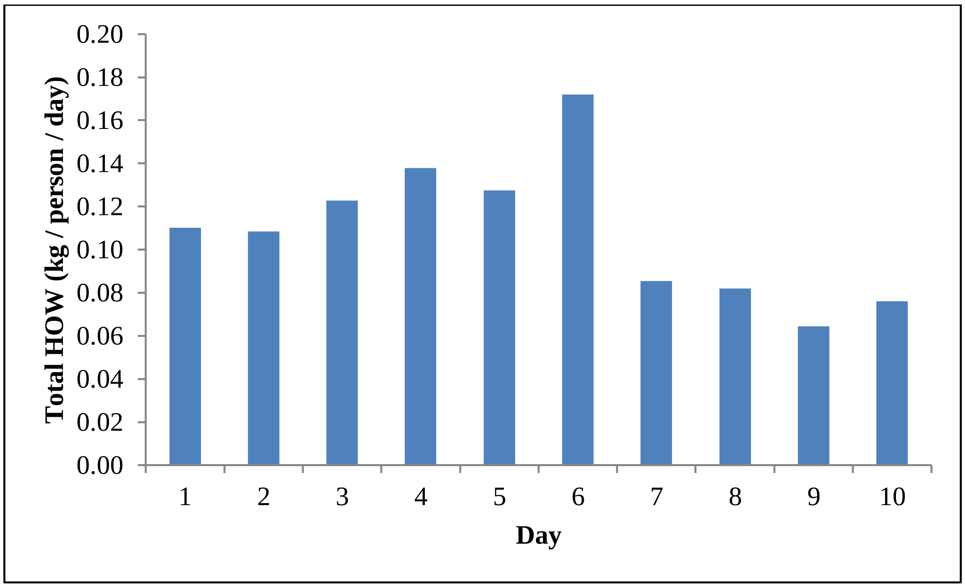

Figure 1. Total generated of HOW

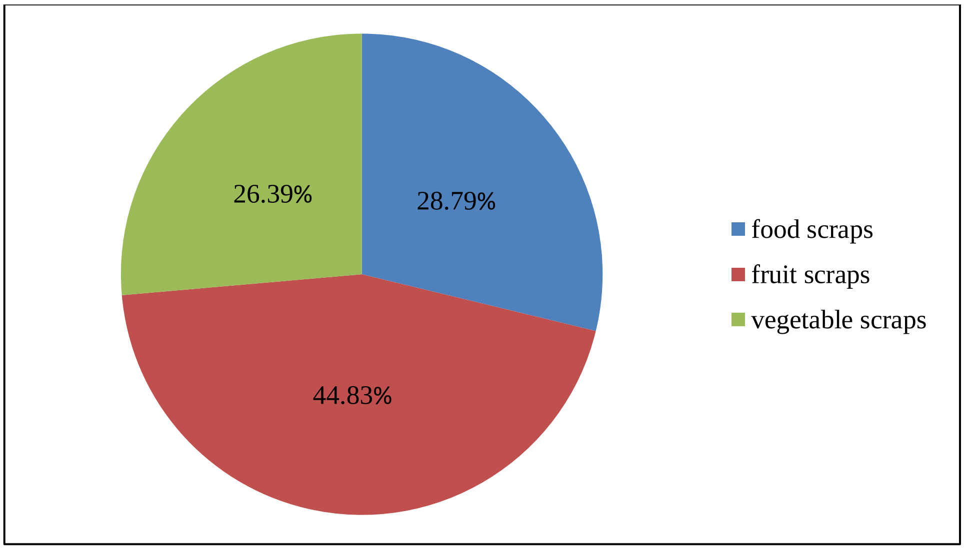

Figure 2. Composition of HOW

3.2. HOW characteristics
Laboratory analysis was carried out on HOW characteristics in the form of temperature, pH, COD, TS, and ultimate content.

3.2.1. Temperature. Temperature is a factor that affects the survival of microorganisms in the anaerobic digestion process. Temperature fluctuations can benefit one group of microorganisms but harm another group of microorganisms. Changes in the activity of microorganisms will affect the production of biogas so the optimum temperature range is very important to observe. Ahamed et al. (2016) [28] reported that in the temperature range 29-35 ^{o}C, biogas production will increase when operating temperatures are high. In this study, slurry HOW was produced with various temperatures ranging from 24.5-32.6 ^{o}C, as shown in Figure 3.

With an average sample temperature of 28.4ºC, it indicates that if this sample is used as a biogas feedstock, the anaerobic digestion process takes place in mesophilic conditions. In this condition, the process of decomposing organic matter will take a long time [23]. However, the mesophilic conditions have a greater variety of microorganisms, and lower processing costs so that it is more profitable [29].

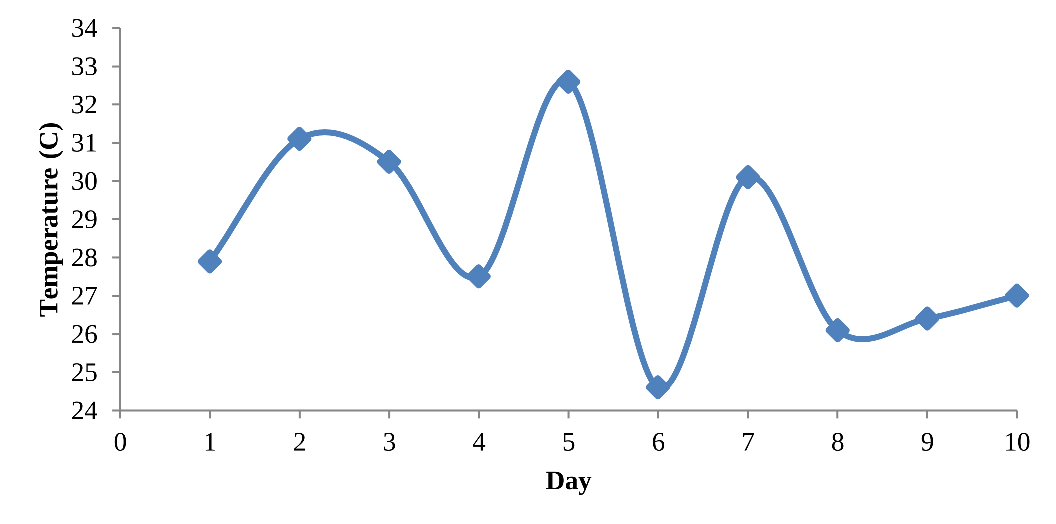

Figure 3. Temperature graph of each HOW sample

3.2.2. *pH*. pH is an essential parameter in the anaerobic digestion process. The results show that the average pH value of the HOW sample is 5.68, which can be seen in Figure 4. According to Hultman and Alshwan (2019) [29], the optimum pH value in the hydrolysis and acidogenesis stages is in the range of 5.5-6.5, so this sample has an appropriate pH value for the biogas feedstock.

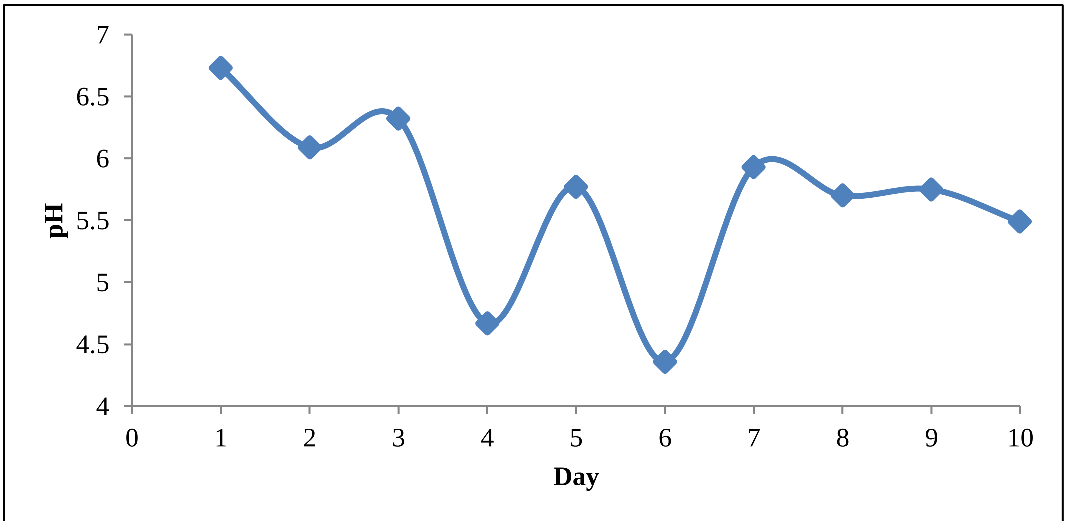

Figure 4. Graph of pH of each HOW sample

3.2.3. *Chemical Oxygen Demand*. COD is a water quality parameter that can determine the amount of organic matter in the water. From the test results, the average COD sample HOW was 22.57 mg/L, as shown in Figure 5. The greater the COD in a sample, the more substrate that can be converted to biogas [30]. In the anaerobic digestion process, COD levels will decrease along with the reduction of organic matter in the substrate because it has been converted to biogas.

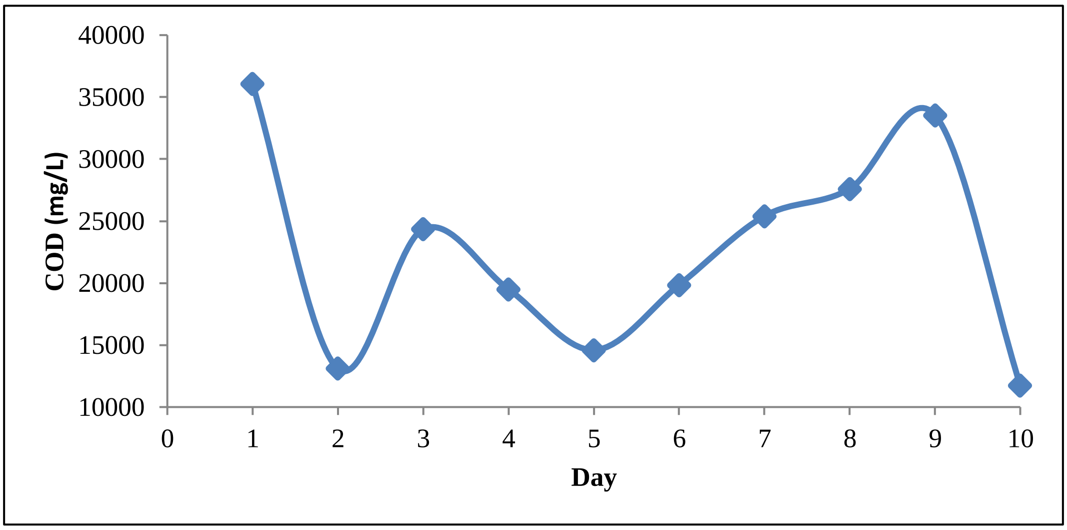

Figure 5. Graph of COD levels for each HOW sample

3.2.4. *Total solids.* The average TS of HOW samples obtained in this study was 6.70%, and HOW juice was 3.79% (Figure 6) which was included in the wet substrate type [31,32]. Yi et al. [31] reported that under mesophilic conditions, the production of biogas and CH_4 gas increased with increasing TS levels of the substrate.

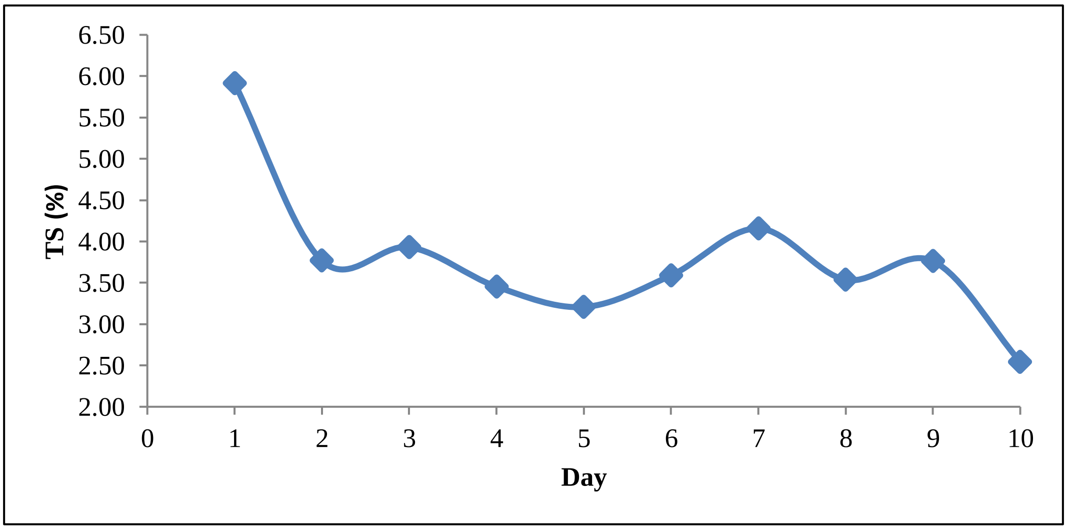

Figure 6. Graph of TS levels for each HOW sample

3.2.5. Ultimate analysis. Carbon is the main energy source in the process of decomposing organic matter, while nitrogen contributes to the growth of decomposing microorganisms [29]. The optimal substrate C/N ratio is in the range of 20-25. If the C/N ratio is too low or too high will produce biogas with low CH_4 levels [33]. The results showed that the C/N ratio of the sample mean 18.92, which is shown in Figure 7.

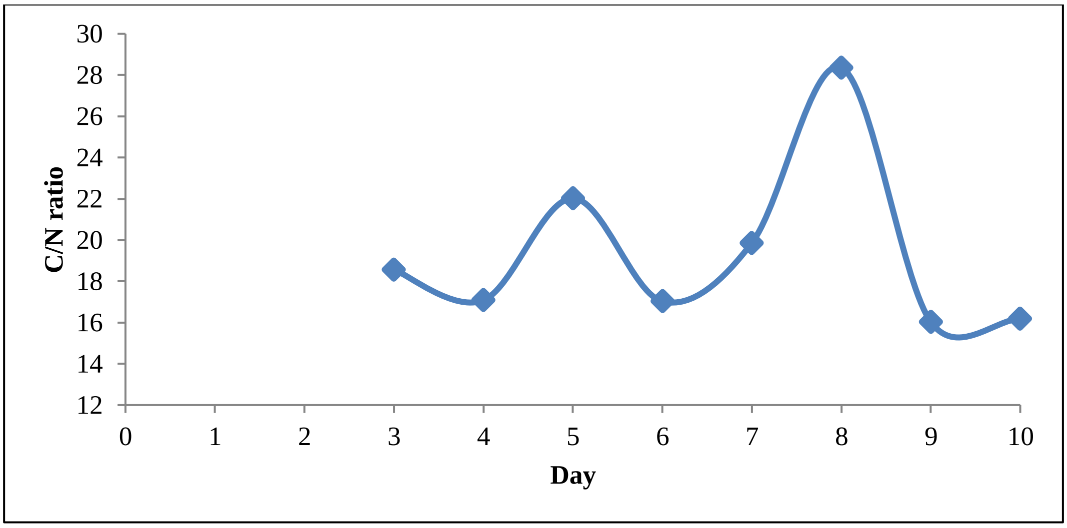

Figure 7. Graph of C/N ratio for each HOW sample

3.3. Energy potential

The high number of HOWs indicates that the city of Bandar Lampung is rich in resources that can be used as raw material for biogas production. The estimated potential energy generated is calculated using Equation 4. The AOM data obtained from the sampling results are converted into tonnes of TS/person/year so that AOM = 0.0027 tonnes TS/person/year. The results of experiments conducted by Shamurad et al. (2020) [17] provided biogas production data, ER = 495 m^3 CH_4/ton TS. Using these data, it can be calculated that the potential energy generated from processing HOW into biogas is 1,406,089.48 m^3 CH_4/year, which is equivalent to 1,072,441.13 kg of LPG gas. This energy potential is expected to be a good opportunity to reduce the use of fossil fuels and reduce GHG emissions.

3.4. Potential for reducing greenhouse gases

World GHG emissions continue to increase due to the use of fossil fuels. It is hoped that the processing of HOW into biogas can contribute to the mitigation of GHG emissions. In this study, the estimation of GHG reduction using equation 5. The estimation results show that processing HOW in Bandar Lampung into biogas can reduce GHG emissions by 21,091,342.21 kg CO_2-eq / year.

4. Conclusion

This research focuses on the lack of attention regarding HOW which can cause various problems for the environment. The results showed that the city of Bandar Lampung could produce energy of 1,406,089.48 m^3 CH_4/year which is equivalent to 1,072,441.13 kg of LPG gas. In addition, GHG emissions can also be reduced by 21,091,342.21 kg CO_2-eq/year. The results of this study aim to show the importance of waste management in circular economy and environmental quality. In the future, energy potential and GHG reduction can be made more accurately using actual research data. Thus, this analysis is made to support government regulation and investment in the waste management sector, especially household organic waste.

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