Design of Organic Waste-based Biogas Lamp for Low Light Area in Universitas Pertamina

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Abstract. Organic waste often has a negative impact on the environment due to the speed of its decomposition. By the production of 31.51% of organic waste at Universitas Pertamina, it has the potential to produce disease vectors and bad aesthetics if not managed properly. In line with the vision and mission of Universitas Pertamina in the energy sector, this study aims to design biogas lamp made from biodegradable waste for the campus area. The location of the placement of the biogas lamp is planned in a low light and safe area for the biodigester installation. There were three alternative designs for biogas lamp circuits (conversion of gas to electricity with a generator, automatic ignition gas lamp, manual ignition gas lamp), the second alternative was selected using the analytical hierarchy process (AHP) method. The design was planned to process 100% biodegradable waste generation at Universitas Pertamina, which produce 0.63 m^3 of methane gas with the ability to turn on the biogas lamp for five days (3 hours/day). Purification of biogas was done by adding zeolite at the installation as much as 0.75 kg/year. The volume of the biodigester required was 1.38m3 as much as 2 units with the addition of a gas regulator and a biogas purification tube in the installation circuit. This series of biogas lighting installations requires an investment of IDR 20 millions with the installation location planning to be in the campus drop-off area.

Keywords: Organic waste, Biogas lamp, Biodigester, Zeolite, Analytical hierarchy.

1 Introduction

The problem of waste in Indonesia is very complicated, making it endlessly discussed by researchers and academics [1],[2],[3],[4],[5],[6],[7],[8],[9],[10],[11],[12],[13],[14],[15]. Jakarta as the nation's capital is not immune from waste problems, including the percentage of waste handling which is very small compared to the amount of waste generated. What's more, the waste does not undergo any processing before being sent to landfills. One type of waste with the largest composition of Jakarta's waste is organic waste (food waste). This type of waste

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needs fast handling if you don't want the development of disease vectors due to rapid decomposition [2],[3].

The waste problem also comes from Universitas Pertamina. As a university that is only 6 years old, the waste management system is still not well managed. Even though segregated trash bins have been provided in many corners of the university, when they are collected at the temporary dump site, the waste is mixed again to be taken to third parties for further management. This condition can reduce the motivation of the campus community in the spirit of sorting waste at the source and cause distrust of waste management. In addition, the potential for the development of disease vectors is very large because food waste is the largest generation, namely 31.51% among other types of waste [16].

So far, composting is a type of organic waste processing that is usually carried out by Indonesian people due to its ease of operation [17], [18]. However, in line with Universitas Pertamina's vision and mission of wanting to become a world-class university in the energy sector no later than 2035, processing organic waste into biogas is one of the new innovations that needs to be developed [19]. The length of the series of activities on campus requires lecturers, staff, and students to be on campus until evening. This is not supported by sufficient lighting in every corner of the campus area, causing inconvenience to the campus community. This study aims to design a biogas lamp in order to provide sufficient lighting for corners of the campus that are poorly lit, as well as predict the potential environmental impacts caused by this design. Besides that, biogas lamps based on organic waste can also be an educational tool for students and researchers to develop better waste management knowledge [14].

Biogas lamps is included in new renewable energy (NRE) which is currently being a national conversation to continue to be improved. According to the Head of the National Research and Innovation Agency (BRIN) Laksana Tri Handoko, the use of NRE is not only to improve the national economy, but can also provide benefits for the environment. The Minister of Energy and Mineral Resources Arifin said that the contribution of NRE to the national energy mix in 2021 reached 11.2% which was still far from the target that Indonesia had to achieve, which was 23% in 2025 [20].

2 Methods

This research begins with collecting data on the generation of food waste which will be used as raw material in the production of biogas. The amount of food waste generated will determine the capacity of the biogas reactor to be designed. In this study, there were 3 design alternatives that will be compared the performance using the Analitycal Hierarchy Process (AHP) method. The design alternatives are differentiated based on the location of the biogas lamp placement, the shape of the reactor, and the type of biogas lamp. In the alternative test with the AHP method, there are 3 parameters compared to the alternative design, namely the area of land used, the investment cost of the product, and the amount of energy produced. After obtaining the selected alternative from the use of the AHP method, a detailed design of the selected alternative is carried out. The detailed design consists of 2 parts, namely the design for the biodigester unit and the biogas lamp unit. After detailed design of the biogas lamp system, an estimate of investment costs, operational costs and maintenance costs were carried out. Layout and Standard Operation Procedure (SOP) for the use of biogas lamps are also discussed in this study.

AHP method

The Analytical Hierarchy Process (AHP) method is often used in solving a problem that is not simple and orderly, namely by providing an assessment of several variables based on the subjective perspective of the reviewer and determining the selected variable as a priority in solving the problem [21]. The working steps of the AHP method are [21]:

1. Define the problem and determine the purpose of the problem you have
2. Arrange a complex problem framework into a hierarchy so that problems can be reviewed in detail and structured
3. Prioritize each problem element in the hierarchy
4. Test the consistency of the comparison between elements.

3 Results

3.1 Existing Conditions of the Universitas Pertamina

In the existing conditions at the Universitas Pertamina complex, several types of waste are generated every day, namely leaves, plastic, paper, rubber, styrofoam, food scraps, pet bottles, glass, metal, and others. Leftover food is the highest percentage of waste generation, which is 31.51% with an average total waste generation per day of 190.68 kg in units of weight. Types of waste in the Universitas Pertamina complex that are biodegradable and can be used as biogas energy include leaf, paper, and food waste. Based on the three characteristics of the waste, the amount generated per day is 427.98 kg in units of weight. Meanwhile, there is no further processing of the waste produced by the Universitas Pertamina complex every day. The waste that has been generated will be collected and immediately transported to the next processing site, and no waste processing is carried out [22].

3.2 Alternative Biogas Lamp Designs

There are 3 alternative designs for the installation of the University's food waste processing into biogas lamps (see Fig. 1), including:

1. Alternative 1:

• The location of the placement of LED lights is in front of the canteen hallway because the canteen lobby area is one of the areas with minimal light at night. The canteen lobby area which is on the ground floor has a rooftop, so that the generator is not exposed to rain which can reduce the budget costs incurred for installing water resistance.

• The biodigester will be placed in the canteen lobby area adjacent to the generator because if the biodigester is placed far from the generator it will increase the cost of the biogas flow hose. The canteen lobby area has a rooftop so that the biodigester is not exposed to rainwater.

• The biodigester uses a centralized system with several considerations, namely: (a) The land used if using the local system is sufficient, but this will interfere with the effective use of the land in front of the canteen hall which is used as a car park, (b) Facilitate the direct distribution of biogas to generators , using a local system will increase the cost of the hose, (c) A centralized system is cheaper than a local system, (d) Placing organic waste is also easier because it is directly put together and put into the biodigester, while organic waste in the local system will be divided first as needed

2. Alternative 2:

• The biogas lamp placement location is in the drop off area because the drop off area is one of the areas with minimal light at night. The biogas lamp has a shield made of glass so it is safe to place it in an open drop off area.

• The biodegester will be placed in a drop off adjacent to the biogas lamp because if the biodigester is placed far from the biogas lamp it will increase the cost of the biogas flow hose. The biodigester is safe if it is placed in a closed or open place, such as in the drop off area.

• Biodegester uses a centralized system with several considerations, namely:

a. The land used if using the local system is sufficient, however this will interfere with the effective use of the land in front of the drop off which is used as a parking area and as a shuttle boundary.

b. Placement of the biodigester and biogas lamp are placed parallel to facilitate the distribution of biogas to the biogas lamp.

c. Centralized systems are cheaper than local systems.

d. Placing organic waste is also easier because it is immediately put together and put into the biodigester, while organic waste in the local system will be divided first according to needs.

3. Alternative 3:

• The location of the placement of the lights is in front of "Gor ABC" because in front of Gor ABC is one of the areas with minimal light at night. The lamp has a shield made of glass so that it is safe to place in front of the open Gor ABC.

• The biodigester will be placed in front of Gor ABC adjacent to the lights because if the biodigester is placed far from the lights it will increase the cost of the biogas flow hose. The biodigester is safe if it is placed in a closed or open place, such as in front of the Gor ABC.

• Biodegester uses the local system with several considerations, namely:

a. The land in front of Gor ABC is sufficient if using the local system and does not interfere with the effective use of the land in front of Gor ABC

b. Facilitate the flow of biogas to the lamp. If the biodigester uses a centralized system, it will be difficult for the flow of biogas due to the abstract placement of the lights following the existing layout.

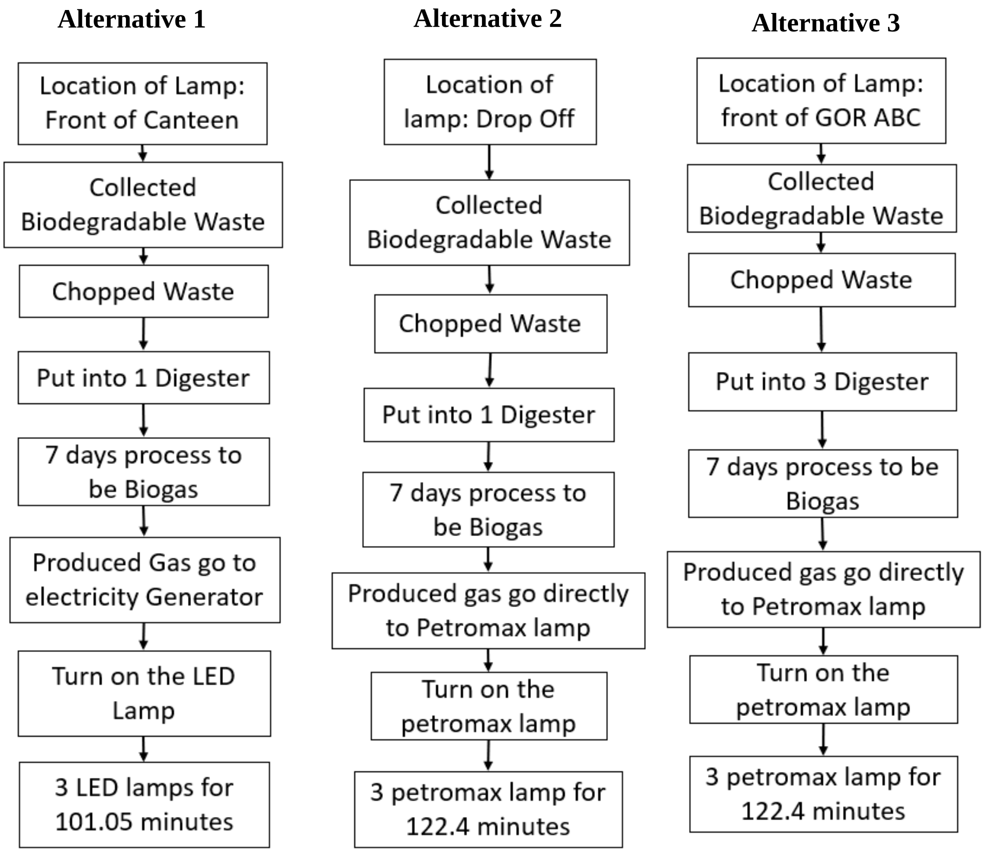

Fig. 1 Alternative biogas processing scheme

3.3 Selection of alternative designs using the AHP method

For the parameter of land area, alternative 2 (biodigester 0.43 m^2, lamp holder 1.2 m^2) requires the least land area compared to alternative 1 (biodigester 0.43 m^2, generator set 0.32 m^2, lamp holder 1.2 m^2) and alternative 3 (biodigester 0.93m^2, lamp base 1.2 m^2). As for investment costs, alternative 2 ranks first in terms of cheapness (1.3 million IDR), followed by alternative 3 (1.6 million IDR), and the most expensive alternative 1 (2.6 million IDR). In terms of the energy produced by the waste processing installation into biogas, the three alternatives have different energy outputs because they have different ways of using the biogas to turn into lamps. For 1m^3 of biogas produced, alternative 1 is capable of turning on 3 LED lamps of 30 watt for 101.05 minutes, while alternatives 2 and 3 are each capable of turning on 3 petromax lamps for 122.4 minutes. By comparing criteria with criteria, calculating normalization, weights, index consistency, and ratio consistency for the three parameters above, alternative 2 is obtained as the selected design alternative.

3.4 Detailed Alternative Design 2

The parts of the biogas lamp installation consist of a biodigester, gas reservoir, gas hose (Sallery Gas Regulator), lamp, methane gas purification section. With the generation of Pertamina University biodegradable waste of 1104.30 kg/week in 2022 (equivalent to 800 liters of waste per week), it takes 1104.30 kg of water to be put into the anaerobic reactor, and will produce sludge with a total amount of waste and water (2208.60 kg/week).

Based on previous research, it is known that the volume of gas produced from 1 m^3 of waste volume is 1.5 m^3 of gas [23]. Of the gas content produced, 52.51% is methane gas which can be used as energy for lighting biogas lamps [24]. With a waste volume of 800 liters, it will be able to produce around 0.6296 m^3 of pure CH_4. Under conditions of petromax lighting that requires at least 0.04 m^3/hour of methane gas (equivalent to 20 watts of LED lamps), then 1 petromax lamp for this reactor can live for 5 days for a duration of 3 hours each day.

The use of zeolite is needed to purify methane gas which is mixed with other gases. Based on the literature, 2.5 kg of zeolite can be used to purify 4m^3 of gas produced by biogas. Meanwhile, 1 m3 of biodegradable waste can produce 1.5 m3 of gas [25]. Based on this equation, it takes about 0.75 kg of zeolite for methane gas purification with a maximum use of 1 year.

The volume of biodigester (closed block) with a capacity of 1000 liters on the market has a length of 1.2 m, a width of 1 m and a height of 1.15 m (Vtotal = 1.38 m^3). With the use of 2 reactors, 2.4 m^2 of clean land area is required, plus a distance of 25cm between the reactor and the outside of the reactor (total land area required is 5.1 m^2). Then for gas storage use 1 baloon gas tube with a gas storage capacity of 1m^3 (available on the market with a thickness of 0.17 mm, length 200 cm, and a diameter of 80 cm). The gas storage is placed above the middle of the two biodigesters because later the gas produced by the two biodigesters will be channeled first to the methane purifier and then channeled into the gas storage. Later the gas storage which will be placed on top of the wall will use a wooden support to ensure that the gas reservoir does not fall and is safely on top. Wooden supports measuring 5 × 5 cm with a distance between gas reservoirs of 10 cm [26],[27].

For the gas hose, it takes 4m from the methane purifier to the biogas balloon tube and 25m from the biogas balloon tube to the petromax lamp. Meanwhile, the distance between the lamp and the gas reservoir is 17 m and the diameter of the gas hose is 0.01 m. Under these conditions, the land area for the gas hose is 0.47 m^2. With a lampside area of 0.4 m^2, and a gas purification tube area (zeolite media) of 0.156 m^2, it can be determined that the total area of land for the installation of this petromax biogas lamp is 8.89 m^2. For more details, the location of the lamp and lamp design can be seen in **Figure 2** and **Figure 3**.

Fig. 2 Location of Biogas Lamp: Drop Off at Universitas Pertamina

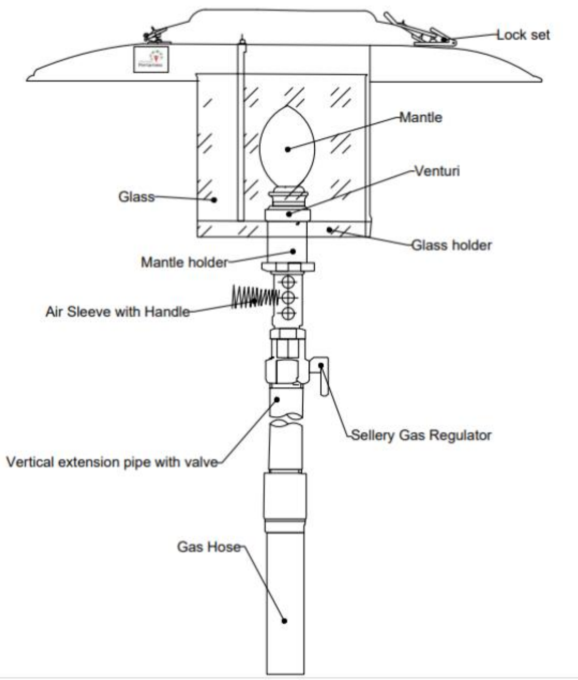

Fig. 3 Petromax Lamp Design at Universitas Pertamina

3.5 Draft Budget

In this Budget Plan (RAB) there are 3 parts, namely investment costs, operational costs and maintenance costs. The investment cost for the biogas lamp installation is 20.7 million IDR. Operational costs include the use of clean water to support the biogas fermentation process, the use of electricity for waste chopping machines, personal protective equipment for workers (helmets, masks, gloves), and workers' salaries [28],[29],[30]. Furthermore, the maintenance costs for this installation are for cleaning the tool, the cost of replacing the tool components (repair of tools such as trash carts, drums, hoses, petromax lamps, etc.)

3.6 Standar Operational Procedure (SOP) of Biogas Lamp

The procedure for making biogas [31] in this installation is as follows:

• Workers chop Biodegradable waste every day which is then weighed and then put into the garbage container located at Pertamina University TPS.

• Workers put chopped Biodegradable waste and clean water into a mixing container with a water to waste ratio of 1:1.

• Workers mix garbage and water using a manual mixer.

• Workers move the mixed waste and water to the drop off using a garbage cart.

• Workers put mixed waste into the digester.

• The process of enumerating, mixing, and entering the waste into the digester is carried out every day after the KBM process is completed or around 17.00 – 18.00 WIB.

• In each waste entry process, every Monday-Saturday, workers stir manually to produce the maximum volume of biogas.

• Waste that has been put into the digester is waited for 7 days until it produces biogas.

• During the process of forming biogas for 7 days, workers still ensure the cleanliness of the environment and ensure that the biodigester does not experience gas leaks.

The biogas lamp is operated by opening the valve and turning on the lights at night from 18.00-21.00 WIB every Monday-Friday. Meanwhile, on Sundays, the outlet cover was opened from the reactor to remove sludge which will be processed into fertilizer.

4 Conclusions

Processing waste into biogas use an anaerobic and closed process. The flow of processing waste into biogas is the University‘s waste collection, waste chopping using a chopper, mixing waste with clean water in a ratio of 1:1, and the process of forming biogas in the biodigester for 7 days. The biogas produced will be used as lighting in the Universitas Pertamina Area. The alternative chosen in the design of this Biogas lamp is the Sallerry Gas Regulator. The biodigester used is a centralized system and the biodigester and petromax lamp will be placed at the drop off. In designing this Biogas lamp, it can light 1 petromax lamp which is equivalent to a 20 Watt LED lamp, this petromax lamp can light up for 5 days with a duration of 3 hours per day. The selection of lights for 5 days is carried out Monday-Friday for 3 hours starting at 18.00 - 21.00 WIB in the Pertamina University Drop-off area. The selection of these hours is based on the urgency and needs of students or workers in the Universitas Pertamina area who need lighting in the Drop off area on working days and these hours.

References

[1] Muhashiby, M.I.N., Hasibuan, H.S., Wahyono, S.: Waste Management in Jakarta Recycle Center: Case Study of Pesanggrahan, Jakarta. IOP Conferebce Series: Earth and Environmental Science. Vol. 1, pp. 940. (2021). DOI:10.1088/1755-1315/940/1/012034

[2] Aprilia, A., Tezuka, T., Spaargaren, G.: Municipal Solid Waste Management with Citizen Participation: An Alternative Solution to Waste Problems in Jakarta, Indonesia. Green Energy and Technology. Vol. 66, pp 56-62. (2011). DOI:10.1007/978-4-431-53910-0_7

[3] Aprilia, A., Tezuka, T., Spaargaren, G.: Household Solid Waste Management in Jakarta, Indonesia: A Socio-Economic Evaluation. INTECH. (2012). DOI: 10.5772/51464

[4] Wulandhary, S., Soesilo, T.E.B., Moersidik, S.S., Asteria, D.: Protecting Water Resources by Sustainable Household Solid Waste Management in Jakarta, Indonesia. IOP Conference Series Earth and Environmental Science. Vol.1. pp 399. (2019). DOI:10.1088/1755-1315/399/1/012094

[5] Pasang, H., Moorse, G.A., Sitorus, G.: Neighbourhood-based Waste Management: A Solution for Solid Waste Problems in Jakarta, Indonesia. Waste Management. Vol. 27, No. 12, pp 1924-38. (2007). DOI:10.1016/j.wasman.2006.09.010

[6] Verawati, S., Tuti, R.W.D.: Policy Implementation of Solid Waste Management in South Jakarta. Jurnal Administrasi Publik. Vol. 10, No. 2, pp 118-126. (2020). DOI:10.31289/jap.v10i2.3107

[7] Putri, A.R., Fujimori, T., Takaoka, M.: Plastic Waste Management in Jakarta, Indonesia: Evaluation of Material Flow and Recycling Scheme. Journal of Material Cycles and Waste Management. Vol. 20, pp 2140-2149. (2018)

[8] The World Bank: Cleaning Up Indonesia’s Urban Soldi Waste. https://www.worldbank.org/en/news/press-release/2019/12/05/cleaning-up-indonesias-urban-solid-waste, accessed on April 2023

[9] Saraswati, S.W.: Waste Problem in Jakarta Will be Solved. https://greeneration.org/en/publication/green-info/waste-problem-in-jakarta-will-be-solved/, accessed on April 2023

[10] Aziz, A., Tobroni, M,I., Sutoyo, S.: Environmental Awareness Education Campaign through Videography at the Rawajati Waste Bank in South Jakarta. KnE Social Sciences. (2023). DOI:10.18502/kss.v8i2.12749

[11] Kristanto, G.A., Pratama, M.A., Rahmawati, D.F.: Estimation of Greenhouse Gas Emissions from Solid Waste Management and Wastewater Treatment in the Nizam Zachman Fishery Port, Jakarta, Indonesia. IOP Conference Series: Earth and Environmental Science. Vol.1, No. 1. (2020)
[12] Mohajit: Financial Prospect of the Waste to Energy Application for Solid Waste Management in Indonesia. Journal of Sustainable City and Urban Development. Vol. 1, pp 31-38. (2018)
[13] Budiharto, W.I.: Sustainability of Integrated Municipal Solid Waste Management (Case Study: Jakarta Recycle center Program in Pesanggrahan District, South Jakarta). Master Thesis, Universitas Indonesia. https://lib.ui.ac.id/detail?id=9999920517650&lokasi=lokal
[14] Rugatiri, J., Abidin, Z., Ismail, A.: Assessing Solid Waste Management Strategy in Higher Education Institution of Indonesia: A Case Study of IPB University. IOP Conference Series: Earth and Environmental Science. (2021). DOI 10.1088/1755-1315/771/1/012023
[15] German-Indonesian Chamber of Industry and Commerce: Indoensia's Waste Management Sector Still Going Strong. https://indonesien.ahk.de/en/infocenter/news/news-details/indonesias-waste-management-sector-still-going-strong, accessed on April 2023
[16] Ridhosari, B., Rahman, A.: Carbon Footprint Assessment at Universitas Pertamina from the Scope of Electricity, Transportation, and Waste Generation: toward a Green campus and Promotion of Environmental Sustainability. Journal of Cleaner Production. (2020). DOI:10.1016/j.jclepro.2019.119172
[17] Akhmad, A., Ulhasanah, N., Sari, M.M.: Desain Komposter Sampah Pasar sebagai Solusi Persampahan di Negara Berkembang (Studi Kasus: Jakarta, Indonesia). Jurnal Ilmu Lingkungan. Vol. 20. No. 2, pp 356-365. (2022)
[18] Ulhasanah, N., Sari, M.M., Akhmad, A.: The Mascot (Market Waste Composter) for Market Waste of Developing Country – Case Study: Jakarta, Indonesia. The Journal of Solid Waste technology and Management. Vol. 48. No. 3, pp 443-449. (2022)
[19] Poudel, M., Adhikari, P., Singh, R.M.: Potential of Biogas as Renewable Energy Technology and Its Role for the Conservation of Environment. American Journal of Engineering and Applied Sciences. Vol. 9, No. 4, pp 1158-1163. (2016). DOI:10.3844/ajeassp.2016.1158.1163
[20] Badan Riset dan Inovasi Nasional: Kepala BRIN: Pemanfaatan Energi Baru Terbarukan (EBT) Solusi Energi Masa Depan. https://brin.go.id/kepala-brin-pemanfaatan-energi-baru-terbarukan-ebt-solusienergi-masa-depan/ accessed on April 2022
[21] Parhusip, J.: Penerapan Metode Analytical Hierarchy Process (AHP) Pada Desain Sistem Pendukung Keputusan Pemilihan Calon Penerima Bantuan Pangan Non Tunai (BPNT) di Kota Palangka Raya. Undergraduate Thesis: Universitas Palangka Raya. (2019)
[22] Djatmiko, T.A.: Inventarisasi Jejak Karbon di Universitas Pertamina dari Aspek Penggunaan dan Pengelolaan Sampah dalam Upaya Pengurangan Emisi Karbon. Undergraduate Thesis: Universitas Pertamina. (2020)
[23] Sanjaya, D., Haryanto, A., Tamrin: Produksi Biogas dari Campuran Kotoran Sapi dengan Kotoran Ayam. Jurnal Teknik Pertanian Lampung. Vol. 4, No. 2, pp 127-136. (2017)
[24] Iriani, P., Heryadi, A.: Pemurnian Biogas Melalui Kolom Beradsorben Karbon Aktif. Sigma-Mu. Vol. 6, No.2. (2014)
[25] Mejadi, F., et al.: Purifikasi Biogas berbasis Absorbent Zeolit Diaktivasi KOH, dan NaOH terhadap Kualitas Biogas. Undergraduate Thesis: Politeknik Negri Madium. (2021)
[26] Pertiwiningrum, A.: Buku Instalasi Biogas. Yogyakarta: Universitas Gajah Mada. (2015)
[27] Prihatiningtyas, S., et al.: Biodigester untuk Biogas. Jombang: Universitas KH. Wahab Hasbullah. (2019)
[28] Razi, M., Turmizi, Ramzi: Pemanfaatan Limbah Kotoran Sapi sebagai Energi Alternatif untuk Skala Rumah Tangga: Studi Kasus Peternak Sapi di Desa Cot Girek Kota Lhokseumawe. Undergraduate Thesis: Politeknik Negri Lhokseumawe. (2018)
[29] Sahri, M., Fachruding, Setiawidayat, S.: Rancang Bangun Purwarupa Pembangkit Listrik Tenaga Biomassa. Undergraduate Thesis: Universitas- Widyagama Malang. (2019)

[30] Kalungan, T.R., Ilat, V., gamaliel, H.: Perlakuan Akuntansi Capital Expenditure dan Revenue Expenditure pada PT. Putra Karangetang. Jurnal Riset Akuntansi Ging Concern. pp 1044-1054. (2017)
[31] Gabriele: Analisis Penerapan Standar Operasional Prosedur (SOP) di Departemen Marketing dan HRD PT. Cahaya Indo Persada. Undergraduate Thesis: Universitas Kristen Petra. (2018)