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Analysis of The Utilization of Palm Oil Liquid Waste (Pome) As A Biogas Power Plant at Palm Oil Mill Bandar Pasir Mandoge

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Abstract. The development of oil palm plantations in Indonesia is so rapid. Palm oil produces liquid waste in the form of Palm Oil Mill Effluent (POME). POME waste, if left untreated, will result in environmental pollution, especially in aquatic ecosystems. The Pasir Mandoge Biogas Power Plant (BPP) is a power plant built by PTPN IV Bandar Pasir Mandoge which utilizes POME waste which is the product of the Pasir Mandoge Palm Oil Mill into a new and renewable energy source in the PTPN IV Bandar Pasir Mandoge area. This study aims to determine the process of utilizing POME waste as a Biogas Power Plant at the Palm Oil Mill Bandar Pasir Mandoge as well as the amount of POME waste and biogas volume needed to produce 1,1 x 2 MW of power. This research uses a qualitative approach. Data collection was carried out by interview, observation, and documentation methods. Data analysis uses data reduction, data presentation, and conclusions drawn. The results showed that the total volume of biogas produced from 1.320 tons of FFB was 23.760 m^3. With a production capacity of 60 Tons/Hour and POME produced at 60% with a production hour of 22 hours/day. Biogas produced per m^3 POME is $30m^3/m^3$ with a storage period of 44 hours. To produce 1,1 x 2 MW of power, it requires 2,640 tons of palm oil FFB, 1.584 m3 of POME waste, and 47,520 m^3 of biogas. To meet the capacity of 2 MW.

Keywords : :POM, POME, Biogas

1. INTRODUCTION

Oil palm is an important type of plantation crop in both the agricultural and plantation industries. Palm oil is the most important commodity in Indonesia, and its growth has been rapid. The environment, the physical characteristics of the land, and the chemical properties of the soil, or soil fertility, should all be considered when determining the ideal oil palm land. The physical and chemical properties of the soil, including soil structure and good soil drainage, need to be considered to obtain the best results from oil palm cultivation in commercial plantations. North Sumatra Province ranks second after Riau which has a huge potential for oil palm plantations in Indonesia [1].

The island of Sumatra has the largest area of plantation land up to 7,944,520 Ha, followed by the island of Kalimantan with an area of 5,820,406 Ha. In North Sumatra Province, the area of oil palm plantations was 1,372,273 hectares in 2019. Meanwhile, Asahan Regency, which is the case study in this study, has an oil palm plantation area of 77,147 hectares with Crude Palm Oil (CPO) production of 356,943 tons. The area of oil palm plantations in Asahan Regency consists of 1,202 Ha of Unproductive Plants, 75,346 Producing Plants, and 559 Ha of Damaged Plants/Non-Producing Plants. Of the total area, the oil palm plantation can produce as much as 4,737 Kg or 4.7 tons/Ha [2]

Simpang Empat District is one of the sub-districts in Asahan Regency that has a leading commodity in oil palm plantations. In Simpang Empat District, Bandar Pasir Mandoge has an oil palm plantation covering an area of 9,461 ha and produced 201,618.22 tons in 2015.

Based on this data, not a small amount of waste is produced from Palm Oil. Palm oil produces two types of waste: liquid waste and solid waste. Oil palm is a cultivated crop that produces 22% CPO, 5% kernels from the palm oil processing process in 1 ton will be able to produce waste in the form of empty fruit bunches (EFB) as much as 22% or 220 kg, shell waste (Shell) as much as 6% or 60 kg, palm sludge (sludge) 4% or 40 kg, Fiber 13% or 130 kg and liquid waste as much as 28% [3].

Palm oil mill liquid waste, also known as boiled condensate, crude oil purification waste, and sludge waste from the separation process, is liquid waste produced or derived from palm oil processing wastewater. The treatment unit produced the most POME liquid waste, followed by the clarification unit (60%), the boiling station (36%), and the core station (4%) [4]. POME has a high level of acidity and a lot of organic matter, so it will cause pollution problems if released directly into the environment. In addition, improper treatment of POME liquid waste can result in the emission of greenhouse gases (GHGs) into the air, which contributes to global warming and also has the potential to pollute the environment with high acidity levels and interfere with the survival of aquatic biota if released into waterways.

Research related to the utilization of POME waste has been carried out in several Palm Oil Mills (POM). The use of POME waste can reduce the environmental impact that occurs around the Palm Oil Mill in the long term. The Pasir Mandoge Biogas Power Plant is a power plant built by PTPN IV Bandar Pasir Mandoge which utilizes waste

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produced from the Pasir Mandoge Palm Oil Mill as a new and renewable energy source in the PTPN IV Bandar Pasir Mandoge area.

Research on the COD loading value generated from palm oil liquid waste energy as an alternative to power plants in POM using minimum and maximum chemical oxygen demand (COD) has obtained values of 240.034.40 kg COD/year to 360.051.60 kg COD/year. The production of CH_4 from palm oil liquid waste energy as an alternative to power generation uses a minimum and maximum COD of 75.610.834 Nm^3 CH_4/year to 113.416.25 Nm^3 CH_4/year. The potential for electrical energy generated from palm oil liquid waste energy as an alternative to power plants using minimum and maximum COD of 287,321,192 kWh/year and 430.981,75 kWh/year [6].

Previous research explained that producing electrical energy can be done by anaerobic processes to produce biogas, starting from the process of processing Fresh Fruit Bunches (FFB) into CPO and all palm oil mill production activities as well as solid waste (shells) and liquid waste (POME) as per a case study in Riau province. Where it is known that with a total production capacity of 6,584 tons/hour, it has a potential for liquid waste of 710,103,744 m3/year with electrical energy that can be generated 434.54 MW, with an electrical energy production of 2,476,849,990 kWh/year [8].

Furthermore, the analysis of the potential use of POME as a raw material for Biogas Power Plant at POM PT. Fajar Saudara Kusuma, located in Sambas Regency, West Kalimantan, is a private palm oil mill with a production capacity of 30 tons/hour. The type of data used in this analysis is secondary data which includes FFB data on processing and waste discharge produced by the factory. In 2016, the Biogas Power Plant of PT. Fajar Saudara Kusuma processed 112.533.22 tons of FFB by producing POME waste of 86.695.08 m3 and in 2017 palm oil mill processed 114.395.38 tons of FFB by producing POME waste of 88.706.80 m^3. Hasil analisa menunjukkan bahan baku Biogas Power Plant dapat membangkitkan daya listrik sebesar 4.596,187 MW pada tahun 2016 dan 4.703,86 MW pada tahun 2017 dengan biaya produksi sebesar Rp 661,00/kWh [9].

This study aims to conduct a study on the volume of liquid waste of POM PT. PN IV Bandar Pasir Mandoge in producing electrical energy managed by PT. Karya Mas Energy.

2. METHOD

2.1. Palm Oil Mill Effffluent (POME)

POME is a waste that has the potential to be converted into an alternative energy source, namely electrical energy. This waste is quite large in number and can be converted into biogas which can then be used as a source of electrical energy. The calculation of the POME flow of 1ton FFB yielded 0.6 m^3 of POME [6]. A palm oil mill with a capacity of 30 tons of FFB/hour that has utilized POME with the Covered Lagoon system will produce biogas ± 600 m^3/hour, or equivalent to an energy of 3,720 kWh. If the energy is used to generate electricity using a gas engine (35% efficiency), 1,303 kWh or 1.3 MW of electricity will be generated. Meanwhile, by using an anaerobic digester, biogas produced ± 28 m3/ton FFB.

The POM capacity of 60 tons of FFB/hour will produce biogas ± 840 m3/hour, or equivalent to an energy of 5,208 kWh. The electrical energy that can be generated by a gas engine (35% efficiency) is 1,822 kWh, or 1.8 MW, by using the general parameters of electrical energy consumption in palm oil processing plants, which is 17-19 kWh/ton FFB, the electricity potential of POME can be used as an energy source. The use of POME will provide added value while increasing profitability. Another benefit is reducing environmental impact and generating renewable energy [7]. POME is also palm oil waste that has high levels of Chemical Oxygen Demand (COD) and Biochemical Oxygen Demand (BOD), thereby damaging aquatic ecosystems and lowering dissolved oxygen (DO) levels. Identification of POME based on the photosynthesis process of Chlorella sp. using 380-780 nm artificial white LED lamps with variations in POME concentration levels of 10%, 20%, and 30%. Based on the measurement of dissolved oxygen (DO) levels, the DO values were 174.15%, 154.66%, 138.98% and the POME sensitivity value was 4 mV/% [10].

POME or palm oil liquid waste can also be used to produce energy that contributes to the reduction of greenhouse gas emissions through methane gas capture and conversion of biogas into electrical energy. The high energy potential in POME has generally not been exploited optimally. POME decay naturally produces biogas with the main content (62%) of methane gas (CH_4). In addition, a fairly high energy value is found in methane gas. CH4 gas has a calorific value of 50.1 MJ/Kg. if the methane density is 0.717 kg/m^3, then 1 m^3 of methane gas energy is equivalent to 35.9 MJ or about 10 kWh [7]. The characteristics of POME depend on the production process and the raw materials used. While a plant with advanced technology can process 150 MT FFB/hour and produce POME with COD as low as 16 g O_2/ml, a plant without advanced technology can process 2.5 MT and obtain POME with COD as high as 100 O_2/ml [6].

To determine the economic value of electricity produced by biogas power plants, the company's calculation standards are used in contrast to the calculations of the Intergovernmental Panel on Climate Change (IPCC) in measuring the amount of emissions produced from the degradation process of POME and Empty Fruit Bunches (EFB). The average emissions produced from the waste treatment sector every year reach 9,503 t-CO_2/year and economic value [11].

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POME is also a liquid waste from palm oil mills that still has fat content and can be used as a raw material for making biodiesel, but the large content of Free Fatty Acids (ALB) makes POME must be prepared before the esterification process is carried out. From a test, it is known the addition of zeolite adsorbents is activated. Preparation was carried out by heating POME at 60oC then degumming using 3% phosphate acid for 30 minutes, and continued with bleaching using activated charcoal with a ratio of 8:3 of POME weight (heated at 100^0 C for 1 hour). Adsorption is carried out at the time of esterification using active zeolite as much as 3% of the weight of POME heated at 60 ^{0}C for 4 hours. The results of the study showed that the best presentation of ALB reduction was in the treatment carried out by degumming, bleaching, and esterification with zeolite. The effectiveness of reducing ALB with this method reached 45.20% [12].

2.2 Conversion of Palm Oil Mill Effluent (POME) into Electrical Energy

The Biogas Power Plant provides a series of utilization options for palm oil mills. Mill managers can use biogas for 1) Fuel burners and boilers to replace some of the shell and fiber users, 2) Generate electricity for mill purposes to reduce fuel costs, 3) Generate electricity to be sold to PLN to increase revenue, 4) Energy needs in palm oil mills and potential profits are the basis for consideration when choosing biogas utilization options. The characteristics of the liquid waste of palm oil mills can be seen in Table 1.

Table 1. Characteristics of POME liquid waste [13]

No.	Parameter	Satuan	Kisaran
1	Biological Oxygen Demand (BOD)	mg/L	20.000 - 30.000
2	Chemical Oxygen Demand (COD)	mg/L	40.000 - 60.000
3	Total Suspended Solid (TSS)	mg/L	15.000 - 40.000
4	Total Solid (TS)	mg/L	30.000 - 70.000
5	Oils and Fats	mg/L	5.000 - 7.000
6	NH3-N	mg/L	30 – 40
7	Total N	mg/L	500 – 800
8	Temperature	oC	90 – 140
9	pH	-	4 – 5

The several equations to determine the value of the volume of biogas produced are as follows:

Produksi TBS = TBS olah x Waktu pengisian (1)

Volume POME = Rasio TBS x Produksi TBS (2)

Volume Biogas = 30 m^3 x Volume POME (3)

Nilai kalor = 33.600 kJ x Kualitas gas CH4 (4)

$$\text{Konsumsi Biogas} = \frac{\text{output gas Engine}}{\text{Efisiensi Elektrikal}} \quad (5)$$

Nilai energy (Joule) = kWh x 3.600 (6)

$$Total\ Fuel\ consumption = \frac{Nilai\ energi}{Nilai\ kalor} \quad (7)$$

$$Volume\ biogas/kWh = \frac{Volume\ Biogas}{Konsumsi\ Biogas} \quad (8)$$

2.3 POME Processing

POME treatment to treat waste with a solids content of less than 3%, and generally must operate in the mesophilic temperature range can be carried out by the closed pond design method. The operator must remove the waste fibrous solids before the decomposition process. In addition to this, it can also use a Continuous Stirred Tank Reactor (CSTR) better known as a contact reactor, usually built of concrete or metal shaped like a cylinder. The diameter as the ratio and height of the cylinder is small. This system is equipped with a checker, clarifier, or dissolved air flotation to concentrate biomass. CSTRs can operate at mesophilic or thermophilic temperatures. Furthermore, through an anaerobic process, the most significant liquid waste from the palm oil industry is palm oil mill wastewater (POME), where each ton of fresh fruit bunches will produce about 0.7-0.8 m^3 of POME waste. POME waste that comes out of the treatment process usually has a high temperature, ranging from 70 to 80°C, with an acidity level (pH) of around 4.56 to 4.98, COD (chemical oxygen demand) ranging from 4.56 to 4.98,57,000 to 60,400 mg/liter and Total Suspended Solids (SS) 0.23 – 5.44 g/L(2) [15] or better known as "Biogas". Biogas is made up of a mixture of various gases, mainly methane (CH4), carbon dioxide (CO2), and 1–5% of other gases, including hydrogen (H2). Gases are produced by bacteria that occur during the bio-degradation of organic matter under anaerobic conditions. Biogas has a high methane content which makes it a renewable energy source. Therefore, it is important to undergo a combustion process before being released into the atmosphere. Physical, chemical, and biological properties as well as other biomass potentials can affect the composition and yield of biogas [16].

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2.4. Methode

In the implementation of this research, a field study was carried out, namely a visit to the Biogas Power Plant owned by PT. Nusantara IV Plantation in Mandoge Village, Pasir Mandoge District, Asahan Regency, North Sumatra Province managed by PT. Karya Mas Energy. The time for conducting the research starts from January 20, 2023, to June 28, 2023. Field data collection was reviewed from the amount of potential palm oil liquid waste as a raw material for the Biogas Power Plant owned by Bandar Pasir Mandoge for the need for electrical energy in the oil palm processing process.

In this study, data collection was used to determine the results of electrical energy conversion produced from biogas power plants in the use of loads. In this method, the data that has been collected is then processed using mathematical calculation techniques to find out the results obtained from field data, so that the results of this research can be applied to the actual situation.

The potential of POME for biogas production can be determined from FFB data used at the Bandar Pasir Mandoge palm oil mill. The amount of FFB used in the Bandar Pasir Mandoge palm oil mill with a production capacity of 60 Tons/Hour in May 2023 is 25,523.02 tons. The average daily FFB production with 16 hours of production reached 823,323 tom with a ratio of 60%, so the total volume of POME produced from FFB production was 15,319,212 m^3. The average number of daily volumes produced is 763,262 m^3. In this case, FFB production data and POME waste are taken every day during production hours. All processes of the Biogas Plant in Bandar Pasir Mandoge are shown in Figure 1.

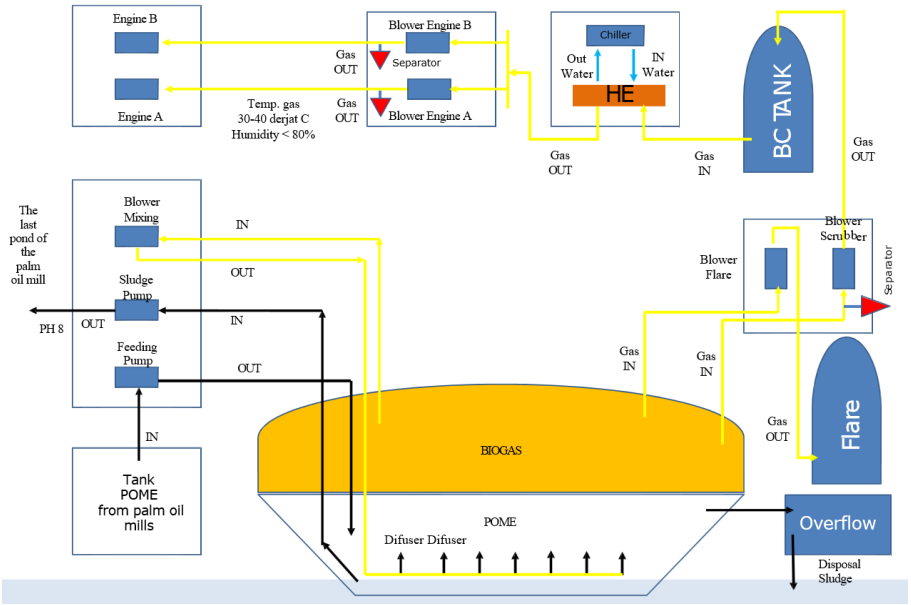

Figure 1. Flow Process of Biogas Power Plant Bandar Pasir Mandoge

3. RESULT AND DISCUSS

Based on data obtained in the field, the total volume of biogas at the Bandar Pasir Mandoge Asahan palm oil mill with a production capacity of 60 Tons/Hour and the ratio of POME waste produced is 60% in production hours for 22 hours/day. To produce 1.1 x 2MW of electrical power with the following mathematical calculation method: From equation (1), the amount of FFB produced during the filling period is obtained as follows:

$$\text{FFB Production} = \text{FFB Processing x filling Time}$$
$$\text{FFB Production} = 60 \text{ ton x } 22 \text{ Hours} = 1.320 \text{ Ton}$$

Based on the number of FFBs, the volume of the filling period is determined using equation (2),

$$\text{Volume POME} = \text{FFB Rayio x FFB Production}$$
$$\text{Volume POME} = 60\% \text{ x } 1.320 \text{ ton} = 792 \text{ m}^3\text{POME}$$

With a total POME volume of 792 m^3, the volume of biogas produced can be calculated by equation (3),

$$\text{Volume Biogas} = 30 \text{ m}^3\text{x Volume POME}$$
$$\text{Volume Biogas} = 30\text{m}^3\text{x } 792\text{m}^3 = 23.760 \text{ m}^3$$

Furthermore, the calorific value can be determined using equation 4, which is:

$$\text{Calorific Value} = 33.600 \text{ kJ x Quality Gas } CH_4$$
$$\text{Calorific Value} = 33.600 \text{ x } 55\% = 18.480 \text{ Kcal/kg}$$

Based on data sources obtained in the field to determine biogas consumption following equation 5,

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$$\text{Biogas Consumption} = \frac{\text{output gas Engine}}{\text{Electrical Efficiency}}$$

$$\text{Biogas Consumption} = \frac{1000\ \text{kWh}}{39\%} = 2.564\ \text{kWh}$$

So, the value of electrical power produced by biogas consumption by Gas engines based on the gas efficiency of the engine per unit is 2,564 kWh. Then to determine the energy (Joule) according to equation (6):

Energy Value (Joule) = kWh x 3.600

Energy Value (Joule) = 2.564 x 3.600 = 9.230.769 KJ

Thus, fuel consumption can be determined based on equation (7), namely:

$$Total\ Fuel\ consumption = \frac{Nilai\ energi}{Nilai\ kalor} = \frac{9.230.769}{18.480} = 500\ m^3/h$$

Meanwhile, the volume of biogas consumed by the gas engine to produce 1 kWh of electrical power can be determined in equation 8, namely:

$$Volume\ biogas/kWh = \frac{Volume\ Biogas}{Biogas\ Consumption}$$

$$Volume\ biogas/kWh = \frac{23.760\ m^3}{2.564\ kWh} = 9{,}26\ m^3/kWh$$

Based on the analysis, it is known that to produce 1MW of electric power requires a biogas volume of 23,760 m^3, then to meet the capacity of 1.1 x 2 MW with a total POME waste volume of 1 MW of 792 m^3 obtained a total volume of 1 MW of biogas of 23,760 m^3 and a total volume of 2 MW biogas of 47,520 m^3.

The results of the analysis using the mathematical calculation method related to the amount of POME waste volume and the volume of biogas needed to generate 1.1 x 2 MW of electrical power are shown in Table 2.

Tabel 2. Hasil Perhitungan Biogas

No	Uraian	Hasil
1	Produksi FFB	1.320 Ton
2	Volume POME	792 m^3
3	Volume Biogas 1 MW	23.760 m^3
4	Nilai Kalor	18.480 Kcal /kg
5	Konsumsi Biogas	2.564 kWh
6	Total fuel consumption	500m^3
7	Volume Biogas/1 kWh	9,26 m^3
8	Volume Biogas 2 MW	47.520 m^3

Based on Table 1, it is known that the Palm oil mill Bandar Pasir Mandoge produces an FFB of 1,320 tons with a production capacity of 60 tons with a storage/filling period of 22 hours/day. POME waste was obtained from the total FFB production of 1,320 tons with a 60% ratio of 792 m3 and it was concluded that 1 ton of FFB was able to produce 0.6 m3 of POME. The volume of biogas produced from 1m3 POME is 30 m^3.

So the total volume of biogas produced from 1,320 tons of FFB is 23,760 m^3. Output 1 unit of 1,000 kWh gas engine with an efficiency of 39% requires 2,564 kWh of power to be able to achieve this output value. 1 kWh can be produced from biogas of 9.26 m^3 and the final result is to reach 1.1 x 2 MW from the total biogas volume of 23,760 m^3/1 MW with a storage period of 44 hours. The biogas reserve capacity of 24,000 m3 to achieve a power of 1.1 x 2 MW Palm oil mill Bandar Pasir Mandoge uses 2 units of synchronized gas engines. So, the total volume of POME waste and the volume of biogas needed to generate electricity is 1.1 x 2 MW of 1,584 m^3 of POME waste and the volume of biogas is 47,520 m^3 requires 2,640 tons of palm oil FFB. To be able to consume and distribute the electricity generated from the POME waste conversion process requires a 2-day charging period plus meeting the biogas reserve capacity of 1 day.

4. CONCLUSION

From the results of the calculation and data analysis that has been carried out in this study, it can be concluded as follows:

1. The amount of FFB produced at the Palm oil mill Bandar Pasir Mandoge, Asahan Regency in May 2023 was 25,523.02 tons with an average daily production of 823,323 tons. With a ratio of 60%, the POME produced is 15,319,212 m^3. The average pome production per day is 763,262 m^3.
2. POME waste was obtained from the total FFB production of 1,320 tons with a 60% ratio of 792 m^3 and it was concluded that 1 ton of FFB was able to produce 0.6 m^3 of POME. The volume of biogas produced

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from 1 m^3 POME is 30 m^3. So the total volume of biogas produced from 1,320 tons of FFB is 23,760 m^3. To produce 1kWh, it requires a biogas consumption of 9.26 m^3.

3. The total output of electrical energy from the turbine is 1.1 x 2 MW at the Palm oil mill Bandar Pasir Mandoge, Asahan Regency with a production capacity of 60 Tons/Hour and POME produced by 60% with a charging period of 22 hours/day with a total power of Biogas consumed to achieve an output power of 2 MW is 347,520 m3 and the total POME waste required is 1,584m3 from the required palm oil FFB of 2,640 tons.

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