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Efficiency of Industrial-Scale Biogas Application from Palm Oil Mill Effluent (POME) as a Renewable Energy Source: A Case Study at PT AMP

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Abstract. The palm oil industry is a large contributor to greenhouse gases in Indonesia. The application of biogas from the palm oil mill effluent (POME) treatment plant has become one of the solutions so it has been implemented at PT Agro Masang Perkasa (AMP). The catch of methane gasses is carried out by covering the waste pond with High-density Polyethylene (HDPE) material to create anaerobic conditions in the waste pool. The data collection for 3 months. The parameters observed and recorded are those related to the operating conditions of the installation such as pH, temperature (ºC), inlet and outlet COD concentration (ppm), percentage of COD reduction (%), percentage of methane gas produced (%), amount of biogas produced (Nm^3), the amount of biogas supplied to the engine and flare (Nm^3), and the total power produced (kWh). The research results show that the methane gas obtained has been utilized as a renewable energy source such as biogas in factories with a total gas flow supplied to the engine of 135957, 121655, and 133736 Nm^3 respectively, and an average power produced of 159530, 153168, and 160161 kWh per month during observations in January, February, and March 2022. Although not all of the captured biogas is used for electrical energy, the benefits of implementing this technology mean that PT AMP has an average electricity efficiency in January, February, and March 2022 of 15.20 %, 22.49%, and 20.96%. Based on calculations, it is found that the use of biogas capture at PT AMP can provide cost efficiency in a year of IDR. 5.21 billion and can return the installation capital within 3.5 years.

Introduction

Palm oil plays a vital role as a critical edible oil. Its industry stands out prominently in the broader global agricultural sector [1]. In 2022, Indonesian palm oil production reached 48.2 million tons. This production is also supported by the availability of Indonesian oil palm plantations covering an area of 15,3 million hectares [2]. In the process of extracting palm oil at palm oil mills, only 20% of the total biomass ends up as palm oil, while the remaining 80% is typically discarded as waste. It's common for each ton of fresh fruit bunches (FFB) to produce approximately 0.5-0.75 tons of palm oil effluent (POME) and 0.2-0.3 tons of empty fruit bunches (EFB). The crude palm oil (CPO) extraction process generates a substantial amount of palm oil mill effluent (POME), averaging 0.5-0.75 m^3 per ton of oil palm FFB [1]. POME comprises waste materials from three main extraction process sources: sterilization, condensation, and hydro-cycloning [1, 3, 4]. So far, POME has mostly been carried out in open waste ponds, releasing methane gas which is a greenhouse gas into the air.

The palm oil industry has become a large contributor to greenhouse gases (GHGs) in Indonesia [4, 5]. Apart from the need for substantial land area, the release of greenhouse gases (GHGs) from this treatment system represents a significant environmental issue [6]. The emission of greenhouse gases has served as the primary catalyst for climate change. The potential to reduce greenhouse gas

emissions and harness energy from organic waste materials is receiving growing recognition and interest [7]. POME is typically seen as a severely contaminating wastewater originating from palm oil mills. Nevertheless, there exists significant potential for its conversion into renewable energy on a large commercial scale, particularly when integrated with wastewater treatment procedures. Through anaerobic treatment, POME can be processed to degrade organic substances, leading to the production of biomethane and biohydrogen [8].

Indonesia continues to strive to convince the international market that the Indonesian palm oil industry has been managed in an environmentally friendly manner. One of the efforts made is by implementing technology biogas in palm oil industry wastewater ponds. Biogas, which contains mainly methane, carbon dioxide, and a lesser amount of hydrogen, is created by subjecting this noxious effluent to anaerobic treatment. The biogas production process involves microbial synthesis stages, including hydrolysis, acidogenesis, acetogenesis, and methanogenesis. The formation of biogas occurs during the anaerobic degradation of POME by native microbial communities [3]. This method can solve the problem of environmental damage due to the release of methane gas and further can produce energy for industry and society [9, 10].

The biogas capture process of converting POME into energy can be done by degrading the POME anaerobically in a closed pond so that the methane gas produced can be collected. The collected methane gas can be converted into useful biogas because biogas itself has the same content as natural gas which can be used as fuel. The calculation assumption is that a factory with a production capacity of 45 tons/hour can produce 1 MW of electricity. These results can supply the electricity needs of around one village (1000 houses) [4]. Efforts are underway to mandate biogas capture at all palm oil mills. This measure is designed to reduce the release of greenhouse gases and highlights the pivotal role that the anaerobic digestion of palm oil mill effluent (POME) will play as a primary source of biogas for generating energy [11].

PT. Agro Masang Perkasa (AMP) plantation is one of the crude palm oil (CPO) processing companies in West Sumatra province which has started implementing technology to capture methane gas (biogas) from its wastewater ponds and use it as an energy source. This article aims to provide information about the application of this technology, both the benefits and efficiency of several parameters obtained by companies after implementing this technology, which is in line with the government's goal towards low-carbon development in the industrial sector.

Materials and Methods

Materials and tools. The application of biogas capture technology has been carried out by PT AMP Plantation located in Tapian Kandis village, Palembayan District, Agam Regency, West Sumatra. Biogas capture is carried out by covering the waste pond with dimensions length x width x height 95 m x 115 m x 7 m. This is done to create anaerobic conditions in the waste pond. To convert methane gas into electrical power, a biogas power plant (biogas engine) is used. For gas distribution, PE pipes or stainless steel pipes have been used, because POME and biogas are corrosive. Flares are used to burn methane gas that is not used for energy. To determine the amount of methane gas produced, the gas analyzer GIR5500 serial No. 1-10304, Hitech Instruments Luton England brand, was used. Other materials and equipment used are baffles, floaters, pumps and pipes.

Methods. The parameters observed and recorded are those related to the operating conditions of the installation such as pH, temperature (ºC), inlet and outlet COD concentration (ppm), percentage of COD reduction (%), percentage of methane gas produced (%), amount of biogas produced (Nm^3), the amount of biogas supplied to the engine and flare (Nm^3), and the total power produced (kWh). Data was obtained from the person responsible for the PT AMP installation. The data used for the article is recorded data from January, February, and March 2022.

The biogas production process at PT. AMP starts with POME (Palm Oil Mill Effluent) being sent to a cooling pond to reduce its temperature and remove residual oil. The wastewater is then transferred to a mixing tank, where it is combined with fresh waste to adjust the pH level and maintain a stable

temperature. From there, the wastewater flows into a digester pond, where bacteria break it down, producing biogas. The biogas is collected using an HDPE membrane cover, while the treated waste is pumped into a storage pond for further treatment before being utilized in land applications.

Results and Discussions

Operational Conditions of PT AMP. PT AMP, which is located in Tapian Kandis village, Palembayan District, Agam Regency, West Sumatra, has a plantation with an area of 14735 Ha and a factory with an area of ± 20 Ha which is on the edge of its plantation area. Everyday the factory processes average of 1259.7 – 1366.9 tons of fresh fruit bunches (FFB), which produces an average of 807.8 - 872.9 m^3/day of POME (Figure 1), so that an average of 59.0 - 69.3% POME is produced from the total fresh fruit bunches (FFB) that come in every day. This is in accordance with research of Ahmed, 2015[1] that one ton of fresh fruit bunch (FFB) releases almost 50 – 75% of POME. For comparison, the POME production at another factory (PT. DAS) averages between 394-466 m^3/day. With an average total of fresh fruit bunches (FFB) processed ranging from 391.5 - 465 tons per day [12].

The factory has several wastewater ponds, one of the ponds with dimensions length x width x height 95 m x 115 m x 7 m, designed to implement biogas capture technology. As can be seen in Figure 1, average POME of 821.0 - 893.8 m^3/day is flowed into the installation. POME that is not put into the biogas capture installation is processed in open ponds and flowed to oil palm plantations using land use techniques to be used by oil palm plants to add nutrients.This also needs to be a concern for PT AMP in the future to process it, so that the degradation of this waste water does not release greenhouse gases (CH_4) into the environment.

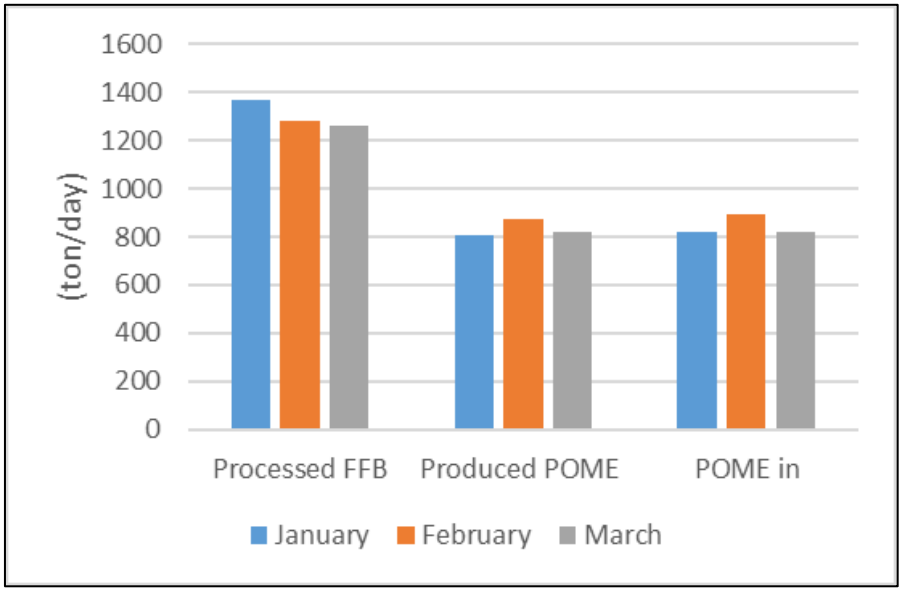

Fig. 1. Operational condition of PT AMP Plantation during observation.

From Table 1 it can also be seen that the pH and temperature of the biogas installation at PT AMP have met the requirements for producing methane gas. pH is another key factor influencing the growth of microbes responsible for biogas production in the reactor. For optimal biogas production, the pH in the reactor should be maintained between 6.8 and 7.2, with a tolerable range of about 4 - 9.5. Temperatures between 37°C - 39°C, are known to offer better process stability[13]. Thermal pretreatment and solid loading can significantly enhance the treatment process of POME [14].

Table 1. pH and temperature of the biogas installation at PT AMP

Parameter	January		February		March	
	pH	Temperature (ºC)	pH	Temperature (ºC)	pH	Temperature (ºC)
out digester	8.00	38.00	8.20	38.90	8.30	38.00
sludge	8.00	38.00	8.10	38.90	8.20	38.00

Biogas Performance. The high COD content, reaching 46777.5 – 63124.3 ppm in POME can be converted into biogas through a processing system without oxygen (anaerobic). From Figure 2 it can be seen that the COD reduction reaches 90-91.5%, and can produce methane gas of 52.1-54.6 %.

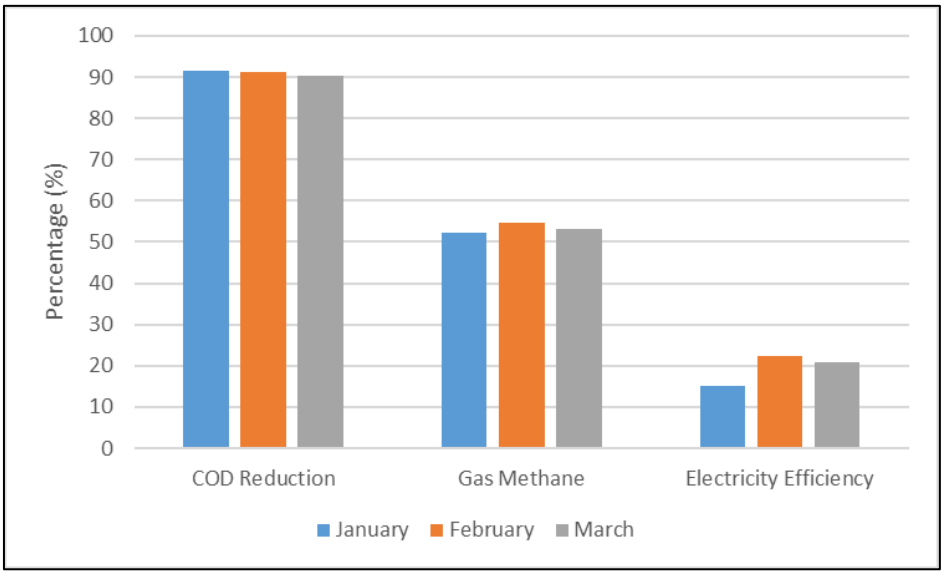

Fig. 2. COD reduction, methane gas produced, and efficiency of electricity used at PT AMP during observation.

Not all of the captured methane gas is used as a renewable energy source, because more than half of it is still burned in flares. It can be seen in Figure 3 that the gas supplied to the engine is lower than that supplied to the flare. This happens because only one of the two engines is supplied with gas. The engine generates 153,168 – 160,161 kWh/month from the supplied gas. Even though not all of the biogas captured is used for electrical energy, the benefits of implementing this technology have provided an average electrical efficiency for PT AMP in January, February, and March 2022 of 15.20 %, 22.49 %, and 20.96 %.

Palm Oil Mill Effluent (POME) is a highly polluting wastewater characterized by elevated chemical oxygen demand (COD) and biochemical oxygen demand (BOD), which can severely impact the environment, particularly water resources. However, POME also holds potential as a valuable resource for producing renewable bioenergies such as biomethane and biohydrogen through anaerobic digestion. This dual approach—combining wastewater treatment with the generation of renewable energy—not only addresses environmental concerns but also offers significant added value to the palm oil industry [8]. However, further technological development is needed to improve the efficiency in utilizing the energy produced. With advancements in anaerobic digester technology, POME has the potential to become a highly efficient biogas resource, significantly contributing to the growth of the renewable energy (RE) sector in the future [15]. Furthermore, advancing technologies like the development of an integrated biogas production and phycoremediation system is essential. This approach incorporates key components such as cultivating microalgae on POME, extracting valuable compounds, and upgrading biogas. By aligning POME treatment with resource recovery and renewable energy production, this strategy demonstrates significant environmental and economic benefits [16].

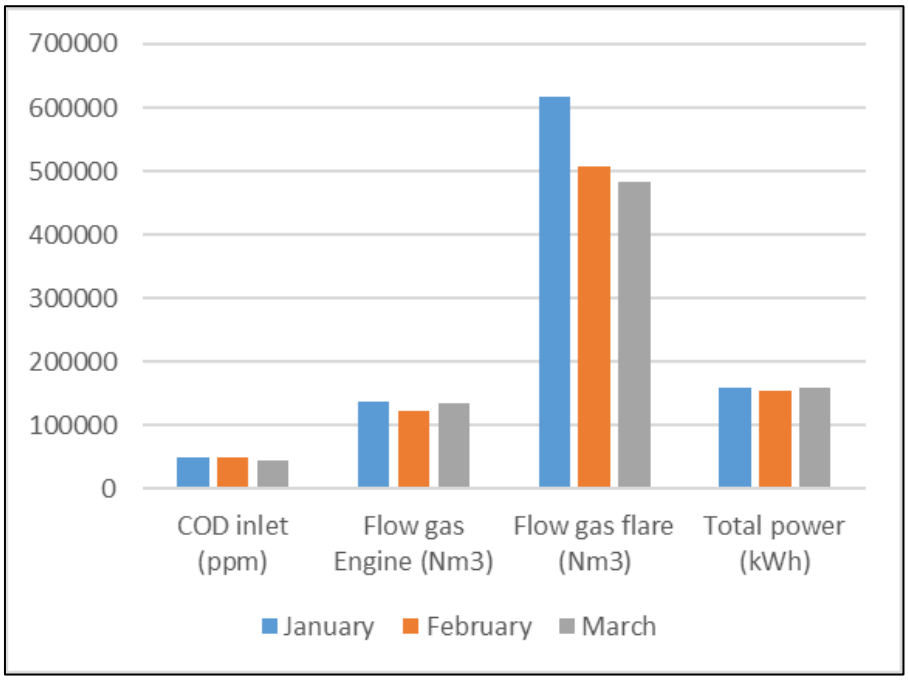

Fig. 3. Working capacity of the biogas installation at PT AMP during observation

Economic Value. The calculation of the cost of capturing methane gas is based on power data produced from January to March with an average demand for petro 4 of 57414,6 kWh/month or 688975,2 kWh/year which is replaced by biogas. If the price of Petro 4/kWh is IDR 7560, then we get a cost efficiency of IDR. 5.21 billion per year. The project cost of creating biogas capture technology is estimated at Rp. 18 billion, so it can be calculated that the return on project costs can be carried out within 3.5 years. The use of biogas derived from POME has the potential to provide energy for nations that produce oil palm, all the while averting the environmental consequences associated with its improper disposal [3].

Conclusion

The application of technology for extracting methane gas from POME as a biogas energy source at PT AMP has a positive impact, both for PT AMP itself and the environment. The captured methane gas has been used as biogas to provide electricity for PT AMP. Meanwhile, not only releasing methane gas directly into the air, but also can reduce greenhouse gas emissions which will cause global warming, and can reduce environmental pollution due to liquid waste from palm oil mills. Even though not all of the biogas captured is used for electrical energy, the benefits of implementing this technology have provided an average electrical efficiency for PT AMP Plantation in January, February, and March 2022 of 15.20 %, 22.49%, and 20.96%. Based on calculations, it was found that the use of biogas at PT AMP can provide cost efficiency in a year of IDR. 5,21 billion and can return the installation capital within 3.5 years. However, further technological development is needed to improve the efficiency in utilizing the energy produced.

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