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An Utilization Of Solid And Liquid Waste From Palm Oil As A Power Plant

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ABSTRACT

The utilization of solid and liquid palm oil waste as a renewable energy source for electricity generation is an effort to address waste management issues while improving energy efficiency. This study aims to analyze the potential of palm oil waste, including empty fruit bunches, fibers, shells, and liquid waste (Palm Oil Mill Effluent - POME), in generating electricity through suitable power generation technologies. The methodology includes data collection on the quantity and characteristics of palm oil waste, calculation of the energy potential, and evaluation of energy conversion technologies such as direct combustion, gasification, and biogas production from liquid waste. The study also exam-ines the technical and economic feasibility of implementing palm oil waste-based power plants. The results indicate that solid and liquid palm oil waste has significant energy potential. Empty fruit bunches and shells can generate energy through combustion, while liquid waste produces biogas with high methane content through anaerobic pro-cesses. With optimal management, palm oil waste can provide a reliable source of elec-tricity, reduce dependency on fossil fuels, and support environmental sustainability. This study concludes that utilizing palm oil waste for electricity generation not only enhances energy efficiency but also delivers economic and environmental benefits. Further imple-mentation requires policy support, appropriate technology, and sustainable waste man-agement practices by the palm oil industry.

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INTRODUCTION

Palm oil is one type of commodity that plays an important role in the agricultural and plantation sectors. Foreign exchange can be obtained from palm oil. North Sumatra is one of the provinces that contributes the largest palm oil plantation results with a production of 3,996,500 tons and a land area of around 1,290,900 hectares (Indonesian Palm Oil Statistics, 2017-2018). Factors of optimal land for palm oil are the environment, physical properties of the land, and chemical properties of the soil or soil fertility. Oil palm plants can grow well at an environmental temperature of 24 ° -28 ° C. Electrical energy is needed at several stages of the palm oil processing process. Along with the development of technology in the industrial sector, the need for energy continues to increase to support the increase in palm oil production. In general, electrical energy consumption in palm oil processing plants is in the range of 17-19 kWh/ton FFB.

The increase in palm oil production each year also results in an increase in the volume of waste. The high organic matter contained in solid waste and liquid waste from the palm oil industry often causes environmental pollution. The solid waste produced is in the form of empty bunches, fibers, and shells. Meanwhile, liquid waste is in the form of POME (Palm Oil Mill Effluent). For every 1 ton of palm oil, waste is produced such as empty palm oil bunches (TKKS) as much as 23% or 230 kg, shells (Shell) 6.5% or 65 kg, palm sludge (wet decanter solid) 4% or 40 kg, fiber (fiber) 13% or 130 kg, and liquid waste (POME) as much as 50% (Mandiri, 2012). From the processing of palm oil, POME is the waste produced in greater quantities than other waste.

The utilization of POME is generally not optimal, even though POME itself has high potential. POME is processed by being decomposed in ponds and left to rot. The result of the decomposition is biogas with the main content (62%) of Methane gas (CH_4). This gas appears due to the process of converting organic compounds anaerobically. Methane gas also has a high emission level.

UNFCCC noted that Methane gas has an emission level 24 times greater when compared to carbon gas (CO_2). In addition, Methane gas has a fairly high energy level. The heat of Methane gas is worth 50.1 MJ/kg. The energy possessed by 1 m3 of Methane when the methane density is 0.717 kg/m3 is 35.9 MJ or around 10 kWh.The waste generated by the palm oil industry, both solid and liquid, represents a significant challenge for the agribusiness sector in Indonesia. As palm oil production continues to grow as one of the country's primary export commodities, the volume of waste also increases. If not managed properly, this waste can have negative environmental impacts, such as water, air, and soil pollution.

However, palm oil waste holds great potential to be utilized as a renewable energy source. Solid waste such as empty fruit bunches, fibers, and shells can be used as fuel, while liquid waste (Palm Oil Mill Effluent or POME) contains high organic content that can be processed into biogas. These energy conversion technologies not only reduce environmental impacts but also produce electricity to support national energy needs.

Utilizing palm oil waste for power generation aligns with sustainable development goals, aiming to reduce carbon emissions and increase the use of renewable energy. Additionally, this approach offers economic benefits to the palm oil industry through energy efficiency and product diversification. This study aims to evaluate the potential of solid and liquid palm oil waste for electricity generation, analyze suitable energy conversion technologies, and assess the environmental and economic benefits of implementing palm oil waste-based power plants. Therefore, this research is expected to provide recommendations for the sustainable management of palm oil waste. Meanwhile, the energy from 1 m3 of biogas will have an energy level of 6.2 kWh if The methane gas content is 62% in biogas. The potential of this biogas can used to meet factory needs, thereby reducing economic costs required to purchase external fuel. By using technology Anaerobic, the company supports the national target in reducing carbon emissions.

Literature Review

Contribution of waste

The palm oil agro-industry in Indonesia has contributed a lot to the country's economy. Its manifestations include expanding employment and business opportunities for the community and entrepreneurs, as well as foreign exchange earnings, regional economic drivers and taxes for the country (Sipayung, 2012). In 2013, Indonesia has succeeded in developing oil palm plantations of around 9.1 million hectares with Fresh Fruit Bunches (FFB) production of 24.4 million tons.

The increasing development of the palm oil industry in Indonesia will increase the productivity of processing the main product of palm oil, which also has an impact on the high level of by-products/waste produced. However, it is unfortunate that the utilization of palm oil by-products has not been used optimally by industry in particular or the government in general. In fact, the future energy program of the National Energy Council (DEN) 2005-2025 to overcome the electricity deficit is to utilize New Renewable Energy (EBT), one of which is biomass from palm oil by-products.

Oil palm (Elaeis guineensis) is a major vegetable oil producing plant with higher productivity when compared to other vegetable oil producing plants. Based on the thickness of the shell and the oil content in the fruit, oil palm can be divided into three types, namely: Dura, Pisifera and Tenera.

The use of waste materials such as shells and coconut fibers as energy sources has become a major issue in the palm oil industry due to its high energy potential and low environmental impact compared to the use of fossil fuels. Several previous studies have discussed the energy efficiency that can be achieved by using biomass boiler technology and its impact on operational costs and CO2 reduction. This literature review discusses various concepts related to the utilization of biomass, boiler technology and related research that form the basis of this research.

The main products of oil palm plants are palm oil or often known as CPO (Crude Palm Oil) and palm kernel. Palm oil can be used in various industries because it has a fairly complete composition and nutritional content. Industries that use palm oil as a raw material are the food industry, cosmetics industry, chemical and pharmaceutical industries. Even palm oil has been developed as a fuel (biofuel).

The processing of oil palm kernels aims to obtain palm kernels that meet quality requirements. The amount and quality of the palm kernel produced are influenced by the stages of the process such as boiling, threshing, stirring and pressing. To manage the raw material of FFB in the Palm Oil Mill (PKS) so as to obtain palm kernel, there are several stages of the process. The productivity resulting from the initial process to the end of palm oil processing in a PKS (Figure 2.) is 22% CPO, 5% Kernel, 22% TKKS, 13% Fiber, 6% Palm Kernel Shell, 28% POME and 4% solid from each ton of TBS (100%) processed.

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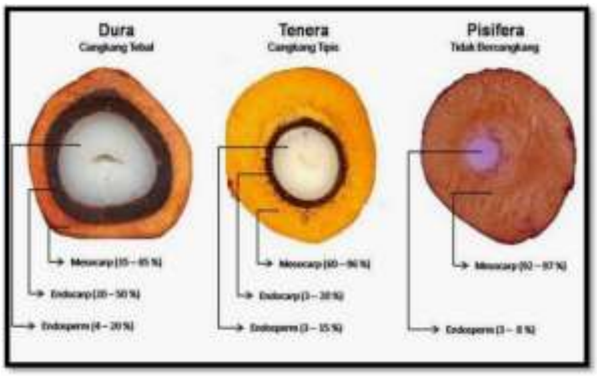

Figure 1. Type of Palm Oil

POME processing

The technology that has been widely used to extract biogas from POME is the Covered Lagoon. This technology involves covering conventional waste ponds with reinforced polypropylene material, so that it functions as an anaerobic digester. Biogas will be collected inside the cover. This system is widely chosen because of its ease of implementation and lower cost. However, this method requires a fairly large area of land for waste processing, with a requirement of around 7 hectares for a capacity of 30 tons of FFB per hour.

In addition, the efficiency of the PMKS liquid waste processing process with this system only reaches 60-70%, with a long waste retention time of 120-140 days. Conventional waste ponds also produce methane (CH4) and carbon dioxide (CO2), which are harmful to the environment because they contribute to the greenhouse effect. In addition, these ponds are prone to silting, so they do not always meet the established waste quality standards.

This technology can produce biogas of around ±20 m^3/ton of TBS. Therefore, with a factory capacity of 30 tons of TBS per hour, biogas is produced of around ±600 m^3 per hour, which is equivalent to 3,720 kWh of energy. If this energy is used to generate electricity using a gas engine (with 35% efficiency), it can produce around 1,303 kWh of electricity or equivalent to 1.3 MW. If calculated economically, assuming the power plant operates for 300 days/year and 24 hours/day and the price is set at Rp. 975/kWh, according to the ESDM regulation (04/2012) for Java, then there is a potential income of Rp. 9.15 M/year.

As another alternative, PMKS liquid waste processing can use Anaerobic Digester technology to replace the processing process in conventional anaerobic ponds. In this system, liquid waste is processed in a digester tank that is controlled with the help of mesophilic and thermophilic bacteria, including methanogenic bacteria that convert the substrate into methane gas. This technology is more efficient in producing more biogas. The processing process is carried out by building an anaerobic digester installation, where the reactor is controlled to regulate the composition, microbes, and temperature to maximize results with a BOD level lower than 100 mg/l. With this technology, the biogas produced is around ±28 m^3/ton of TBS. For a factory capacity of 30 tons of TBS per hour, around ±840 m^3 per hour will be produced, which is equivalent to energy of 5,208 kWh. The electrical energy that can be generated using a gas engine (with 35% efficiency) is around 1,822 kWh or 1.8 MW. So the potential income generated is Rp. 12.8 M/year.

Biomass-based Boiler Technology

Boiler is the most important part of biomass energy production system. Boiler works by converting the chemical energy of waste into heat energy, which is used to produce steam. This steam is used to drive the turbine which ultimately generate electricity. Jumalri et al. (2020) emphasized the importance of routine maintenance to maintain Boiler efficiency. Good maintenance can increase combustion efficiency by up to 15%. In addition, the use of modern technology, such as fluidized bed boilers, offers several important advantages:

1. Uniform Combustion: Fluidized bed boilers ensure that biomass particles are suspended in the air stream during combustion, ensuring that all parts of the biomass are completely burned.
2. Reducing Carbon Emissions: This technology is more environmentally friendly than existing boilers because it can reduce emissions of harmful gases such as carbon dioxide and sulfur.
3. High Efficiency: Optimal combustion produces more energy per unit of fuel used. In addition, Biomass Boilers are very flexible in terms of fuel because they can use various types of Biomass, such as palm bark, coir, or loose fruit bunches. These advantages make Biomass Boiler technology an ideal choice for palm oil mills that want to maximize waste.

METHODS

In this study, we adopted a quantitative descriptive approach which is a method used in previous studies to analyze the efficiency of electricity use in palm oil mills. Based on existing references, data collection was carried out through direct observation in the field by measuring the energy consumption of each station using instruments such as kW-meters and ammeters. This study was conducted through several systematic steps:

1. Data collection
   a. Biomass Boiler Efficiency: Get Biomass Boiler power output and input data and calculate efficiency using Fluidized Bed technology.
   b. Biogas Production from Liquid Waste: a dataset of biogas production from closed lagoon and anaerobic reactor technologies, including the amount of gas produced per ton of FFB.
   c. Energy Capacity: Calculate the power potential of biogas and biomass using the power plant efficiency formula.
2. Boiler Performance Calculation
   Analysis of measurement data to calculate energy efficiency. The purpose of this analysis is to determine whether the energy consumption level of each station is in accordance with the fuel input power used.

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3. Data Analysis

   The collected data is analyzed as follows, Comparison of Biomass Boiler Efficiency Using Fluidized Bed Technology. Comparison of Energy and Potential Input between Closed Tank and Anaerobic Digestion in Liquid Waste Treatment.

   Determining which technology is optimal to improve the energy efficiency of palm oil mills.

a. Biogas Production Measurement

   The data used are Covered Lagoon technology (20 m³/ton FFB) and Anaerobic Digester (28 m³/ton FFB). Record the plant capacity (30 tons FFB/hour) and calculate the total biogas production per hour.

b. Calculation of Eenergy Potential

   Calculate the potential electricity generated from Biogas with a generator efficiency of 35%. Comparison of energy production between Covered Lagoon and Anaerobic Reactor technologies.

c. Biomass boiler analysis

   Formula used to measure the efficiency of Biomass Boiler. Comparison of carbon emissions and fuel flexibility between Conventional and Fluidized Bed Boiler. Data collected

   1. Biomass Boiler Efficiency
      Type: Fluidized bed boiler
      Capacity: 20 tons/hour. Fuel: coconut fiber and loose branches.
   2. Biogas Products
      Amount of Biogas per ton of FFB:
      Closed lagoon: ±20 m³/ton FFB.
      Anaerobic digestion: ±28m³/ton FFB.
   3. Electrical Energy Potential:
      Closed lagoon: 1.3 MW.
      Anaerobic digestion: 1.8 MW.
   4. Income potential
      Closed lagoon year. : Rp 9.15 billion per year.
      Anaerobic digester: Rp 12.8 billion per year.

RESULTS AND DISCUSSION

Utilization of Waste as an Energy Source

Palm Oil Mill wastes, previously considered as by-products with no economic value, can now be used as fuel for power plants. Shells and fibers have high calorific values of 4,700 kcal/kg and 3,850 kcal/kg respectively, making them an efficient alternative fuel choice for boilers. On the other hand, POME liquid waste is rich in organic content, which goes through the process Anaerobic decomposition is capable of producing biogas with Methane content of up to 50-75%. With a calorific value of 35.9 MJ/m³, the biogas produced has great potential to be converted into electrical energy using technologies such as Covered Lagoon or Anaerobic Digester.

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Energy Efficiency in Boilers

Boilers in the Palm Oil Mill show high efficiency in meeting energy needs. Based on the analysis, the total electricity utilization for the palm oil production process reaches 650 kW per day. The Thresher Station recorded the highest efficiency of 90%, while the Clarification Station showed the lowest efficiency of 77%. This shows that process optimization can improve overall efficiency.

In terms of fuel utilization, the production of 730,375 kg of shells and 1,462,336 kg of fibers from the processing of 30,000 kg of TBS per hour is sufficient for the boiler without the need for additional external fuel. With full utilization of this solid waste, the boiler can produce steam that is used for various processes, including turbine drives.

Electricity Production from Waste

Projections of electrical power from waste show that every 1 ton of TBS can produce around 0.7-1 m^3 of POME, which when processed into biogas, can produce electricity of 4.18 kWh per $Nm^3.CH_4$.With a processing capacity of 45 tons of FFB per hour, the electricity generated reaches 1.6 MW, while increasing the capacity to 60 tons of FFB per hour can produce up to 2.1 MW. This electricity potential not only meets the internal needs of the factory, but also provides an opportunity to sell electricity to the external network. This makes the use of waste as an energy source not only technically efficient, but also economically.

Environmental Impact and Emission Reduction

` Utilizing waste for energy has a significant positive impact on the environment. Untreated POME wastewater usually releases methane, a greenhouse gas with a global warming impact 21 times greater than carbon dioxide. By using anaerobic technology, greenhouse gas emissions can be reduced by up to 67%, supporting the national target of reducing carbon emissions. This emission reduction also supports environmental sustainability programs that are in line with government policies. In addition, waste that was previously a source of pollution is now converted into an energy source, improving the company's image as an environmentally friendly industry player.

Relevance to Operational Sustainability

Implementation of technologies such as Anaerobic Digester or Covered Lagoon not only provides solutions to waste problems, but also improves the sustainability of the company's operations. This technology allows fuel cost savings of up to IDR 688,500,000 per month, as well as opening up opportunities for additional income from electricity sales. By utilizing waste as fuel, the company contributes to the renewable energy transition in Indonesia. This also supports the renewable energy mix target of 23% by 2025, in accordance with Presidential Regulation Number 79 of 2014.

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CONCLUSION

The utilization of solid and liquid palm oil waste as a renewable energy source for electricity generation presents a viable solution to both waste management and energy efficiency challenges. This study concludes the following: Solid waste such as empty fruit bunches, fibers, and shells has significant potential to be converted into energy through combustion and gasification processes. Liquid waste (POME) contains high organic content and can be effectively processed into biogas through anaerobic digestion, providing a reliable source of renewable energy. Proper management of palm oil waste reduces environmental pollution, including air, water, and soil contamination. The use of renewable energy from waste helps to lower greenhouse gas emissions and supports sustainable development goals. Although the initial investment in energy conversion technologies is substantial, the long-term benefits include reduced dependency on fossil fuels and cost savings in energy production. The approach also adds economic value to the palm oil industry by diversifying its outputs and improving overall. Successful implementation requires adequate policy support, investment in suitable technologies, and sustainable waste management practices by the palm oil industry. This study highlights that the utilization of palm oil waste for electricity generation not only addresses waste management issues but also contributes to achieving energy sustainability and economic growth. Further research and pilot projects are recommended to optimize technology adoption and scalability in the palm oil sector.

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