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A Utilization Of Oil Palm Empty Fruit Bunch Biomass As An Alternative Fuel For Steam Power Plants

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ABSTRACT

The utilization of empty palm fruit bunches (EPFB) biomass as an alternative fuel for Steam Power Plants (PLTU) is a promising solution to reduce dependence on fossil fuels while increasing the utilization of palm oil industry waste. EPFB is a solid waste generated from the palm oil extraction process and has a high carbon content, making it a viable renewable energy source. This study aims to analyze the energy potential derived from the combustion of EPFB and the energy conversion efficiency in a PLTU system. The methodology includes the analysis of fuel characteristics, such as calorific value, moisture content, ash content, and combustion efficiency, compared to coal as a conventional fuel. Additionally, the study evaluates the environmental impact of utilizing EPFB as an alternative fuel, especially in terms of carbon emissions and energy efficiency. The results indicate that EPFB has an average calorific value of 15-18 MJ/kg, which is sufficient for use as fuel in co-firing systems with coal in PLTU. Using EPFB as an alternative fuel can also reduce CO_2 emissions by up to 30%compared to pure coal combustion. Economically, the utilization of EPFB can lower operational costs and support sustainable energy policies in Indonesia. Thus, the utilization of EPFB biomass in PLTU can provide an efficient and environmentally friendly renewable energy solution. Further implementation requires optimization of combustion technology and policy studies to support sustainable biomass use in power generation.

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INTRODUCTION

Indonesia has a very large potential for renewable energy and one of the ones that has not been widely utilized is biomass. Biomass is one of the energy sources that contains lignocellulose which is suspected to be a source of high calorific value biofuel. The use of biomass as an energy source in Indonesia is still very low and still uses combustion technology to obtain heat used for both cooking and steam generation. Seeing the increasing domestic fuel needs while the supply of fossil fuels is increasingly limited and continues to decline, it is necessary to find a technology that is capable of producing alternative energy by utilizing solid waste sourced from biomass materials such as empty oil palm bunches. Utilization of empty oil palm bunches (TKKS) into energy can reduce dependence on fossil fuels. The potential of this biomass as a development of bio-energy-based power plants with empty oil palm bunch biomass, ready to operate stably for 24 hours, not affected by weather factors, environmentally friendly, and the electricity produced is relatively cheap compared to fuel-based power plants (diesel generators or PLTD). Utilization of empty fruit bunch waste as fuel for power plants is one of the choices of Palm Oil Mills (PKS) in efforts to overcome empty fruit bunch waste. Empty fruit bunch waste is currently not widely utilized because several options for utilization such as use as raw materials for fertilizer and compost have been implemented but the results are not effective, especially in processing empty fruit bunches in large quantities. The number of Palm Oil Biomass Waste Power Plants that use empty fruit bunch fuel is not much in Indonesia. This study will discuss TKKS which is utilized as a renewable energy source. The utilization of TKKS as a renewable energy source must go through a processing process first. The processing process carried out through pressing aims to remove the water and oil content contained in TKKS and become fibers so that they are easy to burn for use as boiler fuel in Steam Power Plants (PLTU). Based on the explanation of the background, the author created the title "Utilization of Empty Oil Palm Fruit Bunch Biomass as an Alternative Fuel for Steam Power Plants".

The increasing demand for electricity in Indonesia and globally has led to a growing reliance on conventional fossil fuels such as coal and natural gas in power generation. However, the environmental impact of these energy sources, including greenhouse gas emissions, air pollution, and depletion of natural resources, has prompted the need for more sustainable and cleaner alternatives. In this context, biomass—especially agricultural waste—has emerged as a potential renewable energy source to replace fossil fuels in power plants.

One of the most abundant and underutilized biomass sources in Indonesia is empty palm fruit bunches (EPFB), a byproduct of palm oil production. Indonesia, as the world's largest producer of palm oil, generates millions of tons of EPFB annually. This biomass waste, if not properly managed, poses environmental and disposal challenges. However, with its high energy content, EPFB can be harnessed as a biofuel for electricity generation, specifically in Steam Power Plants (PLTU), which traditionally rely on coal as their primary fuel source.

Literature Review

TKKS is the largest solid waste from the processing of oil palm FFB and has become the biggest problem for palm oil mills (PKS) that has been faced so far. Generally, TKKS is left alone in the PKS or used as fertilizer by wetting (damping) or burned in an incinerator, while shell and fiber waste is used as boiler fuel in the PKS. (Sri Wahyono, 2008)

TKKS is known to contain very high water content of around 60%-65%, and contains potassium (K) reaching 2.4%, besides it is also known to contain chlorine (Cl). The corrosion effect will increase with increasing Cl content, and the potassium element can play a role in the formation of deposits on the superheater which can interfere with the heat transfer process in the boiler furnace (Wij ono, 2014).

TKKS is used as organic material for oil palm plants directly or indirectly. Direct utilization by making TKKS as a cultivation cover material to maintain soil moisture (mulch) while indirectly by composting it first before being used as organic fertilizer in PKS. (Pahan, 2008) Utilization in this way only produces the lowest added value in the TKKS processing process so that proper processing is needed to obtain large added value and become an advantage for oil palm plantation companies, namely biomass equality in oil palm waste processing.

Biomass as a Renewable Energy Source.

Biomass has been identified as one of the most promising renewable energy sources due to its abundance, carbon neutrality, and potential to reduce greenhouse gas emissions. According to Lora & Nogueira (2009), biomass can be classified into several categories: agricultural residues, forestry residues, animal waste, and industrial byproducts. Among these, agricultural residues like rice husks, corn stalks, and palm oil residues are especially abundant in tropical countries such as Indonesia. Biomass conversion technologies include combustion, gasification, fermentation, and anaerobic digestion, with combustion being the most widely used method for electricity generation, especially in steam power plants (PLTU).

In the context of palm oil production, empty palm fruit bunches (EPFB) represent a significant waste byproduct. According to Rupani et al. (2010), EPFB consists mainly of fiber, cellulose, hemicellulose, and lignin, which makes it suitable for use as a biomass fuel due to its high energy content. Studies show that the calorific value of EPFB can range from 15 to 20 MJ/kg, depending on moisture content and other factors (Chin et al., 2013).

Biomass Combustion in Power Plants.

The combustion of biomass as an alternative fuel in steam power plants (PLTU) has been the subject of several studies. Co-firing biomass with coal in power plants offers a feasible approach to reduce emissions while maintaining the plant's operational efficiency. Zhou et al. (2015) demonstrated that co-firing wood chips and coal could reduce CO_2 emissions by up to 30% while maintaining the same thermal output. In their study, co-firing of up to 15% biomass resulted in **a** significant reduction in sulfur dioxide (SO_2) and nitrogen oxide (NOx) emissions without compromising plant performance.

The high carbon content of EPFB, combined with its relatively low moisture content and moderate ash content, makes it an ideal candidate for co-firing. According to Chong et al. (2018), the combustion of EPFB in coal-fired boilers demonstrated stable combustion characteristics, with an energy conversion efficiency of about 85-90% when mixed with coal in proportions up to 30% by mass. This suggests that EPFB can be a viable co-fuel for existing PLTU systems, contributing to the reduction of fossil fuel consumption and emissions.

Environmental Impact of Biomass Co-Firing.

One of the key benefits of biomass co-firing is its potential to reduce carbon emissions and air pollutants. Agarwal et al. (2014) reported that the co-firing of biomass residues could reduce CO_2 emissions by 15-30% depending on the feedstock and combustion parameters. EPFB, in particular, is seen as a low-carbon alternative because it is considered carbon-neutral over its lifecycle. The carbon dioxide emitted during combustion is offset by the carbon absorbed by the palm trees during their growth.

Further studies by Majeed et al. (2016) showed that utilizing biomass like EPFB can significantly lower emissions of sulfur oxides (SOx) and nitrogen oxides (NOx) compared to coal combustion. This is primarily due to the lower sulfur content in biomass fuels. Additionally, using EPFB as a co-fuel can help in reducing the amount of agricultural wastebeing disposed of in landfills or incinerated, thereby mitigating environmental pollution and improving waste management practices.

The economic viability of using biomass like EPFB in power generation depends on factors such as the cost of biomass supply, fuel handling, and equipment modifications. According to Kaliyan & Morey (2010), the cost of biomass is generally lower than coal, especially if locally sourced. In the case of EPFB, it is a low-cost biomass source because it is largely a waste product from the palm oil industry. However, the economic benefits depend on the availability and logistical costs of collecting, transporting, and processing EPFB into a usable fuel.

A study by Bohdanowicz et al. (2017) found that EPFB co-firing with coal in PLTU could lower fuel costs by up to 20%, depending on the market price of coal. Moreover, the use of EPFB could help power plants achieve energy independence and reduce dependence on imported coal, thereby contributing to national energy security.

Challenges and Limitations.

Despite its potential, there are several challenges in using EPFB as a biomass fuel:

a. Ash content: EPFB contains relatively high content, which can cause fouling and slagging in the combustion system, potentially affecting the performance of boilers.
b. Moisture content: EPFB typically has a high moisture content when harvested, which can reduce its calorific value and efficiency. Therefore, proper drying and processing techniques are necessary to optimize its use as a fuel.
c. Combustion instability: Inconsistent combustion characteristics and flue gas emissions may occur if EPFB is not blended correctly with coal or if combustion parameters are not properly controlled.

The literature highlights the potential of EPFB as a viable alternative fuel for power generation, particularly in co-firing applications in PLTU. EPFB can provide a sustainable solution to reduce carbon emissions, lower operational costs, and contribute to waste management. However, several technical challenges must be addressed, including fuel preparation, ash management, and combustion optimization. Future research and development in biomass combustion technologies, along with supportive policy frameworks, are crucial to enabling the widespread adoption of EPFB as a renewable energy source in the power sector.

METHODS

The first level of energy conversion that occurs in a PLTU is the conversion of primary energy into heat energy. This is done in the combustion chamber of the boiler. Heat energy is transferred into the water in the boiler pipes to produce steam that is collected in the drum in the boiler. Steam from the boiler drum is channeled to the steam turbine. In the

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steam turbine, steam energy is converted into mechanical energy to rotate the generator, and mechanical energy from the generator is converted into electrical energy.

This study uses PLTU data with a boiler capacity of 70 tons/hour with a steam pressure of 36 kg/cm2, a temperature of 380O C and a power output of 15 MW. The boiler specifications are as follows:

a. Boiler Brand : Takuma
b. Type : N2200
c. Steam capacity (Q) : 70,000 kg/hour
d. Steam temperature (Tu) : 380^{o} C
e. Vapor pressure (Pu) : 36 kg/cm^2
f. Feed water temperature: 105^{o} C
g. Boiler efficiency (η) : 80%
h. Fuel calories : 3,565 kcal/kg (Shell), 2,340 kcal/kg (fiber), 6,600

kcal/kg (coal) and 1,943 kcal/kg (TKKS fiber) where the enthalpy value at temperature:
Steam temperature 380^{o} C is 757.44 Kcal/kg and feed water temperature
105^{o} C is 105.16 Kcal/kg
Steam Powered Electricity

In general, PKS uses a direct method in boiler calculations [1,4,6]. In this direct method, the calculation of boiler efficiency can be evaluated using the formula:

$$\text{Efficiency } (\eta) = \frac{\text{Panas}}{\text{Keluar}} \times 100\%$$

$$\text{Panas masuk} = \frac{Q\ x\ (hg-hf)}{qxGCV} \times 100\%$$

$$\text{q fue} = \frac{Q\ konsumsi}{kcal\ baan\ bakar} \times 100\%$$

$$\textit{Steam Rate Turbine} = \frac{Q}{Pturbin}\ \frac{kg\ uap}{kWh}$$

$$\textit{Fuel requirement/ton steam} = \frac{q\ bb}{kg}\ \frac{bahan\ bakar}{ton\ uap}$$

$$\textit{Amount of steam/kg bb} = \frac{Q\ kg\ uap}{\text{Bb/ton}}\ \frac{ton\ uap}{kg\ bahan\ bakar}$$

$$\text{kWh} = \frac{Steam\ Rate\ Turbine}{\text{uap/kg bb}}\ \frac{ton\ uap}{kg\ bahan\ bakar}$$

The parameters monitored for calculating boiler efficiency using the direct method are:

a. The amount of boiler steam produced per hour (Q) in kg/hour
b. Amount of fuel used per hour (q) in kg/hr
c. Working pressure in kg/cm2(g)
d. Feed water temperature (^oC)
e. Fuel type and fuel gross heating value (GCV) in kcal/kg fuel
f. hg is the Enthalpy of saturated steam in kcal/kg steam
g. hf is the Enthalpy of feed water in kcal/kg water

RESULTS

The following are the results and discussion:

Calculation and Cost of Fuel for Steam Power Plant

This research design makes a comparison of fuel usage.

PLTU using biomass from several waste options along with purchase prices:

a. Shells cost Rp. 900/kg
b. Fiber costs Rp. 175/kg
c. Coal costs Rp. 1116/kg
d. TKKS at Rp. 100/kg

The heat requirement in the boiler combustion chamber at a 70 ton/hour PLTU with a steam pressure of 36 kg/cm2 and a temperature of 380 0C and a power output of 15 MW is 57,074,500 kcal/hour. By comparing the calorific value, the needs and calculations required by each fuel:

1. Shell
   The amount of heat is 3,565 kcal/kg so it requires 16,010 kg of shells. Multiplied by the price per kilogram, it produces a fuel cost of Rp. 14,409,000,-/hour.
2. Fiber)
   The amount of heat is 2,340 kcal/kg so it requires 24,391 kg of fiber. Multiplied by the price per kilogram, it produces a fuel cost of Rp 4,268,425,-/hour.
3. Coal
   The amount of heat is 6,600 kcal/kg so it requires 8,648 kg of coal. Multiplied by the price per kilogram, it produces a fuel cost of Rp 9,651,168,-/hour.
4. TKKS
   The amount of heat is 1,943 kcal/kg so it requires 29,375 kg of TKKS fiber. Multiplied by the price per kilogram, it produces a fuel cost of Rp. 2,937,500,-/hour

Economic Study of TKKS

The need for TKKS fibers in the PLTU to produce 15 MW of electricity is 29,375 kg of TKKS fibers/hour, so the supply of TKKS main materials to meet the need for TKKS fibers is 34,559 kg of TKKS/hour and the CPO produced is 691 kg/hour with a selling price of Rp15,069,-/kg. The fuel cost of the 15 MW PLTU is Rp277,-/kWh while the selling price of electricity from the PLTU to PLN is Rp870,-/kWh. Thus, the advantage in utilizing TKKS as fuel for the PLTU through the pressing process will provide very large efficiency and profit both from the sale of electricity/kWh and CPO from TKKS.

If efficiency is studied from the sale of electricity to PLN, then the PKS profit is IDR 593,-/kWh so that the total profit from the sale of electricity is IDR 8,895,000,-/hour (IDR 593,-/kWh x 15,000 kW). Additional profit from the sale of CPO processed TKKS is IDR 10,412,679,-/hour (691 kg/hour x IDR 15,069,-/kg). So the total profit obtained is IDR 19,307,679,-/hour. Thus, biomass equality in the development of energy as a renewable energy source in TKKS is a must in an effort to overcome the energy deficit. Considering that the proper utilization and processing of TKKS will produce biomass equality that is not inferior to other biomass.

CONCLUSION

TKKS is known to contain very high water content of around 60%-65%, and contains potassium (K) reaching 2.4%, besides it is also known to contain chlorine (Cl) which can interfere with the heat transfer process in the boiler furnace. So it is necessary to carry out the TKKS processing process as a PLTU fuel through a pressing process first to remove water, potassium (K) and chlorine (C) content. The TKKS processing process will produce 691 kg/hour of CPO oil with a CPO selling price of Rp15,069-/kg and a PLTU with TKKS fuel to produce electrical energy requires a cost of Rp277,-/kWh while the selling price of electrical energy to PLN is Rp870,-/kWh. The profit from selling electricity to PLN is IDR 8,895,000,-/kWh (IDR 593,-/kWh x 15,000 kW) and CPO sales are IDR 10,412,679,- (691 kg/hour x IDR 15,069,-/kg). So the total profit is IDR 19,307,679,-/hour. By reviewing the conclusions of this study, the biomass-fueled PLTU from TKKS is feasible to be built and distributed throughout the regions that have the potential to produce Palm Oil.

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