

## Technical Feasibility Analysis of Sawdust as Co-firing Fuel at Labuhan Angin Steam Power Plant

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**Abstract.** This study aims to analyze the technical feasibility of using sawdust as co-firing fuel in the Labuhan Angin Steam Power Plant (PLTU). The main focus is on the physical and chemical characteristics of sawdust and its impact on the performance of the power plant. This study is non-experimental and uses secondary data obtained from the operational trial report of sawdust co-firing documented in the company's internal technical report. The analysis was carried out through daily operational data, including coal consumption, electrical load, furnace temperature, and Specific Fuel Consumption (SFC) measurements. The results show that the addition of sawdust up to 5% does not reduce the stability of the power plant operation. Coal consumption decreased as the percentage of sawdust increased, without sacrificing electrical power output, which remained stable in the range of 65–68 MW. The furnace temperature also remained stable, even at a mixture of 5% showing higher stability than other mixtures. Although SFC increased slightly in the sawdust mixture, the system efficiency was maintained well. This is due to the characteristics of sawdust which is flammable and produces cleaner emissions, although its calorific value is lower than coal. This study concludes that sawdust has the technical feasibility to be used as a co-firing material up to 5% without disrupting the performance of the generator. However, adjustments are needed to the feeding system and combustion control for optimization. These results strengthen the potential of sawdust as an alternative environmentally friendly energy in the energy transition towards more sustainable generation.

**Keywords:** Co-firing, Biomass, Sawdust, Coal, Renewable Energy.

### 1 Introduction

Co-firing program in Indonesia has shown positive results. PLN Indonesia Power data shows that the achievement of co-firing performance until December 2023 reached 509.54 GWh or 113% of the target, with a biomass volume absorbed of 478,741 tons. However, this achievement is dominated by a small portion of Steam Power Plant (PLTU). Of the 417 generating machines managed by PLN Indonesia Power, only 18 generators (4.3%) have implemented co-firing. These findings indicate that there are still many PLTUs that do not utilize this technology, so the potential for developing co-firing in Indonesia is still very large.



**Figure 1.** Map of Indonesian PLTU co-firing (Source: Ditjen EBTKE)

One of the generating units managed by Indonesia Power that has not yet conducted co-firing is the Labuhan Angin PLTU. This PLTU, with a capacity of 230 MW, is one of the important power plants that supplies electricity in North Sumatra. Currently, the Labuhan Angin PLTU operates using 100% coal fuel. In this case, biomass, such as sawdust from the Energy Plantation Forest (HTE), is used to complement the energy mix of coal-fired power plants through a co-firing program. The results of the trial showed that co-firing can be said to be successful because it did not have a significant effect on the generator parameters and did not require significant additional equipment investment costs. (source: [Indonesiapower.co.id](http://Indonesiapower.co.id))

In the National Electricity General Plan (RUKN), it can be stated that PLN plans to implement Co-firing for 52 PLTU (Steam Power Plant) units. By implementing Co-firing, the use of Renewable Energy Gap (EBT) can be carried out quickly without the need to build new power plants (Palupi et al., 2023). Agriculture, forestry, fisheries, livestock, and municipal waste such as straw, rice husks, cellulose, sawdust, and animal waste are common types of biomass in large quantities as renewable energy sources (Cao et al., 2020). The classification of biomass includes woody biomass, herbaceous biomass, aquatic biomass, waste including livestock manure, garbage containing biological materials. Woody plants grow abundantly in forests and are widely processed by humans for various purposes (Gunawan, 2019).

Based on data from the North Sumatra Provincial Government, the Energy Plantation Forests (HTE) of North Sumatra (Sumut) in 2023 include oil palm plantations and PT Toba Pulp Lestari Tbk. Energy Plantation Forests, plantations, and agricultural land around the Labuhan Angin PLTU can be a source of sustainable biomass supply. Several types of potential biomass include waste wood from the wood processing industry (sawdust), plantation residues (empty oil palm bunches, oil palm fronds, palm shells), and biomass from agricultural land (rice straw, corn stalks).

Co-firing trial with sawdust, in-depth data and discussion regarding the technical characteristics, as well as the potential for optimizing its co-firing program, are still very limited. In addition, the selection of biomass types such as sawdust should not be immediately determined without a comparative study with other biomass alternatives available in the surrounding area, such as empty oil palm bunches (TKKS), palm kernel shells, or rice straw. Based on previous studies (Kusuma, 2022; Widiyanto, 2003), the selection of biomass fuel for co-firing must consider technical characteristics such as calorific value, water content, ash content, and combustion properties.

The purpose of this study was to analyze the technical feasibility of using sawdust as co-firing fuel at Labuhan Angin PLTU, focusing on the physical and chemical characteristics of the material and its impact on the performance of the generator. This type of research is non-experimental because no direct treatment or new experiments were carried out by the researchers. This study fully uses secondary data obtained from the report on the results of the sawdust co-firing operational trial at Labuhan Angin PLTU, which is documented in the company's internal technical report.

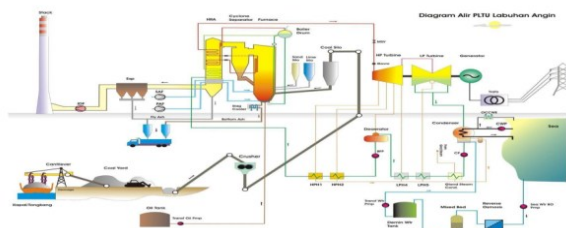
## 2 Literature Review

### 2.1 Labuhan Angin Steam Power Plant (PLTU)

The Labuhan Angin Steam Power Plant operates based on the Rankine Cycle (a closed-loop system) that converts the chemical energy in coal into electrical energy through the following stages:

1. **Coal Processing:** Coal is crushed into uniform sizes and stored in a silo.
2. **Combustion:** The coal is burned in the boiler to produce high-pressure, high-temperature steam.
3. **Turbine Drive:** The steam drives the turbine by rotating its blades.
4. **Electricity Generation:** The rotating turbine powers a generator that produces electricity.
5. **Cooling:** The steam is condensed back into water in the condenser and returned to the boiler.
6. **Electricity Distribution:** The electricity is stepped up in voltage by a transformer and transmitted to consumers.

This process repeats continuously in a closed cycle.



**Figure 2.** Flowchart of Labuhan Angin PLTU  
(Source : PLNindonesiapower.co.id).

### 2.2 Direct Co-combustion, Indirect Co-combustion, Parallel Co-combustion

Direct co-combustion is the simplest and most commonly used co-firing method. In this method, biomass and coal are burned together in the same combustion chamber. Biomass and coal can be mixed first before being fed into the combustion chamber, or they can be fed separately through different routes (Sidiq, AN 2022).

In the indirect co-combustion method, biomass is first converted into gas or other fuels through a gasification or pyrolysis process. The gas or fuel resulting from the biomass conversion is then burned together with coal in the main combustion chamber (Kawiarsio, et al. 2023).

The parallel co-combustion method uses two separate combustion chambers, one for coal and one for biomass. Both fuels are burned separately, and the heat generated is used to increase the water temperature in the same boiler (Cahyo, et al., 2022).

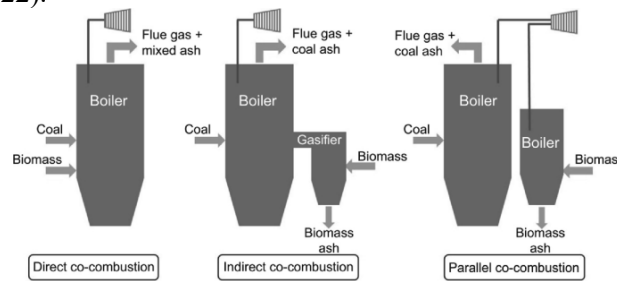


Figure 3. Direct Co-combustion

### 2.3 Coal

In coal there are different chemical elements where these chemical elements cause coal to burn and produce energy. These chemical elements are as shown in Table 1.

Table. 1 Property Value Range of Each Coal Type

Item	Anthracite	Bituminous	Subbituminous	Lignite
Moisture (%)	3 - 6	2 - 15	10 - 25	25 - 45
Volatile matter	2 - 12	15 - 45	28 - 45	24 - 32
Fixed carbon (%)	75 - 85	50 - 70	30 - 57	25 - 30
Ash (%)	4 - 15	4 - 15	3 - 10	3 - 15
Sulfur (%)	0.5 - 2.5	0.5 - 6	0.3 - 1.5	0.3 - 2.5
Hydrogen (%)	1.5 - 3.5	4.5 - 6	5.5 - 6.5	6 - 7.5

Carbon (%)	75 - 85	65 - 80	55 - 70	35 - 45
Nitrogen (%)	0.5 - 1	0.5 - 2.5	0.8 - 1.5	0.6 - 1
Oxygen (%)	5.5 - 9	4.5 - 10	15 - 30	38 - 48
Btu/lb	12,000 - 13,500	12,000 - 14,500	7500 - 10,000	6000 - 7500
Density (g/mL)	1.35 - 1.70	1.28 - 1.35	1.35 - 1.40	1.40 - 1.45

Source: (Speight, 2015)

Table 1 shows that each type of coal has different elements. In this study, the type of coal used is Lignite coal. Lignite coal is a type of coal that has the lowest quality among other types of coal.

#### 2.4 Biomass - Sawdust

In this study, biomass in the form of wood in the form of sawdust was used. The chemical content of sawdust is presented in Table 2.

**Table.2** Chemical Composition and Calorific Value of Sawdust

SAWDUST	Unit	ARB	ADB	DB	DAFB
<b>Proximate Analysis</b>					
Total moisture	%wt	16.85			
Moisture in analysis	%wt		4.54		
Ash content	%wt	0.98	1.13	1.18	
volatile matter	%wt	66.11	75.90	79.51	80.46
Fixed carbon	%wt	16.05	18.43	19.31	19.54
Total sulfur	%wt	0.01	0.01	0.01	0.01
Gross calibrated value	kCal/kg	4036	4634	4854	4913
<b>Ultimate analysis</b>					
Hydrogen	%wt	4.56	5.24	5.49	5.55
Carbon	%wt	45.11	51.80	54.26	54.91
Nitrogen	%wt	0.38	0.44	0.46	0.46
Oxygen	%wt	32.09	36.85	38.60	39.06

Source: (Sucofindo, 2021),

Information: ARB: As Received Basis, ADB: As Dried Basis, DB: Dried Basis, DAFB: Dry As Free Basis

### 3 Methodology

This study employs a non-experimental research method, characterized by the absence of direct manipulation of independent variables by the researchers. Consistent with Sugiyono (2019), non-experimental research focuses on

observing relationships between variables under natural conditions without introducing new interventions or experiments.

The primary objective of this research is to analyze the performance of the Labuhan Angin Steam Power Plant (PLTU) in a co-firing scenario by utilizing pre-existing data. This approach was chosen due to the practical constraints and inherent complexities of conducting direct experimental trials within an operational power plant setting, which would require significant resources, time, and potentially disrupt continuous power generation.

The core of this study relies entirely on secondary data, which was meticulously obtained from the official operational trial report of biomass co-firing conducted at the Labuhan Angin PLTU. These internal technical documents of the company provide comprehensive and detailed information, encompassing various operational parameters, crucial energy efficiency metrics, and documented environmental impacts associated with the utilization of different biomass types in the co-firing process. As affirmed by Arikunto (2019), the use of previously collected data in non-experimental research allows for in-depth investigation of phenomena that have already occurred, without requiring the researcher's direct involvement in the laborious process of new data collection. This methodology ensures that the analysis is based on real-world operational conditions and actual plant performance, providing highly relevant insights.

The data analysis specifically involved examining daily operational data that were recorded during the co-firing trials. These parameters included:

- **Coal consumption:** To evaluate the reduction in fossil fuel usage.
- **Electrical load:** To assess the stability and consistency of power output when sawdust was introduced.
- **Furnace temperature:** To monitor the stability of the combustion process within the boiler.
- **Specific Fuel Consumption:** To determine the overall efficiency of fuel utilization in kWh produced per unit of fuel consumed.

These specific parameters were chosen because they are critical indicators of power plant performance and directly reflect the technical feasibility and operational impact of co-firing. The data collection for these parameters was conducted systematically, with observations of operating parameters for eight hours after mixing and stabilization, followed by data recording from Coal Combustion Residuals (CCR) every hour between 10:00-18:00. Furthermore, samples of coal, Fly Ash and Bottom Ash (FABA), and flue gas were periodically taken for further analysis. The trials were conducted with variations in sawdust concentration at 1%, 3%, and 5% in all feeders, allowing for a comparative evaluation of its impact on power plant performance across different blending ratios. This detailed approach to data acquisition from existing reports provides a robust foundation for a comprehensive technical feasibility analysis without the need for new, costly, and potentially disruptive experiments.

## 4 Results and discussion

### 4.1 Technical Feasibility of Sawdust for Co-firing

The technical feasibility analysis of sawdust as co-firing fuel in PLTU was conducted through performance testing by mixing sawdust and coal in the coalyard. After the mixing and stabilization process, observation of operating parameters was conducted for eight hours, followed by data recording from Coal Combustion Residuals (CCR) every hour between 10:00–18:00. Samples of coal, Fly Ash and Bottom Ash (FABA), and flue gas were taken periodically for analysis. Tests were conducted with variations in sawdust concentration of 1%, 3%, and 5% in all feeders to evaluate its impact on power plant performance.

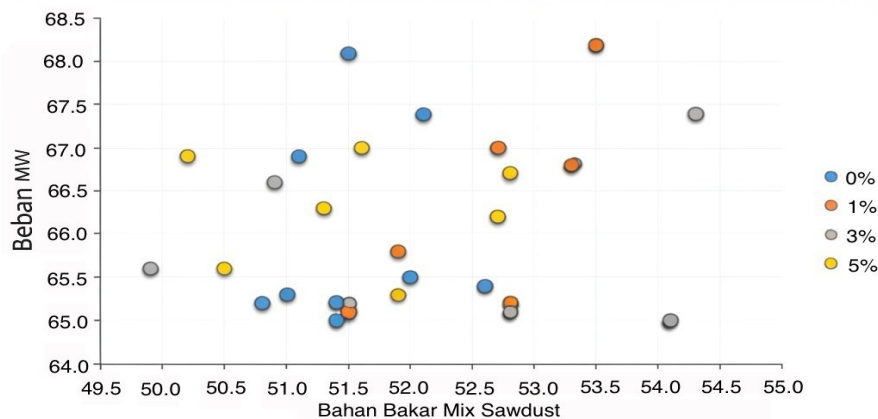


Figure 2. Coal Flow vs Load (mix sawdust combination)

The use of sawdust up to 5% in co-firing showed stable power plant performance, even more stable than other mixtures. Coal consumption data from hour to 10:00–18:00 showed a decreasing trend as the percentage of sawdust increased, without reducing the electricity load. At 0% biomass, coal consumption was 53.4–55.8 tons/hour; at 1% it dropped to 50.8–52.6 tons/hour with a constant load of 65–68 MW. The mixtures of 3% and 5% showed lower consumption (51.5–53.5 and 50.2–52.8 tons/hour) with a stable load. This success was supported by the appropriate technical characteristics of sawdust and the adjusted combustion system, allowing for coal and emission reductions without reducing power plant efficiency.

Table 3. Specific Fuel Consumption

No.	O'clock	0% (Kg/KWh)	1% (Kg/KWh)	3% (Kg/KWh)	5% (Kg/KWh)
1	10:00	0.76	0.81	0.81	0.80
2	11:00	0.79	0.79	0.79	0.75
3	12:00	0.79	0.78	0.81	0.77

4	13:00	0.80	0.81	0.83	0.79
5	14:00	0.76	0.79	0.81	0.77
6	15:00	0.77	0.78	0.83	0.77
7	16:00	0.78	0.80	0.83	0.79
8	17:00	0.78	0.79	0.76	0.77
9	18:00	0.79	0.79	0.76	0.79

The technical interaction between sawdust and coal in co-firing at the PLTU was analyzed through the measurement of Specific Fuel Consumption (SFC) during the performance test. The SFC graph shows a relatively stable pattern from hour to 10:00 to 18:00, although there is a slight increase in the SFC value as the proportion of sawdust increases (1%, 3%, to 5%). This increase reflects a slightly higher fuel consumption to produce the same energy, due to decreased combustion efficiency because the calorific value of sawdust is lower than that of coal.

The increase in SFC is also influenced by the characteristics of sawdust combustion which is fast but less stable, although in some conditions, the 5% mixture actually shows better performance than the 1% and 3% mixtures. This emphasizes the importance of operational factors such as material mixing, combustion system, and process control. Although the increase in SFC is relatively small, attention is still needed so that efficiency is not compromised. Further studies on parameters such as combustion temperature, exhaust emissions, and ash characteristics are essential to determine the optimal limit of biomass mixing without sacrificing the stability and performance of the plant.

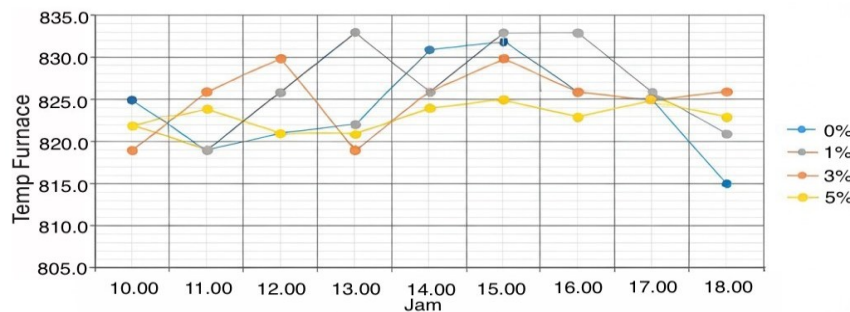


Figure 3. Furnace Temperature

Temperature Furnace tends to be relatively the same, and Temperature with 5% sawdust tends to be stable. Based on the average temperature data of the furnace bed from the hour of 10:00 to 18:00 for various variations of sawdust mixtures, it can be seen that the temperature in all variations of the mixture is relatively stable with small fluctuations between hours. The average temperature

of the furnace bed at a mixture of 0%, 1%, and 3% shows a fairly consistent value, ranging from 815°C to 833°C. This indicates that the addition of sawdust up to 3% does not have a significant impact on the stability of the combustion temperature in the furnace.

Interestingly, in the 5% sawdust mixture, the furnace temperature actually showed higher stability with very small fluctuations over time. The temperature values ranged from 821°C to 825°C almost throughout the observation hours. This condition indicates that although sawdust has different combustion characteristics from coal, at a mixing level of 5%, the furnace system is still able to adapt well and maintain the stability of the combustion process. This strengthens the indication that technically, a sawdust mixture of up to 5% can be applied without disturbing the temperature stability in the PLTU combustion chamber.

According to Tanbar's research (2021), a comparison of the characteristics between coal and sawdust biomass was carried out by comparing the results of the Ultimate analysis and Proximate analysis obtained from suppliers between typical medium rank coal (Coal A) and typical low rank coal used in PLTU with typical sawdust biomass.

Based on research by Tanbar (2021), it shows that sawdust has the potential as a co-firing fuel in PLTU because of its low humidity, high volatile content, and lower ash, sulfur, and nitrogen content compared to coal, so it can increase combustion efficiency and reduce pollutant emissions. Although the calorific value of sawdust is lower than coal, its contribution remains significant in fuel mixing. However, challenges such as low grindability index and smaller bulk density require modifications to the storage, feeding, and mixing systems. With proper adjustments, sawdust can be an environmentally friendly and efficient co-firing option in PLTU.

According to research by Winahyu et al., (2024) both experiments used coal from the same source and sawdust, which has a lower calorific value compared to the coal used. Ensuring the uniformity of coal from one source is complex, which has the potential to cause variations in the results of coal calorific value tests in different layers. The proportion of sawdust used is much smaller compared to coal, so the impact of the lower calorific value of sawdust on the calorific value of the composite is relatively small.

Operators noted an increase in fly ash volume with sawdust addition, especially at 5%, due to its higher volatile and fine particle content. While the ash still fell within design handling limits, minor increases in hopper cleaning frequency were needed. There was no reported clogging or significant slagging, but these parameters should be studied further for long-term implications.

#### **4.2 Estimation of Sawdust Requirements to Achieve Co-firing Ratio**

Co-firing is a technique of simultaneous combustion of coal with biomass, such as sawdust, in a PLTU. This method aims to reduce greenhouse

gas emissions and increase the use of new and EBT. Indonesia is targeting an EBT mix of 23% by 2025 (ESDM, 2021)

**Table 4.** Sawdust Co-firing on PLTU Performance

Parameter	0% (Without Co-firing)	1% Sawdust	3% Sawdust	5% Sawdust
Average Coal Flow (ton/hour)	54.70	51.99	52.84	51.50
Average Load (MW)	65.18	66.10	65.89	66.42
SFC (Kg/KWh)	0.78	0.79	0.80	0.78
Average Furnace Temp (°C)	821.33	825.11	827.11	823.24
O <sub>2</sub> Excess (Left) (%)	4.47	4.33	4.38	4.29
O <sub>2</sub> Excess (R) (%)	5.42	5.22	5.56	5.46

Based on operational performance data, mixing sawdust up to 5% in PLTU fuel shows a significant increase in efficiency. The decrease in coal flow with increasing sawdust mixture for example from 55.8 tons/hour at 0% to 50.5 tons/hour at 5% indicates increased combustion efficiency, especially since the electricity generated remains stable or increases slightly. This is also reflected in the Specific Fuel Consumption (SFC) value, which is slightly lower at a 5% mixture, as well as the stability of the furnace temperature in the range of 821–825°C and the level of excess O<sub>2</sub> which remains safe. Thus, the use of sawdust not only reduces coal consumption, but also maintains the thermal performance and safety of power plant operations.

In the context of the national energy transition, sawdust co-firing is a fast and effective strategy to reduce dependence on coal without requiring new infrastructure. Data shows that mixing up to 5% can support the target of EBT mix of 23% in 2025 by utilizing abundant local biomass and low implementation costs. Sawdust co-firing in existing PLTU is a real example of renewable energy integration in the existing system, supporting carbon emission reduction while maintaining the reliability of electricity supply.

With the technical and operational success demonstrated in the 5% sawdust mixture, PLTU can be an active contributor in achieving the national EBT target. If this co-firing program is widely replicated in various PLTUs in Indonesia, its contribution to achieving the national energy mix can be very large. Moreover, this approach also encourages a circular economy in the forestry and agriculture sectors, and opens up new economic opportunities in biomass producing areas.

In other words, co-firing is not only an intermediate technology, but also a strategic bridge towards a cleaner and more sustainable energy system, which is very relevant to Indonesia's vision of achieving the 23% EBT target by 2025.

According to (Elbl et al., 2022) to achieve a co-firing ratio of 23%, it is necessary to calculate the amount of sawdust needed. The calorific value of

sawdust ranges from 15-20 MJ/kg. Suppose the average calorific value is 18 MJ/kg. If the PLTU operates at a certain capacity, the amount of sawdust needed can be calculated based on the energy produced and the desired co-firing ratio.

To achieve the target of 23% renewable energy mix by 2025 through coal-sawdust co-firing, specific calculations are needed based on the capacity of the PLTU and the heating value of biomass. Previous studies have shown that co-firing can reduce carbon emissions and utilize biomass waste effectively. Proper implementation and accurate calculation of biomass needs are essential to achieve the national target in renewable energy utilization.

### 4.3 Comparison with Palm Kernel Shell Biomass

The primary sample in this study is sawdust used as a co-firing fuel at Labuhan Angin PLTU. To provide broader context and strengthen technical validity, a comparative review was also conducted against another biomass type, palm kernel shell (PKS), which has previously been tested under similar operational conditions at the site.

Palm kernel shell is a commonly used biomass in the Sumatra region due to its availability and relatively high calorific value. Based on testing data from Labuhan Angin PLTU, the following presents a technical performance comparison between co-firing using sawdust and palm kernel shell, focusing on two main parameters: furnace combustion temperature stability and flue gas emissions.

Sawdust shows a relatively small decrease in furnace temperature when used up to 5% co-firing. This trend is also observed in co-firing tests with palm kernel shell, although the temperature values tend to be slightly higher, particularly at the right seal pot measurement point.

**Table 5.** Furnace Temperature Stability

Measurement Point	Sawdust Co-firing 5% (°C)	Palm Kernel Shell Co-firing 5% (°C) (Estimated Average)
Bed	831.2	840–845
Seal Pot Left	794.2	800–810
Seal Pot Right	803.1	805–815

Operational temperatures for both biomass types remain within the boiler's stable combustion range.

Regarding emissions, both biomass types demonstrate reductions in SO<sub>2</sub> and NO<sub>x</sub> emissions. Sawdust exhibits a greater reduction effect on NO<sub>x</sub>, whereas palm kernel shell shows a slight advantage in lowering SO<sub>2</sub> emissions. Particulate emissions increase marginally for both but remain below the Maximum Emission Limits (MEL).

**Table 6.** Flue Gas Emissions

Parameter	Unit	Sawdust 5% (Estimated)	Palm Kernel Shell 5%	Maximum Emission Limit (MEL)
SO <sub>2</sub>	mg/Nm <sup>3</sup>	460.2	469.13	750

NO <sub>x</sub>	mg/Nm <sup>3</sup>	139.1	144.2	750
Particulates	mg/Nm <sup>3</sup>	82.1	82.50	100

Based on the technical evaluation, both sawdust and palm kernel shell (PKS) have demonstrated feasibility as co-firing biomass fuels in PLTU combustion systems. Co-firing with sawdust up to 5% maintained furnace temperature stability across critical points and resulted in a more significant reduction in NO<sub>x</sub> emissions compared to PKS. On the other hand, PKS showed a slightly greater reduction in SO<sub>2</sub> emissions. Both biomass types recorded a modest increase in particulate emissions, although still within permissible emission limits. Therefore, sawdust is not only technically feasible but also environmentally beneficial as a co-firing option performing comparably, and in some aspects, better than the commonly used PKS. The selection of biomass type should also consider local availability, logistics cost, and specific combustion characteristics of each material.

#### 4.4 Discussion

##### 4.4.1 Technical Feasibility of Sawdust for Co-firing

The study confirms that sawdust has good potential as an alternative fuel in PLTU co-firing. Mixing up to 5% sawdust with coal does not significantly affect power plant performance. From 10:00 to 18:00, coal usage decreases as sawdust ratio increases, while power output remains stable at 65–68 MW, indicating maintained energy efficiency.

Although Specific Fuel Consumption (SFC) slightly rises at 1–3% sawdust, it stabilizes at 5%, showing system adaptability. Furnace temperatures also remain stable, with the highest stability at 5% sawdust. Sawdust helps reduce coal usage and emissions due to its favorable combustion properties (low moisture, low sulfur/nitrogen, high volatility).

However, challenges like low bulk density and poor grindability require system adjustments. With proper handling, sawdust is a technically viable co-firing fuel that supports renewable energy targets.

##### 4.4.2 Estimation of Sawdust Requirements to Achieve Co-firing Ratio

The use of sawdust as biomass fuel in PLTU co-firing supports energy diversification and carbon emission reduction efforts. Research and actual data show that while sawdust has strong potential as a supplementary fuel, technical challenges such as differing combustion characteristics compared to coal must be addressed. The IEEFA (Efendi & Garniwa, 2022) stresses the importance of evaluating fuel supply stability and technical feasibility in co-firing systems.

To achieve a 23% co-firing ratio, calorific value differences must be considered. With sawdust averaging 18 MJ/kg and coal 25 MJ/kg, around 1.28 tons of sawdust are needed to replace 1 ton of coal at this ratio. However, actual values depend on PLTU design and fuel quality (Lunguleasa, Ayrilmis, Spirchez, & Croitoru, 2019).

#### 4.4.3 Limitations and Challenges

- **Limitations of Sawdust Concentration Variation:**  
Testing was only carried out on variations of 1%, 3%, and 5% sawdust mixture, so the maximum limit of sawdust that is still technically acceptable without disrupting the stability of the generator is not yet known.
- **Limitations of Test Parameters:**  
The main focus is on fuel consumption, electrical load, furnace temperature, and SFC; it does not cover detailed measurements of exhaust emissions (CO, NOx, SOx), and ash characteristics (FABA) which are important for environmental aspects.
- **Sawdust Quality and Particle Size Control:**  
The particle size and moisture content of sawdust greatly affect combustion. Quality control must be carried out strictly so as not to interfere with boiler efficiency.
- **Feeding System Adaptation:**  
The feeding system in conventional coal-fired power plants is designed for coal, so it requires modification to be able to handle sawdust with lower bulk density and flammability.

#### 4.4.4 Comparison with Previous Studies

Research at Labuhan Angin PLTU demonstrates that using sawdust as co-firing fuel up to 5% is both technically and economically feasible. Performance tests show that power output remains stable, while coal consumption decreases and furnace temperature stays consistent—indicating efficient combustion. Although Specific Fuel Consumption (SFC) slightly increases, overall efficiency is maintained.

Supported by earlier studies (Tanbar, 2021; Winahyu et al., 2024), sawdust's low moisture and pollutant content make it a promising biomass fuel. These findings suggest that sawdust co-firing can reduce emissions and coal usage without major infrastructure changes, contributing to a cleaner and more sustainable energy transition.

## 5 Conclusion

This study confirms that sawdust has strong technical potential as a co-firing fuel at Labuhan Angin PLTU, offering high efficiency and stable performance. With its high volatile content and low ash content, sawdust can be

mixed with coal up to 5% without disrupting plant operations. Key indicators such as coal consumption, electrical load, furnace temperature, and Specific Fuel Consumption (SFC) remained stable, while coal usage decreased and combustion efficiency improved, especially at 3% and 5% mixtures.

Although sawdust has a lower calorific value than coal, requiring adjustments in storage, feeding, and combustion systems (as noted by Winahyu et al., 2024), this study demonstrates that these challenges can be managed without harming overall efficiency. Stable furnace temperatures further confirm safe and efficient co-firing. Overall, the use of sawdust supports the national energy transition by reducing coal use and increasing renewable energy contribution.

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