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Comparative Analysis of the Effectiveness and Environmental Impact of Sawdust Biomass on Greenhouse Emissions for Power Plants Steam

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ABSTRACT

Indonesia's dependence on fossil fuels, especially coal, causes greenhouse gas (GHG) emissions that have a significant impact on global climate change. As an energy transition solution, biomass is offered through co-firing technology at the energy industry's Steam Power Plants (PLTU). This study aims to analyze the sustainability of the use of biomass, especially sawdust, as an alternative fuel to replace some coal in the power generation sector. The Life CycleAssessment (LCA) approach is used to assess the environmental impact of the entire biomass life cycle, starting from the process of extracting raw materials, producing and drying sawdust, transportation to coal-fired power plants, to the combustion and residue disposal stages. The analysis was carried out using SimaPro software by considering various categories of environmental impacts, such as potential global warming (GWP), eutrophication, acidification, and depletion of natural resources. The results show that the use of sawdust biomass through co-firing has the potential to significantly reduce GHG emissions compared to the burning of pure coal, supports the Nationally DeterminedContribution (NDC) target, and contributes to the achievement of Sustainable Development Goals (SDG) 7 (Clean and Affordable Energy) and SDG 13 (Action on Climate Change).

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INTRODUCTION

The use of fossil fuels such as natural gas, oil, and coal in large-scale industries has been the backbone of the global energy system for decades. However, the burning of fossil fuels produces large amounts of carbon dioxide (CO_2) emissions which are the main cause of global climate change. In Indonesia, dependence on fossil energy sources is still very high, with coal accounting for around 43% of the total national energy mix in 2020.

The energy sector is the main contributor to GHG emissions, with around 40% coming from coal-fired power plants. Therefore, efforts to accelerate the transition to clean energy are very important. The government targets increasing renewable energy to 25% and reducing coal usage significantly.

One of the strategies used is biomass co-firing technology in coal-fired power plants. Co-firing is the process of mixing biomass with coal as fuel without major modifications to existing infrastructure. This makes co-firing an efficient and economical solution in the transition to renewable energy. However, sawdust biomass has the potential to be carbon neutral, as the CO_2 released during combustion can be reabsorbed by plants and need to be defined.

RESEARCH METHODS

Biomass Sawdust, Co-Firing, dan Life Cycle Assessment (LCA)

Biomass is a material that can be obtained from plants either directly or indirectly and is used as energy, and biomass is a renewable resource. Burning biomass energy will produce CO_2, however biomass is said to have a net amount of CO_2 that is zero based on the assumption that new plants will provide the CO_2 produced. Biomass is increasingly seen as an alternative to fossil fuels because of its renewable nature and its potential contribution to reducing greenhouse gas (GHG) emissions. One type of biomass widely used is sawdust which is categorized as lignocellulose biomass and has a calorific value of around 4.7 kWh/kg or ±16–17 MJ/kg, making it technically possible to be used as a partial substitution for coal. Sawdust has the potential to be carbon neutral, and its use contributes to reducing environmental risks from wood waste and provides a lower emission profile than coal, as co-firing sawdust–coal is able to reduce CO_2, NOx, and SO_2 emissions [4].

Biomass energy conversion is carried out by burning biomass to produce heat which is converted into electrical energy through turbines and generators [5]. Fossil fuels cause greenhouse gas effects and global warming because they increase CO_2 concentration in the atmosphere [1], therefore co-firing is used as the activity of adding biomass as a partial substitute fuel in coal-fired power plants with substitution levels generally ranging from 3% to 10% [4]. Renewable energy is energy derived from sustainable natural processes [2]. Life Cycle Assessment (LCA) is a method to analyze the environmental impact at all stages of a product life cycle [6], consisting of goal and scope, inventory analysis, impact assessment, and interpretation [7]. Impact assessment methods include CML, ReCiPe, IPCC, and Cumulative Energy Demand (CED), while LCA system boundaries include cradle to grave, cradle to gate, gate to grave, and gate to gate. The analysis is supported by SWOT analysis, Product Life Assessment (KHP), and SimaPro software to analyze environmental impacts and support sustainability evaluation.

Research Flow Diagram

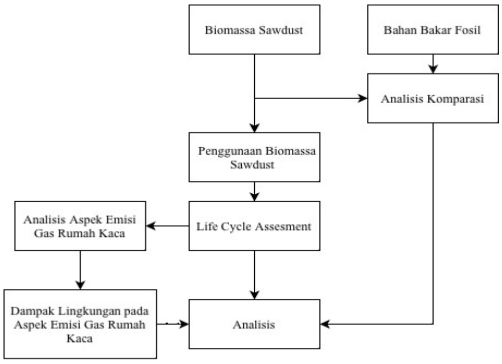

Figure 1. Research Flow Diagram

RESULT AND DISCUSSION

The Banten 3 Lontar Coal-Fired Power Plant is located in Lontar Village, Kemiri District, Tangerang Regency, Banten Province, Indonesia. The power plant is operated by PT PLN Indonesia Power and occupies a total area of 94.02 ha, consisting of 72.48 ha owned by PT PLN (Persero) and 21.54 ha managed by Perum Perhutani. The facility comprises three generating units, each with an installed capacity of 315 MW, resulting in a total installed capacity of 945 MW. The electricity generated is transmitted through a 150-kV high-voltage transmission network to the Teluk Naga and Tangerang Baru substations, contributing to the electricity supply of the Java–Bali interconnected power system, particularly for the Greater Jakarta metropolitan area.

As a coal-fired steam power plant, the Banten 3 Lontar Power Plant generates electricity by converting the thermal energy produced from coal combustion into mechanical energy through a steam turbine-generator system. The electricity generation process is supported by several major operational units, including boilers, steam turbines, generators, condensers, pulverizers, air preheaters, and electrostatic precipitators (ESP). Supporting facilities include a Water Treatment Plant (WTP), Wastewater Treatment Plant (WWTP), coal handling system, ash pond, hazardous waste temporary storage facility, hydrogen plant, chlorine plant, and fuel oil storage tanks. These auxiliary systems ensure operational reliability while supporting environmental management throughout the power generation process.

To ensure sustainable electricity production while minimizing environmental impacts, PT PLN Indonesia Power has implemented environmental management practices based on the principles of sustainable development. One of the approaches adopted is the application of Life Cycle Assessment (LCA), which systematically evaluates the environmental impacts associated with electricity generation throughout its life cycle, from raw material acquisition to electricity distribution (cradle-to-grave approach). The implementation of LCA also supports compliance with the requirements of Indonesia's Program for Pollution Control, Evaluation, and Rating (PROPER), an environmental performance assessment program administered by the Ministry of Environment of the Republic of Indonesia.

The results of this study indicate that the use of sawdust biomass as a co-firing fuel in coal-fired power plants has a positive impact on reducing environmental burdens, especially greenhouse gas (GHG) emissions. Based on the Life Cycle Assessment (LCA) analysis, the stages that contribute the most to environmental impact are the combustion process, energy consumption, and ash management. The characterization results show that the Global Warming Potential (GWP) value from the co-firing system is lower compared to the use of pure coal, indicating that the substitution of coal with sawdust biomass is effective in reducing carbon emissions. In addition, the impact categories such as acidification and eutrophication also show a decreasing trend due to the lower sulfur and nitrogen content in biomass compared to coal.

The co-firing process of sawdust biomass in coal-fired power plants can be illustrated in a process flow diagram starting from biomass reception, mixing with coal, to the combustion process and electricity generation.

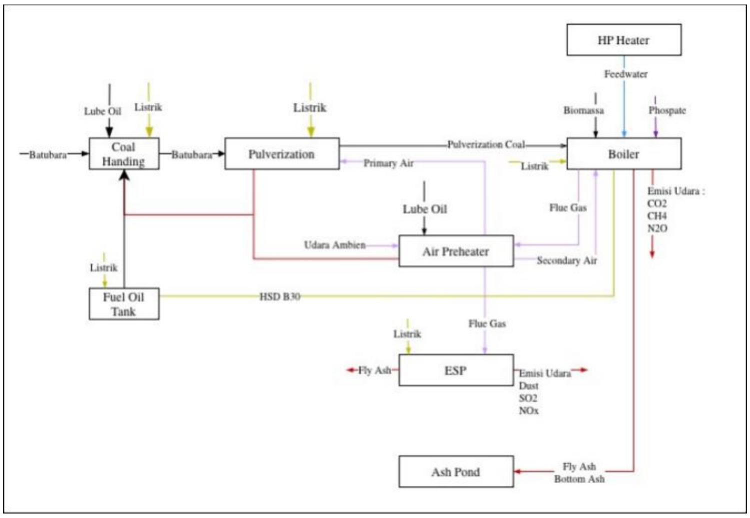

Figure 2. Lontar Coal-Fired Power Plant Electricity Production System

Furthermore, the results of the Life Cycle Assessment (LCA) analysis using SimaPro show the contribution of each process unit to environmental impacts, where the combustion unit becomes the main hotspot.

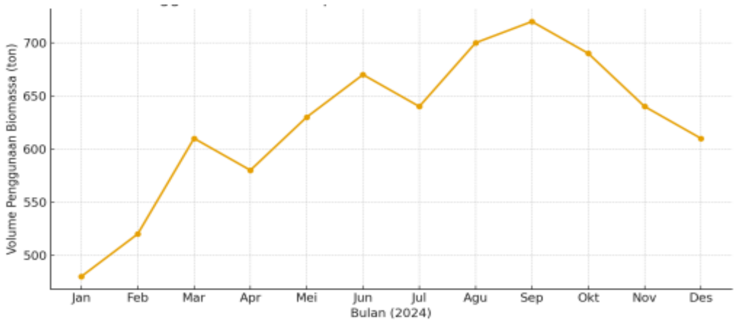

Figure 3. Trend of Sawdust Biomass Use at Lontar Banten Coal-Fired Power Plant

The comparison of emissions between conventional coal systems and co-firing systems shows a decrease in CO_2, NOx, and SO_2 emissions (Cahyo, 2021) while the comparison of Global Warming Potential (GWP) indicating a lower impact in the co-firing system.

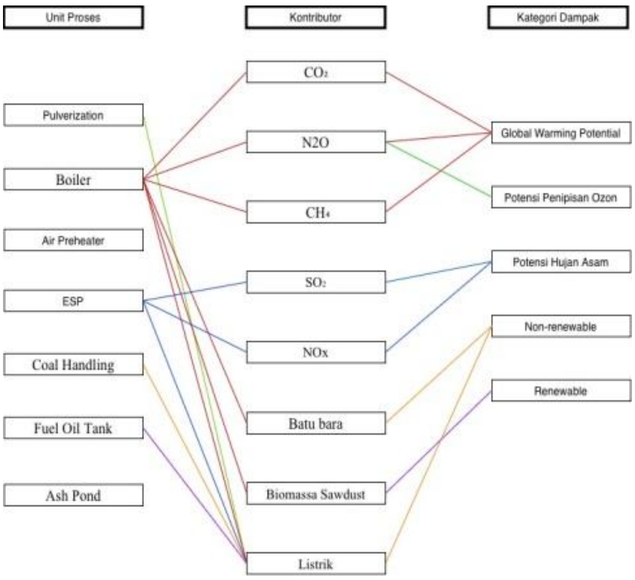

Figure 4. Scheme of Value Characteristics of Environmental Impact of Lontar Coal-Fired Power Plant

From an operational perspective, the use of sawdust biomass shows relatively stable performance at a substitution level of 5–10%. The calorific value of sawdust, which is around 16–17 MJ/kg, supports its feasibility as an alternative fuel, although it is still lower than coal. The fluctuation in biomass supply, ranging from 480–720 tons per month, indicates that supply chain stability is a critical factor in increasing the co-firing ratio. Despite this limitation, the annual supply of 7,490 tons is still sufficient to support current co-firing operations. The results also show that the use of biomass contributes to waste utilization from the wood industry, thereby reducing environmental risks such as methane emissions and particulate pollution from unmanaged sawdust.

The comparison of environmental impacts between coal and co-firing systems, which shows that the co-firing system has lower emissions and better environmental performance.

Tabel 1. Input Inventory Data of the Lontar Power Plant Process Unit

No	Main Category	Sub Category	Inventory Parameter	Total Annual Amount	Unit	Amount per Functional Unit	Unit/FU
1	Raw Materials	Air	Udara	28.158.986,00	ton	4,64E-03	ton/kWh
2	Fuel	Coal	Coal	4.001.617,11	ton	6,59E-04	ton/kWh
3	Fuel	Biomass Sawdust	Biomass Sawdust	54.528,18	ton	8,99E-06	ton/kWh
4	Fuel	HSD	HSD	1.200.720	L	1,98E-04	L/kWh
5	Chemicals	Phosphate	Phosphate	395	kg	6,51E-08	kg/kWh
6	Electricity	Electricity	Electricity	308.382.154,83	kWh	5,08E-02	kWh/kWh
7	Water	Seawater	Seawater	2.264.536.778	ton	3,73E-01	ton/kWh

The LCI results indicate that electricity generation is predominantly dependent on coal, with a specific consumption of 6.59×10^{-4} ton/kWh, while biomass contributes only 8.99×10^{-6} ton/kWh, corresponding to approximately 1.35% of the total fuel input on a mass basis. Although the biomass fraction remains relatively small, its incorporation is expected to reduce fossil carbon emissions and improve the environmental performance of the power plant. The inventory further reveals a considerable demand for seawater (0.373 ton/kWh) for condenser cooling, highlighting cooling operations as one of the most resource-intensive processes in the system. In contrast, the consumption of chemicals such as phosphate is negligible compared with fuel and water inputs. Internal electricity use of 0.0508 kWh/kWh indicates that approximately 5.08% of the generated electricity is utilized to support auxiliary equipment, including coal handling, boiler feedwater pumps, cooling systems, and flue gas treatment units. These inventory characteristics suggest that fuel combustion, cooling operations, and auxiliary electricity consumption are the principal contributors to the environmental impacts evaluated in the subsequent LCIA.

Tabel 2. Output Inventory Data of the Lontar Power Plant Process Unit

No	Main Category	Sub Category	Inventory Parameter	Total Annual Amount	Unit	Amount per Functional Unit	Unit/FU
1	Product	Electricity	Electricity	6.068.419.503	kWh	1,00E+00	kWh/kWh
2	Air Emissions	CO_2	CO_2	4.576.210,31	ton	7,54E-04	ton/kWh
3	Air Emissions	CH_4	CH_4	47,62	ton	7,85E-04	ton/kWh
4	Air Emissions	N_2O	N_2O	71,43	ton	1,18E-03	ton/kWh
5	Air Emissions	SO_2	SO_2	5.539,89	ton	9,13E-07	ton/kWh
6	Air Emissions	NO_x	NO_x	5.468,65	ton	9,01E-07	ton/kWh

The life cycle inventory (LCI) was established based on operational data collected for one production period of electricity generation. A total of 6.07×10^9 kWh of electricity was produced and used as the reference flow, with inventory data normalized per 1 kWh of electricity generated. The process generated atmospheric emissions of 4.58×10^6 tons of CO_2, 47.62 tons of CH_4, and 71.43 tons of N_2O, corresponding to 7.54×10^{-4} ton CO_2/kWh, 7.85×10^{-4} ton CH_4/kWh, and 1.18×10^{-3} ton N_2O/kWh, respectively. Furthermore, emissions associated with acidification reached 5,539.89 tons of SO_2 and 5,468.65 tons of NO_x, equivalent to 9.13×10^{-7} ton SO_2/kWh and 9.01×10^{-7} ton NO_x/kWh. These inventory data constitute the input for the subsequent LCIA phase and enable the assessment of environmental impacts related to climate change and acidification. Furthermore, the SWOT analysis results of sawdust biomass utilization, which identifies strengths, weaknesses, opportunities, and threats in the implementation of biomass as an alternative fuel.

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Global Warming Potential (GWP)

The Global Warming Potential (GWP) was assessed using the 100-year time horizon recommended by the Intergovernmental Panel on Climate Change (IPCC). Greenhouse gas emissions were expressed in kilograms of carbon dioxide equivalent (kg CO_2-eq) using characterization factors of 1 for CO_2, 28 for CH_4, and 265 for N_2O following the IPCC assessment framework (IPCC, 2019). The inventory data were normalized to the functional unit of 1 kWh of electricity generated, enabling a consistent evaluation of climate change impacts within the Life Cycle Impact Assessment (LCIA) framework in accordance with ISO 14044 (ISO, 2006).

Tabel 3. Characterization Results of Global Warming Potential (GWP)

Emission	Inventory (ton/kWh)	Inventory (kg/kWh)	Characterization Factor	Characterized Result (kg CO_2-eq/kWh)	Contribution (%)
CO_2	7,54E-04	7,54E-01	1	7,54E-01	99,56
CH_4	7,85E-09	7,85E-06	28	2,20E-04	0,03
N_2O	1,18E-08	1,18E-05	265	3,13E-03	0,41
Total	-	-	-	0,7573	100

As shown in Table 6, the electricity generation process resulted in a total Global Warming Potential of 0.7573 kg CO_2-eq/kWh. Carbon dioxide (CO_2) was identified as the dominant contributor, accounting for 0.754 kg CO_2-eq/kWh, equivalent to 99.56% of the total climate change impact. This dominance reflects the intensive use of coal as the primary fuel in the power generation process. During coal combustion, most of the carbon contained in the fuel is oxidized into CO_2, making it the principal greenhouse gas emitted by coal-fired power plants. Similar findings have been widely reported for fossil-fuel-based electricity generation systems, where CO_2 emissions overwhelmingly determine the overall GWP (IPCC, 2019).

Methane (CH_4) contributed 2.20×10^{-4} kg CO_2-eq/kWh, representing only 0.03% of the total GWP. Although methane possesses a global warming potential 28 times greater than CO_2 over a 100-year time horizon, its contribution remained negligible because the emitted quantity was relatively small. Likewise, nitrous oxide (N_2O) contributed 3.13×10^{-3} kg CO_2-eq/kWh, corresponding to 0.41% of the total GWP. Despite its high characterization factor of 265, the low emission rate of N_2O during combustion limited its overall contribution to climate change.

findings indicate that CO_2 emission reduction should be prioritized to mitigate the climate change impacts associated with electricity generation at the Banten 3 Lontar coal-fired power plant. One promising mitigation strategy is the implementation of biomass co-firing using sawdust, which partially replaces coal with renewable biomass. By reducing fossil fuel consumption, biomass co-firing has the potential to lower fossil-derived CO_2 emissions while maintaining the operational performance of the power plant.

Acidification Potential (AP)

Acidification Potential (AP) was evaluated to quantify the environmental impacts associated with acid-forming atmospheric emissions generated during electricity production. Acidification primarily results from sulfur dioxide (SO_2) and nitrogen oxides (NO_x), which undergo atmospheric oxidation and subsequently react with water vapor to form sulfuric acid (H_2SO_4) and nitric acid (HNO_3), respectively. These acidic compounds contribute to soil and freshwater acidification, deterioration of infrastructure, ecosystem degradation, and adverse effects on human health (Ye et al., 2022; Greenfelt et al., 2022). The characterization factors adopted in this study were 1 kg SO_2-eq/kg SO_2 and 0.7 kg SO_2-eq/kg NO_x, with all inventory data normalized to the functional unit of 1 kWh of electricity generated.

Tabel 4. Characterization Results of Acidification Potential (AP)

Emission	Inventory (ton/kWh)	Inventory (kg/kWh)	Characterization Factor	Characterized Result (kg CO_2-eq/kWh)	Contribution(%)
SO_2	9,13E-07	9,13E-04	1	9,13E-04	59,14
NO_x	9,01E-07	9,01E-04	0,7	6,31E-04	40,86
Total	-	-	-	1.54E+03	100

The characterization results presented in Table 7 indicate that the electricity generation process produced a total Acidification Potential of 1.54×10^{-3} kg SO_2-eq/kWh. Sulfur dioxide (SO_2) was identified as the dominant contributor, accounting for 9.13×10^{-4} kg SO_2-eq/kWh, or 59.14% of the total acidification impact. This finding is primarily attributed to the sulfur content of coal, which remains the principal fuel used in the Banten 3 Lontar power plant. During combustion, sulfur compounds contained in coal are oxidized to SO_2, which subsequently forms sulfuric acid in the atmosphere and contributes significantly to acid deposition.

Nitrogen oxides (NO_x) contributed 6.31×10^{-4} kg SO_2-eq/kWh, representing 40.86% of the total Acidification Potential. Although its contribution was lower than that of SO_2, NO_x remains a significant acidifying pollutant because atmospheric reactions convert it into nitric acid, which also contributes to acid rain formation. Furthermore, NO_x emissions are associated with photochemical smog formation and respiratory health problems, highlighting their broader environmental significance beyond acidification.

The results demonstrate that effective reduction of Acidification Potential should focus on controlling SO_2 and NO_x emissions. Potential mitigation measures include the use of lower-sulfur fuels, optimization of combustion conditions, and implementation of advanced flue gas treatment technologies. In addition, the application of sawdust biomass co-firing is expected to reduce sulfur input into the combustion process because woody biomass generally contains substantially lower sulfur concentrations than coal. Consequently, biomass substitution may contribute not only to reducing greenhouse gas emissions but also to lowering the acidification impacts associated with electricity generation.

Environmental Impact Inventory Evaluation (Global Warming Potential and Acidification Potential)

The environmental impact evaluation stage was conducted to quantify the contribution of each emission parameter to the selected impact categories. Based on the characterization results for Global Warming Potential (GWP) and Acidification Potential (AP), the contribution of each emission to the total environmental impact of the PLTU Banten 3 Lontar power plant system was identified.

This evaluation aims to determine the most dominant emission parameters, which can serve as key targets for environmental mitigation strategies and emission control improvements. According to ISO 14044, the interpretation phase is required to identify significant environmental issues and to understand the relationship between inventory flows and impact categories (ISO, 2006).

Global Warming Potential (GWP) Results

The Global Warming Potential was calculated as the sum of characterized greenhouse gas emissions, namely carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). The total GWP is expressed as follows:

Total Global Warming Potential:

Total GWP = $GWPCO_2 + GWPCH_4 + GWPN_2O$

Total GWP = 0.754 + 0.0002198 + 0.003127 = 0.7573 kg CO_2-eq/kWh

The contribution of each emission was calculated using the following equation:

Contribution (%) = Characterized valueTotal impact × 100Contribution (%)

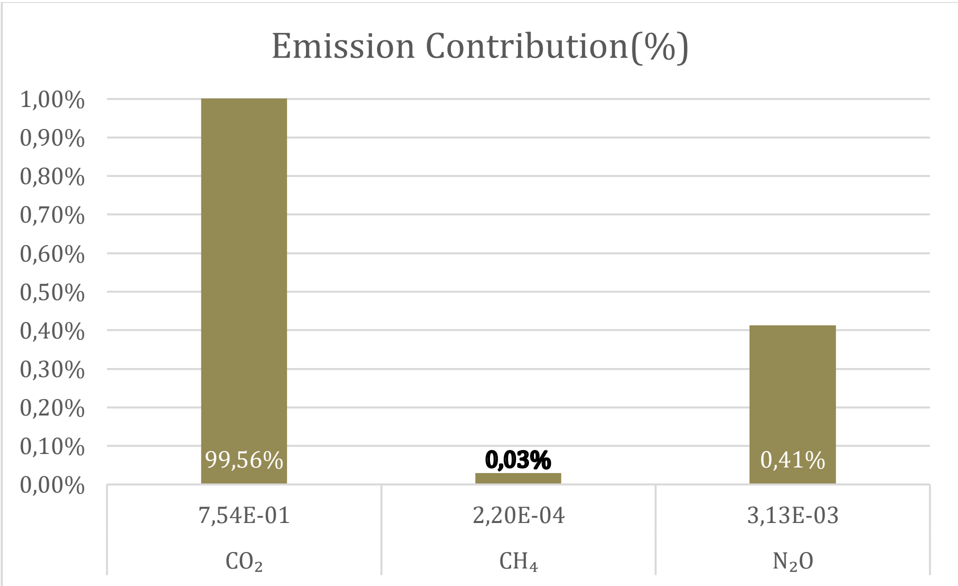

Figure 5. The contribution of each greenhouse gas to the Global Warming Potential (GWP)

The results show that CO_2 dominates the GWP category with a contribution of 99.56%, followed by N_2O at 0.41% and CH_4 at 0.03%. This indicates that carbon dioxide emissions from combustion processes are the primary driver of climate change impact in the studied system.

Acidification Potential (AP) Results

The Acidification Potential was derived from the sum of sulfur dioxide (SO_2) and nitrogen oxides (NO_x), which contribute to acid rain formation.

Total Acidification Potential:

Total AP = $APSO_2$ + APNOx

Total AP = $9.13\times10^{-4} + 6.307\times10^{-4} = 1.5437\times10^{-3}$ kg SO_2-eq/kWh

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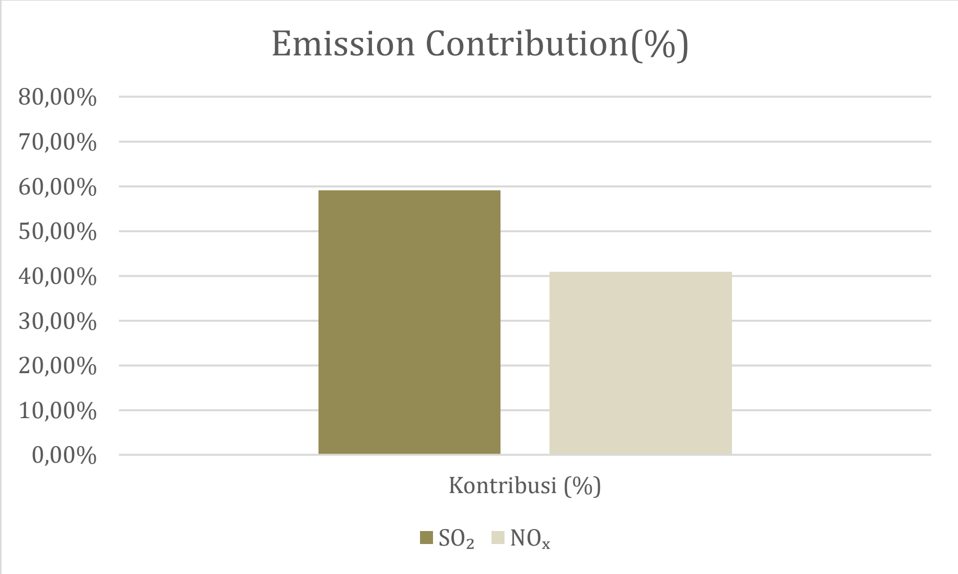

Figure 6. The contribution of each greenhouse gas to the Acidification Potential (GWP)

Contribution analysis indicates that SO_2 accounts for 59.14% of the total acidification impact, while NO_x contributes 40.86%. This suggests that sulfur emissions remain the dominant contributor to acidification, although nitrogen oxides also play a substantial role.

Interpretation of Key Environmental Issues

Interpretation represents the final phase of Life Cycle Assessment (LCA), in which significant environmental issues (hotspots) are identified for each impact category. This stage evaluates which unit processes contribute most significantly to each environmental impact. In this study, the interpretation focuses on two main impact categories: Global Warming Potential (GWP) and Acidification Potential (AP), considering relevant air emission flows including CO_2, CH_4, N_2O, SO_2, and NO_x.

Hotspot Identification for Global Warming Potential

Overall, the primary contributors to GWP in the electricity generation system originate from the main combustion process in the boiler unit. These emissions are released into the atmosphere through stack emissions and contribute directly to the accumulation of greenhouse gases. Therefore, GWP assessment at the boiler unit level is essential to identify key emission sources and to support the development of energy efficiency improvements and emission reduction strategies aimed at climate change mitigation.

Sensitivity Analyst

Sensitivity analysis is conducted as a verification procedure to ensure that the results obtained from the model are robust and reliable for drawing conclusions and formulating recommendations. This procedure is essential to confirm that the outcomes of the sensitivity assessment are consistent and suitable for interpretation within the context of environmental impact evaluation. A one-at-a-time (OAT) sensitivity analysis approach is applied, in which individual input parameters are varied while all other parameters are held constant, allowing the effect on output results to be systematically observed.

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In this study, a variation range of ±25% is applied to selected input parameters. The resulting changes in environmental impacts are then compared with the baseline scenario to identify the magnitude of response. A change in output exceeding 10% is considered significant, indicating a high sensitivity of the system to the selected parameter. The sensitivity analysis is specifically performed for the Global Warming Potential (GWP) category, focusing on carbon dioxide (CO_2) emissions, which represent the dominant hotspot in the system. This is particularly relevant for the electricity generation process at PLTU Banten 3 Lontar, where CO_2 emissions from combustion processes constitute the main contributor to climate change impact.

Sensitivity Analysis Calculation

Based on the GWP contribution analysis, carbon dioxide (CO_2) is identified as the primary driver of climate change impact in the electricity generation system. Therefore, the sensitivity assessment focuses on variations in CO_2 emissions resulting from changes in the fuel composition of the boiler system. The study evaluates the influence of increasing biomass (sawdust) substitution for coal on environmental performance in PLTU Banten 3 Lontar.

A Life Cycle Assessment (LCA) approach with a gate-to-gate system boundary is applied, covering the combustion process in the boiler unit and the subsequent release of emissions through the stack. In this context, CO_2 emissions from Boiler Unit 1 are identified as the most significant contributor to GWP and are selected as the key parameter for sensitivity testing.

Three fuel composition scenarios are defined to evaluate environmental performance:

1. Scenario 1 (Baseline): 100% coal, 0% biomass
2. Scenario 2: 95% coal, 5% biomass
3. Scenario 3: 90% coal, 10% biomass

The following assumptions are applied in the analysis:

1. The total electricity output is constant at 1 kWh.
2. Combustion efficiency is assumed to remain unchanged across scenarios.
3. Sawdust biomass is assumed to directly substitute coal on an energy basis.
4. All other inventory inputs (e.g., chemicals, auxiliary electricity) remain constant.
5. Only the fuel composition is varied, while all other system parameters are held fixed.
6. This framework allows for a controlled assessment of how changes in fuel mix influence CO_2 emissions and, consequently, the overall Global Warming Potential of the system.

Scenario 1 (Baseline):

CO_2 = 0,754 kg/kWh

CH_4 = 0,00000785 kg/kWh

N_2O = 0,0000118 kg/kWh

Skenario 2 (95% Batubara, 5% Biomassa):

CO_2 = 0,754 × 0,95 = 0,7163 kg/kWh

CH_4 = 0,00000785 × 0,95 = 0,00000746 kg/kWh

N_2O = 0,0000118 × 0,95 = 0,00001121 kg/kWh

Skenario 3 (90% Batubara, 10% Biomassa):

CO_2 = 0,754 × 0,90 = 0,6786 kg/kWh

CH_4 = 0,00000785 × 0,90 = 0,00000707 kg/kWh

N_2O = 0,0000118 × 0,90 = 0,00001062 kg/kWh

Based on the calculation results, three fuel composition scenarios were evaluated to assess the environmental implications of biomass co-firing in the power generation system.

Scenario 1 (100% coal) is used as the baseline condition and serves as a reference for comparison of environmental impacts. This scenario represents the conventional operational configuration of coal-fired power plants in Indonesia, where electricity generation is fully dependent on coal combustion without any biomass substitution.

Scenario 2 (95% coal, 5% biomass) represents the initial stage of biomass co-firing implementation. This level reflects current common practice in Indonesian coal-fired power plants, where co-firing is typically introduced at a low substitution rate to ensure operational stability and gradual adaptation of the system.

Scenario 3 (90% coal, 10% biomass) represents a more advanced energy transition scenario with a higher share of renewable biomass. This configuration aligns with a more ambitious decarbonization pathway and supports national targets for renewable energy penetration, including the 23% renewable energy mix target. It also reflects a stronger commitment toward reducing dependency on fossil fuels and lowering greenhouse gas emissions from the power sector.

SimaPro Modeling Approach

The system modeled in this study represents the energy generation chain of a coal-fired power plant with potential biomass integration. The modeled process chain includes coal handling, pulverization, boiler combustion, air preheater, electrostatic precipitator (ESP), and the final waste management system in the form of an ash pond. Each unit process is represented as a distinct unit process in the model, interconnected through material and energy flows.

The system inputs include coal, biomass, electricity, ambient air, lube oil, and supporting chemical additives such as phosphate used in the boiler system. These flows are modeled to reflect their interactions within the operational boundary of the power plant, ensuring that both energy transformation and emission generation pathways are properly represented.

The life cycle inventory (LCI) data used in the modeling process is compiled from a combination of literature sources, the ecoinvent database, and operational data from the power plant. This hybrid data approach is employed to improve the representativeness of the model and to approximate real operational conditions as closely as possible.

Accordingly, the developed model enables a comprehensive assessment of the contribution of each process unit to the overall environmental impacts associated with electricity generation, particularly across the full life cycle of energy production within the system boundary.

In terms of sustainability, the integration of LCA with SWOT analysis and Product Life Assessment (KHP) provides a comprehensive evaluation. The strengths of sawdust biomass include its renewable nature, local availability, and lower emissions. However, weaknesses such as lower calorific value, high moisture content, and fluctuating supply must be addressed. Opportunities arise from government support for renewable energy and national energy transition policies, while threats include dependence on the timber industry and supply chain instability. Overall, the use of sawdust biomass through co-firing technology is proven to be a viable and sustainable strategy to support emission reduction targets and the transition to cleaner energy systems.

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CONCLUSION

The work gives several highlights as conclusions. Biomass briquette for cow manure is successfully made by using the carbonization method at 400°C for 2 hours. Calorific value is the main parameter in briquettes production and the optimal value is produced by briquettes with 10% sugar cane binding as it produces the largest calorific value of 3907.5 cal/g.

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