LITERATURE REVIEW ON CO-FIRING OF SUB BITUMINOUS COAL AND BIOMASS FOR GREENHOUSE GAS EMISSION MITIGATION

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Abstract The overuse of fossil fuels has led to global warming and air pollution due to greenhouse gas emissions, particularly CO2. The toxic effects of coal combustion can be reduced by mixing coal with biomass, which is called the co-firing method. This study aims to analyze the use of co-firing using various types of biomass based on previous studies. The results show that different biomass blending ratios affect the emission reduction significantly. Mixing palm kernel shell biomass at a ratio of 10% biomass and 90% coal reduced emissions by 20%, while mixing mesua ferrea tree biomass and sawdust at a ratio of 75% coal and 25% biomass reduced emissions by 45%. The use of empty fruit bunch biomass at a ratio of 30% biomass and 70% coal can reduce CO2 emissions by 72.14%. Overall, co-firing proved effective in reducing greenhouse gas emissions and accelerating the transition to renewable energy, although its effectiveness depends on the type of biomass and the blending ratio.

Keywords: Co-firing, Sub-bituminous, Biomass, GHG Mitigation

I. INTRODUCTION

The overuse of fossil fuels has led to climate and social problems. Global warming and air pollution are caused by excessive greenhouse gas emissions, particularly CO2 [1]. The large consumption of fossil fuels results in greenhouse gas emissions that cause environmental pollution, acid rain and global warming, where among fossil fuels carbon emissions from coal combustion are the highest at 43% [2]. The toxic effects of coal combustion can be reduced by mixing coal with some other carbonaceous materials, which contain fewer toxic and environmentally harmful components than those in coal [3]. Biomass is one of the important renewable and available energy sources, which can reduce greenhouse gas emissions during energy production due to its carbon-neutral nature. However, the smaller heating value, greater moisture content, and lower particle density are major drawbacks in considering biomass as an alternative to coal for thermochemical conversion processes [4].

The application of co-firing in existing power plants is one of several renewable energy projects initiated and proposed to PLN. Co-firing is a technique to add biomass as a partial replacement fuel into the boiler of a coal-fired power plant. By using the existing facilities in the existing PLTU, co-firing is one of the environmentally friendly ways to accelerate the increase in the use of renewable energy [5]. In co-firing systems, alternative fuel substitution has reached 3% to 10%. The more alternative fuels used, the less greenhouse gases produced [6].

The advantage of using this co-firing method is the reduction of carbon dioxide (CO_2) emissions because biomass is considered carbon neutral. This means that the CO_2 released during biomass combustion is expected to be equivalent to the CO_2 absorbed by the biomass plant during its growth [7]. By blending fossil fuels with alternative fuels such as biomass, the use of fossil fuels can be reduced. This can help reduce dependence on non-renewable energy sources [8]. Cofiring can improve the efficiency of energy generation by utilizing multiple fuel sources. In some cases, cofiring can also optimize the performance of boilers and other combustion systems [9]. The use of biomass waste as fuel in cofiring can help in waste management. For example, agricultural waste or unused wood waste can be utilized for energy generation [10].

The disadvantage of co-firing is that biomass fuels often have high variability in quality and energy content, which can affect combustion performance and efficiency, and lead to instability in plant operation

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[11]. Cofiring can cause technical problems, such as the formation of ash or scale deposits that can interfere with the operation of the boiler and combustion system. These problems can require additional maintenance and cost expenditure [12].

Based on previous relevant research that has been carried out on blending sub-bituminous coal with various types of biomass are palm kernel shells, mesua ferrea trees, sawdust, empty fruit bunches, palm trunks and mallee wood. The purpose of the study is to analyze the use of co-firing using various types of biomass based on previous studies. The following comparison between blending sub-bituminous coal and various types of biomass is shown in Table 1:

Table 1. Similar Research

Researcher Name	Year	Title of Research	Research Results
[15]	2016	Co-gasification of Sub-Bituminous Coal with Palm Kernel Shell in a Fluidized bed Coupled to a Ceramic Industry Process	Recommendation to use a co-firing method using palm kernel shell biomass
[3]	2019	Effect of Biomass Addition on the Devolatilization Kinetics, Mechanisms and Thermodynamics of a Northeast Indian Low-Rank Sub-bituminous Coal	Recommendation to use a co-firing method using mesua ferrea tree biomass and sawdust.
[16]	2019	Microwave-assisted Pyrolysis of EFB-derived Biochar as Potential Renewable Solid Fuel for Power Generation: Biochar versus Sub-bituminous Coal	Recommendation using the co-firing method using empty fruit bunch biomass
[2]	2021	Co-combustion of oil palm trunk bio coal/sub-bituminous coal fuel blends	Recommendation to use a co-firing method using palm trunk biomass
[17]	2022	Investigation into Kinetic Compensation Effects for the Production of Hydrogen-rich Gas During Gasification of Sub-bituminous Coal Char in Varying Gas Environments	Recommendation using a co-firing method using mallee wood biomass

II. METHODS

Literature review is the process of compiling and analyzing literature relevant to the research topic. Summaries of scientific papers from national and international journals are used to conduct research. In creating the theoretical or conceptual framework to be used in research, a literature review is often used, where this includes selecting relevant theories and concepts based on literature research [13]. The purpose of the literature research on this topic is to identify the types of biomass that can help reduce emissions at the power plant through the co-firing method with sub-bituminous coal types. The stages of the research are as follows:

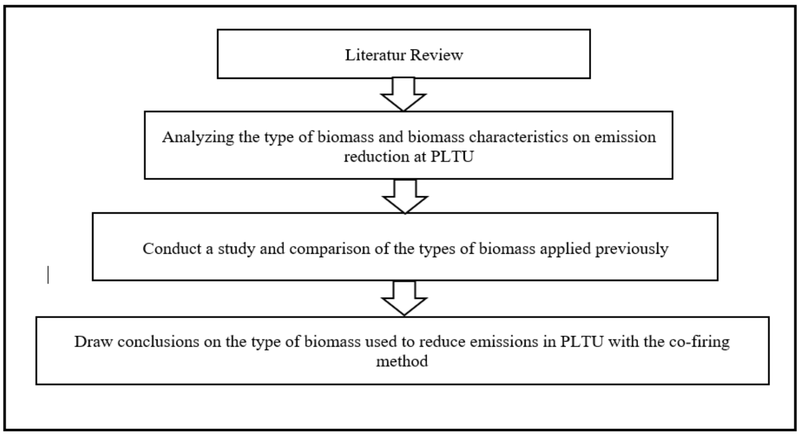

Figura 1. Research Stages

III. RESULTS AND DISCUSSION

The dependence of the world's energy production on fossil fuels and alternative fuels, as well as environmental pollution, remains one of the biggest challenges today. The use of new alternative fuels and new efficient combustion technologies for sustainable utilization of energy production is essential to achieve a smooth transition to low-carbon energy technologies [14]. An application applied by the government to reduce greenhouse gases with renewable energy is the application of co-firing, where co-firing is the process of burning two or more fuels simultaneously in an energy generation system. Typically, this involves mixing fossil fuels with biomass fuels or other alternative fuels. The following types of biomass can be used in mixing sub-bituminous coal for combustion in PLTU based on previous research, among others:

Table 2. Biomass-type Co-firing method

Researcher Name	Types of Biomass	Blending Ratio	The Most Effective Ratio	Emission Reduction
[15]	Palm kernel shell	90% coal and 10% palm kernel shell	90% coal and 10% palm kernel shell	20%
[3]	Mesua ferrea tree and sawdust	1. 87,5% coal with 12,5% biomass mesua ferrea tree and sawdust 2. 75% coal with 25% biomass mesua ferrea tree and sawdust 3. 50% coal with 50% biomass mesua ferrea tree and sawdust	75% coal with 25% biomass mesua ferrea tree and sawdust	45%
[16]	Empty fruit bunches	1. 10% biomass: 90% coal 2. 30% biomass: 70% coal	30% biomass: 70% coal	72,14% (carbon dioxide emissions)
[2]	Oil palm trunk	20% biomass:80% coal 50% biomass:50% coal	20% biomass:80% coal	296 ppm (NOx) 190 ppm (SO_2)
[17]	Mallee wood	1. 10% biomassa:90% coal 2. 20% biomass:80% coal 3. 30% biomass:70% coal	30% biomass:70% coal	30%

Based on the table of biomass types in the co-firing method that has been studied by previous researchers above, it can be seen that the most effective mixing ratio is in reducing emissions. Research conducted by Carlos F. Valdes, Farid Chejne, Gloria Marrugo, Robert J. Macias, Carlos A. Gomez, Jorge I. Montoya, Carlos A. Londono, Javier De La Cruz and Erika Arena in 2016 explained that the use of the co-firing method with palm kernel shell biomass with a mixing ratio of 90% coal and 10% biomass. The results of the study showed that the ratio could reduce emissions by 20%. Research conducted by Kaberijyoti Konwar, Hari Prasad Nath, Nilutpal Bhuyan, Binoy K. Saikia, Ramesh Chandra Borah, Alok Chandra Kalita and Nabajyoti Saikia in 2019, explained that mixing sub-bituminous coal with Mesua ferrea tree biomass and sawdust with a mixing ratio of 87.5% coal with 12.5% biomass, 75% coal with 25% and 50% coal with 50% biomass. The results obtained in the study are that the mixing ratio of 75% coal with 25% biomass is the most effective in reducing emissions, with a percentage reduction of 45%.

In research conducted in 2019 by Atiyyah Ameenah Azni, Wan Azlina Wan Ab Karim Ghani, Azni Idris, Mohammad Fakri Zaky Ja'afar, Mohammad Amran Mohd Salleh, and Syafizah Ishak, it was found that the co-firing method with empty fruit bunch biomass uses a mixing ratio of 10% biomass and 90% coal and 30% biomass and 70% coal. The most effective blending ratio is the ratio of 30% biomass and 70% coal. With this ratio, emissions decreased by 72.14% in CO_2. In 2021 Nadly Aizat Nudri, Wan Azlina Wan Abdul Karim Ghani, Robert Thomas Bachmann, B. T. Hang Tuah Baharudin, Denny K.S. Ng and Mohamad Syazarudin Md Said found that the co-firing method is effective for palm trunk biomass with mixing ratios of 20% biomass with 80% coal and 50% biomass with 50% coal. The results showed that the ratio of 20% biomass to 80% coal reduced emissions by 296 ppm (NO_x) and 190 ppm (SO_2). Research by Manoj Kumar Jena, Vineet Kumar and Hari Vuthaluru in 2022 explained that blending coal with the addition of mallee wood can reduce the use of coal as fuel. The most effective addition is in the variation of 30% biomass with 70% coal. The emission reduction in the blending is 30%. The following is a table of advantages and disadvantages of the types of biomass in blending sub-bituminous coal combustion in PLTU based on previous research:

Table 3. Advantages and Disadvantages of Biomass

Types of Biomass	Excess	Disadvantages
Palm kernel shell	1. Palm kernel shell blending with coal can reduce pollutant emissions compared to pure coal combustion, contributing to the reduction of environmental impacts.	1. Palm kernel shell has a lower calorific value compared to coal which may affect the overall energy efficiency of the combustion process.
	2. The blending can improve the thermal efficiency and carbon conversion in the gasification process, resulting in cleaner energy and efficiency	2. Palm kernel shell blending can cause particle segregation phenomena and multi-phase fluidization problems due to differences in density, particle shape and size
Mesua ferrea tree	1. Blending biomass residue from mesua ferrea with coal can reduce the emission of greenhouse gases and toxic elements during the combustion process.	1. Some parts of the mesua ferrea tree may contain potentially toxic compounds that may affect the quality of emissions during combustion.
	2. Has properties that favor the pyrolysis process which can increase the efficiency of energy conversion	2. Mixing with mesua ferrea tree biomass can affect combustion characteristics, which may not always be favorable under all conditions
Sawdust	1. Sawdust can improve the efficiency of the coal combustion process which has the potential to produce cleaner and more efficient energy.	1. Has a high water content which can reduce calorific value and combustion efficiency.
	2. Can reduce greenhouse gas emissions and toxic elements produced during combustion	2. Availability in large quantities for industrial use may be limited, depending on location and local wood industry
	3. Has a high content of volatile matter, which can affect the pyrolysis rate and increase the energy yield of the mixture	
Empty fruit bunches	Can reduce greenhouse gas emissions such as carbon dioxide compared to pure coal	1. Empty fruit bunches have varying physical and chemical properties depending on the growing and processing conditions that can affect combustion efficiency and energy conversion. 2. It has a high moisture content which can reduce its calorific value and requires a drying process before being used as fuel 3. Biomass combustion can also produce emissions of other pollutants such as fine particulate matter and organic compounds
Oil palm trunk	1. The use of biomass helps to solve the problem of solid waste generated from the palm oil industry, thus contributing to better waste management.	1. Palm trunk biomass has a high moisture content which can reduce the calorific value and combustion efficiency
	2. With the high productivity of the palm oil industry, this biomass can be obtained in very large quantities, providing significant potential for energy production	2. The physical structure of the biomass can make it difficult to grind
	3. Combustion of oil palm trunk biomass, especially in the form of coal can produce lower emissions compared to conventional coal combustion	3. Biomass has a lower calorific value compared to fossil fuels so it requires a larger volume to produce the same energy
Mallee wood	1. Mallee wood burning can produce lower carbon emissions compared to coal, thus contributing to the reduction of carbon footprints	1. Biomass availability can be affected by seasonal and climatic factors that can affect supply and price.
	2. Has good reactivity in pyrolysis and gasification processes which can improve energy conversion efficiency when blended with coal	2. Processing of mallewood before use as fuel and transportation costs from the production site to the use site can be challenging.

IV. Conclusion

Switching to cleaner and more sustainable energy remains a major challenge due to the global dependence on fossil fuels and their effects on the environment. Co-firing, the process of mixing fossil fuels with biomass fuels or other alternative fuels in energy generation systems, is one method used to reduce greenhouse gas emissions. Studies conducted show that co-firing with different types of biomass has different results in terms of emission reduction. According to the research, mixing palm kernel shell biomass with a ratio of 10% biomass and 90% coal can reduce emissions by 20%, mixing mesua ferret tree biomass and sawdust with a ratio of 75% biomass and 25% biomass can reduce emissions by 45% and using empty fruit bunch biomass with a ratio of 30% biomass and 70% coal can reduce emissions by 72.14%. In general, it is evident that co-firing reduces greenhouse gas emissions and increases the use of renewable energy. However, the type of biomass used and the mixing ratio used determine how effective the emission reductions are.

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