Biomass Generator Analysis for Renewable Energy Transition with the Co-Firing Program at PLTU Pelabuhan Ratu

1st Alfaozan Imani Muslim*
Electrical Engineering
Nusa Putra University
Sukabumi, Indonesia
alfaozan.imani_te20@nusaputra.ac.id

2nd Andika Kurniawan
Electrical Engineering
Nusa Putra University
Sukabumi, Indonesia
andika.kurniawan_te20@nusaputra.ac.id

3rd Wahyu Dwi Nurhidayat
Electrical Engineering
Nusa Putra University
Sukabumi, Indonesia
Wahyu.dwi_te20@nusaputra.ac.id

3rd Aryo De Wibowo Muhammad Sidik
Electrical Engineering
Nusa Putra University
Sukabumi, Indonesia
aryo.dewibowo_te20@nusaputra.ac.id

Abstract*— In PT PLN (Persero)'s Electricity Supply Business Plan (RUPTL) for the period 2021 - 2030, there is a biomass co-firing program with coal at Steam Power Plants (PLTU). This program reflects PLN's innovative efforts to increase the use of renewable energy sources without requiring large investment expenditures. The PLTU co-firing program involves partially replacing the coal with biomass such as sawdust from Energy Plantation Forests (HTE). The decision to implement PLTU co-firing commercially was based on the results of co-firing trials which showed that it was technically feasible and did not affect the reliability of power plant operations. There are 52 PLTUs owned by PLN that have the potential to implement co-firing with a biomass requirement of around 10 million tonnes per year by 2025. One of the PLTUs included in the co-firing program is the Pelabuhan Ratu PLTU with a capacity of 3 x 350 MW located in Sukabumi. The research stage involves mapping the potential of biomass sawdust to determine the availability of biomass around the PLTU location that implements co-firing, analysis of technical aspects and specifications for biomass sawdust raw materials to check compliance with the requirements of the Pelabuhan Ratu PLTU. One of the efforts made is the cofiring method. Co-firing coal-fired power plants is a technology that replaces coal with fuel from renewable sources with a certain composition ratio, and still pays attention to the quality of the fuel according to requirements. Among other things, this is caused by the presence of biomass and waste that is not used, has no economic value.

***Keywords*—co-firing, biomass, coal, green energy, boiler type power plant, Biomass Feedstocks,**

I. Introduction

A. background

At present, the need for energy continues to increase along with population growth and industrial development. However, the continued use of fossil fuels to meet energy needs can cause various environmental problems, such as climate change, air pollution, and dependence on limited resources.[1], [2].[3]–[5]

Therefore, the development of green energy sources is very important as an alternative fuel that is environmentally friendly. One form of developing green energy sources is by utilizing biomass as fuel. Biomass is organic material that can be used as a source of energy and is renewable, such as wood, straw, rice husks and other agricultural waste.[2], [5], [6].

However, because biomass has different characteristics from fossil fuels, such as higher water content and lower density, blending or mixing with fossil fuels such as coal can be done to increase combustion efficiency and reduce greenhouse gas emissions.[2], [7]–[9].

PLTU Pelabuhan Ratu is a power plant that uses coal as the main fuel. However, by utilizing the potential of biomass around the generating area, it is hoped that it can increase co-firing production and support the development of green energy sources.[6], [7], [10]. Therefore, an analysis of coal-biomass blending needs to be carried out to evaluate the efficiency and effectiveness of using the fuel mixture[6], [10], [11]

Challenges in Co-firing Implementation using biomass as a mixing material with coal used in coal-fired power plants. Biomass is organic waste obtained from the results of production processing, in the form of wood and so on that comes from plants[2], [4], [6], [8], [9]. The characteristics of biomass are diverse and have different specifications[8], [11]. For the initial co-firing at the Palabuhanratu PLTU, sawdust was used as biomass[3], [4], [10].

At the beginning of the experiment the conventional method was used, where before filling sawdust into the bunker, coal and sawdust were mixed in the coal yard with the help of heavy equipment in the form of excavators and bulldozers.[4], [5], [9]. The sawdust that is unloaded from the dumptruck to the coal yard will be mixed with coal from the storage (stacking) the amount of which has been determined according to the blending composition between the coal and sawdust[10], [12].

II. Method

A. Co-firing System

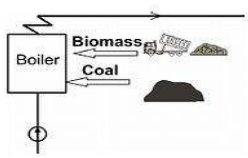
First, confirm that you have the correct template for your paper size. This template has been tailored for output on the

U. S. Saputri and M. A. S. Yudono (eds.), *Proceedings of the International Conference on Consumer Technology and Engineering Innovation (ICONTENTION 2023)*, Advances in Engineering Research 233,
https://doi.org/10.2991/978-94-6463-406-8_3

A4 paper size. If you are using US letter-sized paper, please close this file and download the Microsoft Word, Letter file.

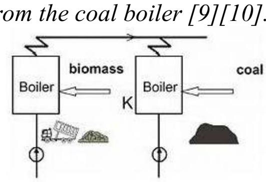
Co-firing is a process in which two or more different types of fuel are burned simultaneously. In this context, co-firing refers to the practice of burning biomass fuel as a partial replacement for coal in the same steam power plant. This can be done by using an existing combustion chamber that is usually used for burning coal, or by designing a special combustion chamber that can be used for both coal and biomass, or even a mixture of both. The application of co-firing technology aims to reduce environmental impacts and can also provide financial benefits. There are 3 applications of co-firing technology, including the following:

1) Direct Co-firing: Biomass is put into the boiler beside the coal. Mixing can be done in warehouses, spraying, or using special systems. This is the method most frequently used in co-fire processes, with the hope that if the biomass and coal are combined under the same conditions, the generation parameters will be more accurate.



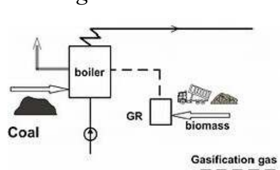
Picture. I. Direct co-firing

2) Parallel Co-firing: Biomass combustion is carried out in a separate boiler furnace. Usually, this method is applied if there are many differences in the characteristics of biomass and coal. The steam generated from the biomass boiler then flows to the main coal boiler. This approach uses a separate biomass boiler from the coal boiler [9][10].



Picture. II. Parallel co-firing

3) In-direct Co-firing: Biomass fuel is gasified separately, then the gas produced will be supplied and burned in the boiler. Can also use biogas produced from the process of anaerobic digestion.



Picture. III. In-direct co-firing

B. Biomass

In general, biomass is a material that can be obtained from plants either directly or indirectly and used as energy, biomass comes from natural sources, the use of biomass as an energy source is an energy source with a net amount of CO2 which is zero, therefore it does not contribute to an increase in greenhouse gas emissions , this also means biomass is carbon neutral. According to the rules, there is no increase in the amount of carbon in the atmosphere.

Trees, or biomass, have long been used to store carbon, and at the end of their life, they emit carbon into the atmosphere. By increasing biomass in coal-fired power plants, we can reduce the amount of carbon in the atmosphere without converting it into energy that can be used to combat coal.

Power plants that implement co-firing biomass are also in the carbon neutral category which is more environmentally friendly than the existing carbon positive coal power plants. Joint development in several countries has become a priority to reduce GHG emissions by replacing coal with biomass. Heating is reduced by the different properties and lower sulfur content of most biomass fuels. Strategy to increase the contribution of biomass to reduce Indonesia's RUEN and NDC GHG emissions by 29% in 2030.

C. PLTU Boiler Type

The use of various types of boilers in Steam Power Plants (PLTU) for co-firing often depends on the availability of suitable combustion technology for coal or gas. The three types of boilers commonly used in coal-fired power plants are pulverized coal combustion boilers (PCC), fluidized bed combustion (FBC), and layered bed combustion (PBCP) In Indonesia, there are ongoing discussions about direct co-firing, which would allow biomass to be burned in boilers that also burn coal. This is the simplest and most economical co-firing method, and can be a suitable choice to achieve the goals of high bias and high radiance through co-firing. Alternative approaches such as biomass gasification can also be used in situations where larger quantities of biomass are required than usual,

D. Biomass Feedstocks

Because the quality of biomass can vary so much, purchasing high-quality biomass building materials is essential. Different pre-treatment procedures may be required to ensure safe joint firing. Pre-processing procedures often include drying, densification, and palletizing of the biomass to increase the feedstock content. The following should be considered when using biomass:

- Higher energy consumption, with higher Calorific Value and higher Water Content (CV, where the energy content per unit mass is often expressed in kcal/kg). Biomass co-firing has the potential to increase the efficiency and productivity of the list production process so that the same number of lists are produced. A larger amount of fuel will increase the load on the PLTU system for processing fuel.
- More efficient transportation. More than half of the biomass has stronger energy, requires a larger volume to be quenched, and increases transportation costs. This situation is further complicated by the idea of removing water from the biomass while resulting in a longer challenge for long-distance transportation.
- Physical and spiritual satisfaction for PLTU. The impact of Biomass in PLTU operations must be examined in detail, starting from the requirements for boiler operations with risky physical and chemical properties, as well as special handling and storage

requirements. Different types of boilers will also hinder the user's ability to tolerate different types of building materials.

The table below describes the typical types of biomass fuel with reference to the different calorific values:

TABLE I. COMPARISON OF BIOMASS FUEL

Biomass Type	Caloric Value (kcal/kg)
Sawdust	2000-3600
Waste Pellets	3400
Palm Kernel Shells	4000-4800
Wood chips	4100-4319
Rice Husk Pellets	3700
Coal	3500-4900
Sawdust	2000-3600

Co-firing enables the burning of biomass waste which can come from the forestry or wood industry, agriculture, urban waste, and special energy sources. Compared to more compact and less scaled pure biomass power plants, cofiring offers the benefits of more favorable interest rates, better economic conditions, and higher PLTU efficiency. To maximize the efficiency of biomass processing, it is necessary to ensure that biomass is used efficiently from a volume and cost perspective. Industrial or Energy Forest Plantation Production can be marked as biomass to indicate co-combustion of fuel. The results can then be communicated to the PLTU.

The biomass supply chain starts from forestry or biomass processing within 100 KM from the PLTU for a price that is affordable for generators to purchase.

III. Results

The government is encouraging the use of new, renewable energy using the co-firing method in Steam Power Plants (PLTU), where biomass will be used as an alternative mixture with coal. In order to support this initiative, a PLTU that can implement the co-firing program is being prepared. The hope is that through an inventory of PLTUs that can participate in this co-firing program, it will increase the contribution of renewable energy in Indonesia [13]. The location of the co-firing PLTU will be in areas that have biomass potential, such as industrial plantation forests and other energy sources. In particular, within a radius of 50 km to 100 km from the PLTU, potential biomass was found which could be used as raw material in implementing the co-firing program. Thus, the distance for transporting biomass to the power plant will be relatively short, and this can reduce the cost of biomass. This step is expected to ensure the smooth supply of raw materials needed by energy generators[14].

After identifying the distribution of biomass potential in production forests, the next step is to calculate the biomass potential around the Pelabuhan Ratu Steam Power Plant (PLTU) using a radius of 50 km to 100 km from the center of the PLTU. In this area, there are several Forest Management Units (KPH) managed by Perum Perhutani, especially the Sukabumi KPH, which can play a role in supplying biomass to the Pelabuhan Ratu PLTU. There are plans to build a Biomass factory around the Sukabumi KPH area which is around 30 km from the PLTU [15].

TABLE II. PERHUTANI KPH POTENTIAL

KPH	AREA(Ha)	Biomass Potential (tonnes/year)
Sukabumi	4,519	164,664

In order to meet the co-firing quota of 5% of 236,520 Tons per year for PLTU Pelabuhan Ratu, the results of meeting biomass will be adjusted to the availability of biomass plants that have been planned at this time. In this scenario, "etah tebang" is defined, which refers to the allocation of pruning done annually to ensure that the amount of pruning remains evenly distributed throughout the cycle[14],[15].

Selection of suitable trees as a source of biomass for energy is very important to achieve optimal results in producing energy. Calorific value is a key parameter used to determine the type of wood suitable for use as fuel. The calorific value of a fuel reflects the amount of energy released when the fuel is completely burned. According to research conducted by Montes and his colleagues in 2011, the calorific value of wood is influenced by its chemical composition, water content, density and the amount of ash contained in the wood. Apart from that, the book written by Haygreen and Bowyer, as explained by Soettjipto in 2007, explains that the heating value also varies between types of wood due to differences in the proportion of charcoal, oxygen and hydrogen in the wood. Fengel and Wegener in 1995 also stated that the percentage of bark ranges from 10% to 20% of the trunk, depending on the type of tree and growing conditions. Apart from that, the water content in wood has a significant influence on the calorific value, where the higher the water content, the lower the calorific value of the wood [14], [15].

TABLE IV. POTENTIAL ENERGY CROPS TO BE DEVELOPED IN INDONESIA

No	Tree Name	Latin name	Calorific Value (kcal/kg)*	Average crop cycle (years)
1	Acacia Auri (chords)	Acacia Auriculiformis	4,500	5
2	Mangium	Acacia mangium	4,000	5
3	Kaliandra	Caliandra calothirsus	4,600	4
4	Gamal	Gliricidia sepium	4,000	3
5	E. lamp	Eucalyptus lamp	4,000	5
6	Lamporogung	Leucaena luciocephalid	4,400	5
7	Pilang	Acacia Leucophloea	4,500	4
8	turi	Sesbania grandiflora	4,000	5

IV. Discussion

Ultimate and proximate test results

shows that calliandra in chopped form has a water content of 21.1% and a heating value of around 3,642 kcal/kg. Meanwhile, gamal in chopped form has a water content of 26.8% with a calorific value of around 3,471.5 kcal/kg. When this biomass is converted into flour, the water content of calliandra becomes 8.48% with a calorific value of 4,218.3 kcal/kg, while the average gagal in the form of flour has a moisture content of 8.25% with a calorific value of 4,185 kcal/kg. By comparing these values, it can be concluded that both calliandra and gamal in the form of powder are suitable for use as an alternative to PLTU fuel, considering that the calorific value of coal commonly used is around 4,100 kcal/kg.

TABLE V. ULTIMATE AND PROXIMATE BIOMASS HTE TESTING RESULTS

Jenis Biomass	Jenis Treatment	Total Moisture	Proximate Analysis				Total Sulfur (adb)	Gross Calorific Value (ar)	Ultimate Analysis			
			Moisture in Analysis	Ash Content	Volatile Matter	Fixed Carbon			C	H	N	O
		% ar	% adb	% adb	% adb	% adb	kcal/kg	kcal/kg	%adb	%adb	%adb	%adb
Kaliandra	Cacah	21.13	8.45	1.05	73.90	16.60	0.11	3642	46.39	6.45	0.45	45.56
	Tepung	8.48	6.48	1.02	74.78	17.72	0.11	4218	46.92	6.63	0.54	44.81
Gamal	Cacah	26.83	7.83	2.48	71.73	17.98	0.12	3471	46.22	6.35	0.55	44.28
	Tepung	8.25	6.98	2.44	72.21	18.37	0.12	4185	46.16	6.59	0.64	44.07

Process of processing wood biomass samples from the forest

Energy crops (HTE) involve several steps. First, the biomass plants that are ready to be harvested are felled and prepared for the next process, namely processing into sawdust. Although the process of making sawdust uses simple machines such as the woodchipper and hammer mill, it requires special attention to moisture content, particle size, and heating value to match the fuel requirements required by the boiler design used.

Fuel requirements may vary depending on the type of boiler used. For example, Pulverized Coal (PC) type boilers have more stringent requirements, including smaller particle sizes, lower moisture content, and higher heating values. Meanwhile, boiler types such as Circulating Fluidized Bed (CFB) and Stoker require more flexible supply requirements.

The processing of this wood sample includes the logging stage, followed by the wood chipping process (first chopping), transportation, drying, the process of pulverizing using a hammer mill into sawdust, and finally transporting it to the off-taker location.

TABLE VI. SAWDUST MANUFACTURING PROCESS AND RENDERMENT

NO	drying	Rendement
1	Natural Dried	28.57%
2	Dryer (15%forest waste+85% biomass)	28.98%
3	Dryer (100% waste)	40.48%

The natural drying process is a drying method that relies on solar radiation energy, while the dryer is a drying process that uses a heating device with a certain type of fuel.

The result of using the natural dried drying method was a yield of 28.57%. This means that, from the initial amount of 88 tons of wood, around 25.15 tons of wood that have undergone the drying process are ready to be used in boilers. The basic design of the Energy Plantation Forest (HTE) industry has several aspects that need to be considered.

- Biomass Requirements PLTU Pelabuhan Ratu has a generating capacity of 3x350 MW and requires around 8,640 tons of coal every day. The type of boiler used at the Pelabuhan Ratu PLTU is the Pulverized Coal type, which means the type of biomass suitable for use is sawdust. Based on technical data, the productivity of HTE land around the KPH PLTU Pelabuhan Ratu is around 88 tons of HTE wood per hectare. From this data, it can be concluded that the average productivity of HTE land in producing biomass is around 25.15 tons of biomass per hectare.

- Technical Data, the Pelabuhan Ratu PLTU uses coal with medium rank coal quality (4500-5000 kcal/kg) and low rank coal (4000-4400 kcal/kg). PLTU Pelabuhan Ratu has carried out trials and implemented co-firing using biomass in the form of sawdust. The source of sawdust biomass is obtained from several wood craftsmen and collectors located around the Pelabuhan Ratu PLTU.

TABLE VII. SAWDUST SPECIFICATION DATA USED DURING THE TEST

Proximate Parameters	Units (Ar)	Mark
Total Moisture	%	53.28
Ash Content	%	1.72
Volatile Matter	%	21.71
Fixed carbon	%	16.1
Total sulfur	%	0.02
Gross calorific value	kCal/kg	18567
HGI	-	<31

The results of these trials show that during the trial process at the Pelabuhan Ratu PLTU, operating parameters such as load, total biomass coal flow, main steam temperature and main steam flow ran relatively normally. Flue Gas Temperature (FEGT) is also within safe limits and on average decreased from 1125 °C to 1079 °C. In addition, the emission test results show a reduction in SO2 and NOx emission levels in the flue gas resulting from combustion in the boiler. Based on the results of this trial, it can be concluded that the use of 5% co-firing at the Pelabuhan Ratu PLTU is safe and in normal conditions.

The design of the factory that will supply biomass for the Pelabuhan Ratu PLTU takes into account the needs of the PLTU and the supply capacity of the Energy Plantation Forest (HTE) managed by the supplier. Taking into account the biomass (gamal and Kaliandara) which has a calorific value of around 4,100 kcal/kg, around 347.69 tons of sawdust are needed to supply the Pelabuhan Ratu PLTU. Details of biomass plant requirements can be found in the table below:

TABLE VIII. PALABUHAN RATU POWER PLANT PROCESSING PLANT INVESTMENT DATA

Table Head		Factory Needs		
		units	*Specification*	*Total (Rp)*
1	Mobile Chipper Machine	28	Kap. 5 TPH. Power 30 kW	2,016,000,000
2	Hammer Mills	9	Hood. 5 TPH. Power 172 kW	3,838,086,000
3	Wheel Loaders	1	Bomac BWL-22RZ	450,000,000
4	Steerloader	1	Bomac TX-3505	400,000,000
5	Conveyor Belts			708,493,500

Table Head		Factory Needs		
		units	***Specification***	***Total (Rp)***
6	Conveyor Rollers			35,000,000
7	Storage Construction		Area: 9,595 m2	26,778,663,785
8	Factory construction		Area: 724 m2	3,798,600,000
9	Drying construction		Area: 21,062 m2	5.225.105.129
10	Weighbridge			300,000,000
11	Machine. Other Equipment			4,165,645,491
	Total Investment			49,487,354,905

V. Conclusion

1. This research stage involves mapping the potential of biomass sawdust to determine the availability of biomass around the PLTU location that implements co-firing, analysis of technical aspects and specifications of biomass sawdust raw materials to check compliance with the requirements of the Pelabuhan Ratu PLTU. One of the efforts made is the co-firing method, where biomass is used as fuel together with coal in steam power plants. This aims to reduce environmental impacts and greenhouse gas emissions and support the development of green energy.

2. The co-firing process can replace some coal with biomass with a certain composition, but it is necessary to pay attention to the quality of the fuel according to the needs of the PLTU. By identifying the biomass potential around the Pelabuhan Ratu PLTU, steps to procure and process biomass can be taken to support this co-firing program.

3. Calculation of the potential biomass needed to supply the Pelabuhan Ratu PLTU was obtained, amounting to 236,520 tons/year. The biomass specifications used in the co-firing trial, the results of the trial operation of the PLTU required coal requirements of ± 14,350 tons per day.

References

[1] air conditioningOpia, MKBA Hamid, S. Syahrullail, ABA Rahim, and CAN Johnson, "Biomass as a potential source of sustainable fuel, chemical and tribological materials – Overview," Mater Today Proc, vol. 39, pp. 922–928, 2021, doi: 10.1016/j.matpr.2020.04.045.

[2] S. Fogarasi and C.-C.Cormos, "Assessment of coal and sawdust co-firing power generation under oxy-combustion conditions with carbon capture and storage," J Clean Prod, vol. 142, pp. 3527–3535, Jan. 2017, doi: 10.1016/j.jclepro.2016.10.115.

[3] Danish, R.Ulucak, and SU-D. Khan, "Determinants of the ecological footprint: Role of renewable energy, natural resources, and urbanization," Sustain Cities Soc, vol. 54, p. 101996, March. 2020, doi: 10.1016/j.scs.2019.101996.

[4] air conditioningOpia, MKBA Hamid, S. Syahrullail, ABA Rahim, and CAN Johnson, "Biomass as a potential source of sustainable fuel, chemical and tribological materials – Overview," Mater Today Proc, vol. 39, pp. 922–928, 2021, doi: 10.1016/j.matpr.2020.04.045.

[5] Z. Wang, Q. Bui, B. Zhang, and TLH Pham, "Biomass energy production and its impacts on the ecological footprint: An investigation of the G7 countries,"*Science of The Total Environment*, vol. 743, p. 140741, Nov. 2020, doi: 10.1016/j.scitotenv.2020.140741.

[6] R.Kommalapati, I. Hossan, V. Botlaguduru, H. Du, and Z. Huque, "Life Cycle Environmental Impact of Biomass Co-Firing with Coal at a Power Plant in the Greater Houston Area," Sustainability, vol. 10, no. 7, p. 2193, Jun. 2018, doi: 10.3390/su10072193.

[7] MV Gil and F. Rubiera, "Coal and biomass cofiring," in*New Trends in Coal Conversion*, Elsevier, 2019, pp. 117–140. doi: 10.1016/B978-0-08-102201-6.00005-4.

[8] Y. Xu, K. Yang, J. Zhou, and G. Zhao, "Coal-Biomass Co-Firing Power Generation Technology: Current Status, Challenges and Policy Implications,"*Sustainability*, vol. 12, no. 9, p. 3692, May 2020, doi: 10.3390/su12093692.

[9] VTPSidabutar, "Study of Increasing the Export Potential of Indonesian Wood Pellets as a Renewable Source of Biomass Energy," Journal of Forestry Science, vol. 12, no. 1, p. 99, Jan. 2018, doi: 10.22146/jik.34125.

[10] MF Ilham and N. Sinaga, "Cofiring Effect of Using Sawdust on Exhaust Emissions at the Steam Power Plant,"*REM (Manufacturing Energy Engineering) Journal*, vol. 7, no. 2, pp. 75–80, Oct. 2022, doi: 10.21070/remv7i2.1644.

[11] MF Ilham and SWASuedy, "Effect of Cofiring Using Sawdust on Steam Coal Power Plant Heat Rate Value," Journal of New and Renewable Energy, vol. 3, no. 2, pp. 121–127, Jun. 2022, doi: 10.14710/jebt.2022.13828.

[12] AS Nejad and AR Zahedi, "Optimization of biodiesel production as a clean fuel for thermal power plants using renewable energy sources,"*Renew Energy*, vol. 119, pp. 365–374, Apr. 2018, doi: 10.1016/j.renene.2017.11.087.

[13] Republic of Indonesia Government Regulation Number 79 of 2014 concerning PolicyNational Energy, 2014.https://jdih.esdm.go.id/peraturan/PP%20No.%2079%20Thn%202014.pdf

[14] PT PLN (Persero), "PT PLN (Persero) RUPTL 2021 2030," 2020. https://web.pln.co.id/statics/uploads/2021/10/ruptl-2021-2030.pdf

[15] Perhutani Annual Report 2020."2020. https://drive.google.com/file/d/1EspiZwE5f_RrU9bR9BCamjkgarsFvEx/view