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Analysis of Heat Rate Co-firing Pacitan PLTU

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ABSTRACT

Through RUEN in 2025, the government is launching a co-firing program for coal-fired power plants towards achieving net zero emissions. Biomass is one solution to replace or replace fossil fuels in the field of energy supply. Some of the energy plants commonly used for co-firing are calliandra and gamal. The aim of this research is to analyze the Heat Rate efficiency of the use of calliandra and gamal biomass. This research method in quantitative form to achieve measurable results. The results of the analysis of using calliandra biomass at a percentage of 5% produce an NHPR of 2975 kCal/kWh. This value is greater than the use of gamal biomass at a percentage of 5% with a GHPR of 2942 kCal/kWh, and using a percentage of 10% produces an NHPR of 2986 kCal/kWh and at 10% gamal co-firing it produces an NHPR of 2920 kCal/kWh, the smallest thermal efficiency value is produced when the plant uses 10% kalindran co-firing with a value of 30.9%. and the highest thermal efficiency of the generator is when 10% galvanic co-firing is used.

INTRODUCTION

RUEN in 2025, new and renewable energy sources are expected to account for 23% of Indonesia's total primary energy consumption, according to the General National Energy Plan (RUEN). Nonetheless, the Paris Agreement is being implemented by statute number. 16/2016. A significant international accord to address climate change is the Paris accord. Indonesia has committed to reducing greenhouse gas emissions by 29 percent by 2030 as part of its participation in the Paris Agreement (Ariefianto, 2021). Reorienting its energy system strategy toward reaching net zero emissions (NZE) is one way Indonesia hopes to carry out this plan. The government established a co-firing program for coal-fired power stations in order to expedite the attainment of national energy distribution (Maskur et al., 2021).

There are several obstacles to overcome in Indonesia's co-firing implementation in order to guarantee its long-term viability and efficacy. Low heating value or high water content in biomass can have an impact on a power plant's thermal efficiency and combustion performance. To process biomass to the right quality, a substantial increase in investment is needed(Zhang, 2020). Utilizing biomass on a large scale may result in environmental issues like deforestation or conflict with food demands. To ensure fair social benefits, local communities' participation in the biomass supply chain must also be regulated(Palupi et al., 2024).

Efficiency as stated by Sudarmaji and colleagues, n.d. The aforementioned heat rate is the basis for measuring steam power generation units; the unit value that represents the heat rate is kCal/kWh (Latifianto et al., n.d.). In kilowatt-hours (kWh), this metric shows the energy input value in relation to the energy output. Gross Plant Heat Rate (GPHR), Net Plant Heat Rate (NPHR), Turbine Heat Rate (THR), and Boiler Efficiency are metrics used to assess the performance of power plants, particularly PLTU (Suhendra Permana dan Agung Wahyudi Bintoro, 2021). The generator's total power and net power are the two fundamentals used to determine the heat rate. The energy needed by the generator to generate one kWh of filthy electricity is known as the GPHR. These are the requirements for PLTU boilers in Pacitan, whereas NPHR is the energy needed by the generator to generate one kWh of clean electricity(Alfonso Nainggolan, 2021).

Tabel 1. Pacitan power plant specifications table

Items	Unit	BMCR	TMCR
Steam flow rate of superheater outlet	Ton/H	1050	950
Steam Pressure of superheater outlet	Mpa(g)	16,8	16
Steam Temperature of superheater outlet	°C	583	583
Steam flow rate of reheater outlet	Ton/H	1000	900
Steam pressure of reheater outlet	Mpa(g)	3,92	3,8
Steam temperature of reheater outlet	°C	583	583
Steam temperature of reheater inlet	°C	330	330
Steam pressure of reheater inlet	Mpa(g)	4,1	4
Temperature of feed water	°C	248	245
Air temperature at air preheater outlet (primary/secondary)	°C	300/200	295/315
Air temperature at air preheater inlet (primary/secondary)	°C	30/35	28/33
Flue gas temperature at air preheater outlet (unrevised)	°C	140	135
Flue gas temperature at air preheater outlet (revised)	°C	120	115
Boiler efficiency	%	90	89,8

In the field of energy production, biomass is one of the solutions for reducing or eliminating fossil fuels (Novita et al., 2021)The fundamental idea of biomass is the harvesting of energy from the photosynthesis process that produces organic matter (Parinduri et al., 2020). When biomass is converted to energy, carbon is released into the atmosphere (Winarno, n.d.). There are many types of biomass such as wood, plants, agricultural and forestry waste, organic components of municipal waste and others. According to (Barata, 2021) the two types of biomass are kaliandra (Calliandra Calothyrsus) and gamal (Gliricidia Sepium). According to(Utomo & Bambang Suwignyo, 2015), kaliandra and gamal are forms of energy that can be used for daily living in a kering environment or can be produced in a hutan environment.

In 2018, Dedi Hudaedi conducted research under the title "Potensi Gamal (Gliricidia Sepium) Sebagai Bahan Baku Pembangkit Listrik Tenaga Biomassa Studi Kasus: Kabupaten Manggarai Timur (NTT)". The study's goal was to determine the potential of gamal in Kabupaten Manggarai Timur that was being developed for the purpose of meeting the needs of listrik and the potential of listrik that was discovered(Hudaedi Dedi, 2018). In 2018, Siti Fadilah Salleh and colleagues conducted a study titled "Potential of Deploying Empty Fruit Bunch (EFB) for Biomass Cofiring in Malaysia's Largest Coal Power Plant." The study's goal was to determine how the project would be carbonized using a tandan buah kosong kelapa sawit with batu bara. The study conducted by Muhammad Farras Ilham and his colleagues under the title "Pengaruh Co-Firing Menggunakan Sawdust Terhadap Heat Rate PLTU" aims to analyze the Heat Rate Co-Firing using sawdust biomass and barley(Ilham & Suedy, 2022). According to the research, there are differences between the methods of analysis and biomssa.

The purpose of this study is to compare the best biomass as a co-firing material. To determine the best biomass, the hatred rate analysis of using kaliandara and gamal as co-firing material substitutes can be used. In this study, the nilai kalor of bara will be determined through literature review, and the nilai kalor of biomass will be used to calculate the nilai kalor. After understanding the nilai kalor data entered in the study, it is anticipated that this study will serve as a subtistusi co-firing in PLTU pacitan, or PLTU, throughout Indonesia.

RESEARCH METHODS

The author of this study went to PT PJB UBJOM JATIM. The author then lists issues from an economic and technical standpoint. The purpose of the literature study phase was to ascertain the scope of earlier studies. Previous studies, textbooks, undergraduate research, theses and dissertations, government policies, and planning and literature studies are some of the sources used in the literature review.

Primary data on biomass consumption and secondary data on biomass features are the two types of data required for the study. Following a literature review, the results of tests for biomass calorific value, hatred rate, and bioler efficiency are analyzed, and conclusions are then made. The last phase of this research, which will address the goals of the study, is conclusions and recommendations. The following research flow is presented in Figure 1 below:

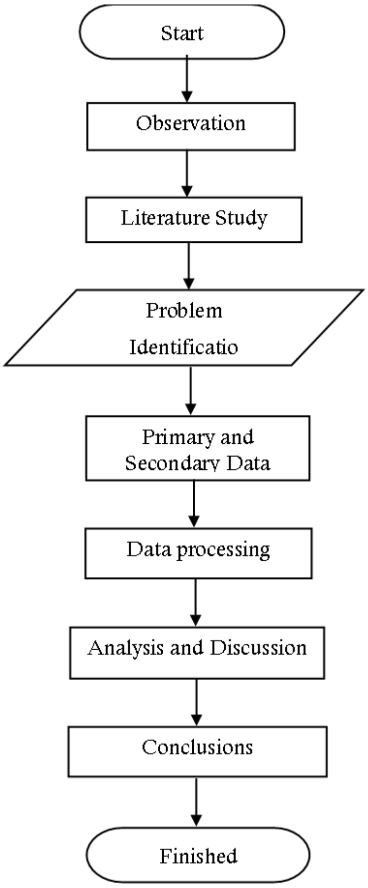

Figure 1. Research Flow

This study uses a quantitative approach with data collected from PLTU Unit 2 Pacitan. Next, it uses a termal analysis of PLTU data to determine the heat rate for each variation with a propensity of 5% and 10%. Finally, it uses Excel software to analyze the data.

Gross Plant Heat Rate analysis uses the following equation:

$$GHPR = \frac{THR}{Eff\ BOILER} \quad (1)$$

Information :

GHPR : Gross Plant Heat Rate (kCal/kWh)

THR : Turbine Heat Rate (kCal/kWh)

Eff. Boiler : Efisiensi Boiler (%)

Nett Plant Heat Rate analysis uses the following equation:

$$NHPR = GHPR\ x\ \frac{Gen,Output}{Gen,Output - Aux.Power} \quad (2)$$

Information:

NHPR : Net Plant Heat Rate (kCal/kWh)

GHPR : Gross Plant Heat Rate (kCal/kWh)

Gen. Output : The amount of power the generator produces (kW)

Aux. Power : Amount of use alone (kW)

$$GHPR = \frac{THR}{Eff\ BOILER} \quad (3)$$

Information :

860 kkal = 1 kWh

GHPR = Gross Plant Heat Rate (kCal/kWh)

Following the collection of the necessary data, the following phase is the calculation stage, when the known data is entered into equations 1, 2, and 3. The outcomes of these computations are then examined in relation to the use of biomass at the Pacitan power plant.

RESULTS AND DISCUSSION

Based on the data mentioned above and table 1, the results of the heat rate analysis are shown in figure 1. The data also shows that the consumption of bakar at PLTU pacitan was 115 tons per jam, the batubara weight was 4200, the kaliandra weight was kaliandra, and the gamal weight was kaliandra.

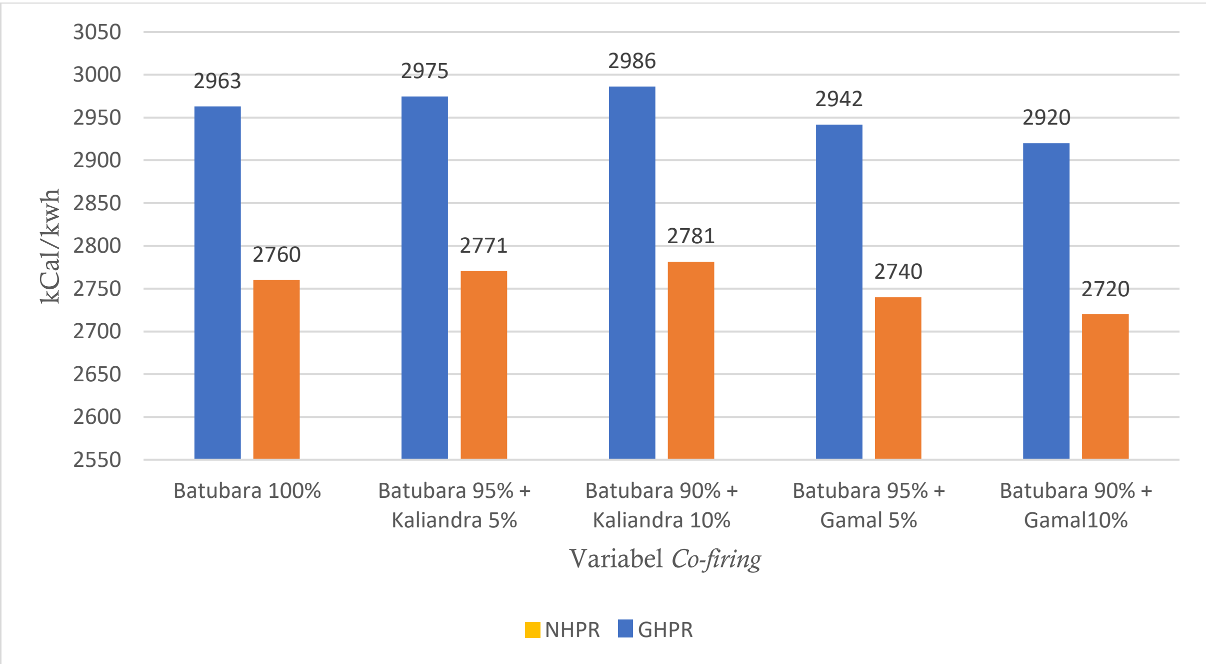

Figure 2. Comparison of GHPR and NHPR

According to the analysis's findings, using 5% calliandra biomass resulted in an GHPR of 2975 kCal/kWh. This figure is higher than the 5% usage of gamal biomass, which has a GHPR of 2942 kCal/kWh and a substantial GHPR. The high calorific value of calliandra biomass is the reason for cofiring it; using a 10% cofiring percentage yields an GHPR of 2986 kCal/kWh, while using a 10% cofiring percentage yields an GHPR of 2920 kCal/kWh. The calorific value increases as the percentage amount of cofiring increases; the higher the calorific value, the higher the GHPR value (Nyoman et al., 2010). An increase in temperature will produce breaking in the structure of coal or biomass, where water will emerge as an initial product of thermal breakdown of coal or biomass (Sutanto et al., 2021), which will harm the content, according to (Ilham & Suedy, 2022). As the temperature rises during the coal/boimass drying process, the amount of water in the coal and biomass reduces (Sudarmaji et al., n.d.). According to this study, the GHPR increases with temperature(Nurhasanah & Firdaus, n.d.). Higher temperatures can raise the heat demand to sustain steady pressure and steam flow in the cycle under partial or suboptimal load circumstances, resulting in a situation where the heat energy used exceeds the electrical energy generated. To a certain degree, the turbine's thermal efficiency can be raised by raising the temperature of the steam that enters it. Too high of a temperature, however, might result in further losses, like using more fuel to generate more heat, which raises the overall amount of heat energy needed in relation to the electrical energy generated(Zhang, 2020).

Thermal efficiency

Thermal efficiency is an important parameter in determining how efficient the use of fuel is on plant performance (Harnowo, 2016). Thermal efficiency analysis is shown in figure 2

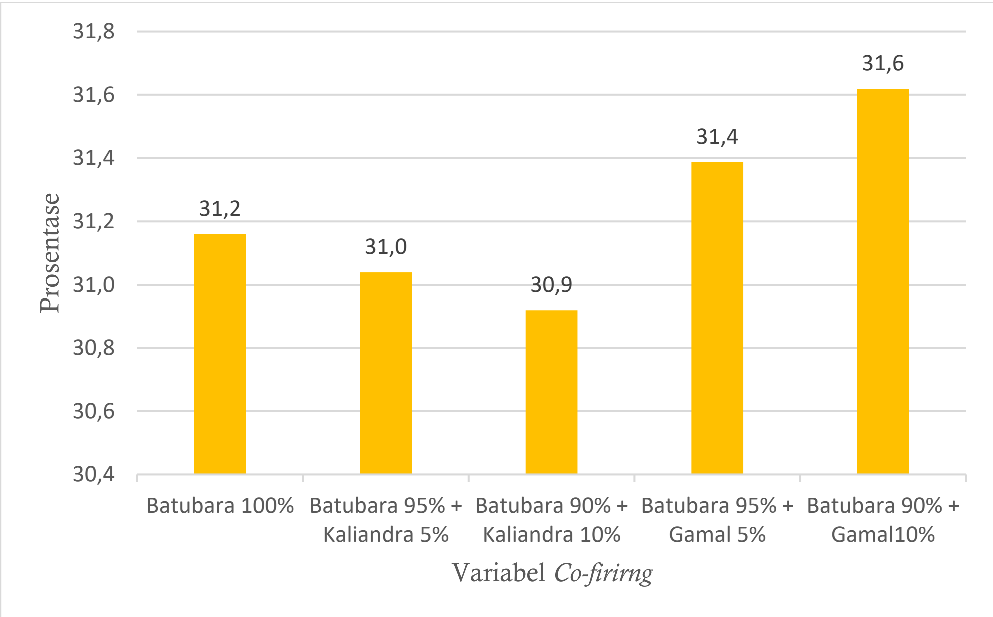

Figure 3. Comparison of Thermal Efficiency

The generator that uses a 10% co-firing kalindran produces the lowest thermal efficiency value, with a value of 30.9%, according to the analysis results displayed in Figure 2 above. The generator's maximum thermal efficiency occurs when it is operating at 10% cofiring. The higher the thermal efficiency figure, the better the generator performs, according to(Sidiq & Suwardi, 2022). GHPR and load also affect thermal efficiency; a larger load necessitates a higher NHPR(Febianto et al., n.d.) on the other hand, a generating system is less efficient if the NHPR value is high and the PLTU load is less than 100%(Suhendra Permana dan Agung Wahyudi Bintoro, 2021). The generator is less effective while using co-firing calliandra at the Pacitan PLTU since the loading is 50% of the capacity (Daud et al., 2020). A high GHPR indicates low thermal efficiency since more heat energy is required to generate a given amount of electrical energy. On the other hand, because more heat energy is transformed into electrical energy when the GHPR is low, thermal efficiency is typically high. GHPR reduction can be accomplished by using high-calorific-value fuel, optimizing system design to increase thermal efficiency, and enhancing boiler and turbine efficiency(Sidiq, 2022).

CONCLUSION

An GHPR of 2975 kCal/kWh is the outcome of the analysis of the use of calliandra biomass at a percentage of 5%. The high calorific value of calliandra biomass contributes to the size of the GHPR co-firing calliandra, which is higher than the use of gamal biomass with a percentage of 5% and a GHPR of 2942 kCal/kWh. Using a percentage of 10% yields an GHPR of 2986 kCal/kWh, and at co-firing 10% gamal, the GHPR is 2920 kCal/kWh. According to the analysis's findings, the generator's maximum thermal efficiency was achieved when it used co-firing gamal 10%, while the smallest thermal efficiency was achieved when it used co-firing kalindran 10%, with a value of 30.9%.

REFERENCES

Alfonso Nainggolan. (2021). *Analisa Peningkatan Nilai Net Plant Heat Rate (NPHR) pada Unit 1 PLTU Tenayan 2 x 110 MW*. *8*(1), 259–264.

Ariefianto, R. M. (2021). *Peluang Dan Tantangan Menuju Net Zero Emission (NZE) Menggunakan Variable Renewable Energy (VRE) Pada Sistem Ketenagalistrikan Di Indonesia*. https://www.researchgate.net/publication/357448042

Barata, L. O. A. (2021). *Studi Karakteristik Biomassa Batang Pohon Gamal (Gliricidia Sepium)*.

Daud, A., Hartono, R., & Seng, A. (2020). Analisis Efisiensi Bahan Bakar Batubara Tipe Low Rank Coal Pada Boiler Stoker PLTU Tidore Unit 2. In *Dinamika Jurnal Teknik Mesin Unkhair* (Vol. 5, Issue 2).

Febianto, I., Arsyad, M. I., Lubis, G. S., Program,), Mesin, S. T., & Mesin, J. T. (n.d.). *STUDI EFISIENSI THERMAL BOILER MENGGUNAKAN DIRECT METHOD PADA PLTU SUNGAI RINGIN DI KABUPATEN SINTANG*.

Harnowo, S. (2016). Jurnal Mekanika dan Sistem Termal (JMST) Analisis Kinerja Pembangkit Listrik Tenaga Biomasa Sawit (PLTBS) Pabatu PT Perkebunan Nusantara IV. *Harnowo Jurnal Mekanika Dan Sistem Termal*, *1*(1), 14–20.

Hudaedi Dedi, H. A. S. (2018). POTENSI GAMAL (Gliricidia sepium) SEBAGAI BAHAN BAKU PEMBANGKIT LISTRIK TENAGA BIOMASSA STUDI KASUS : KABUPATEN MANGGARAI TIMUR (NTT). *Journal of Env. Engineering & Waste Management*, *3*.

Ilham, M. F., & Suedy, S. W. A. (2022). Effect of Cofiring Using Sawdust on Steam Coal Power Plant Heat Rate Value. *Jurnal Energi Baru Dan Terbarukan*, *3*(2), 121–127. https://doi.org/10.14710/jebt.2022.13828

Latifianto, A., Prawatya, Y. E., Ivanto, M., Mesin, J. T., & Mesin, T. (n.d.). *ANALISIS PENGARUH PERUBAHAN TEKANAN KONDENSOR (VAKUM) TERHADAP EFESIENSI HEAT RATE TURBIN UAP DI PT. PJB (PEMBANGKIT JAWA BALI) PLTU KETAPANG 10 MW*.

Maskur, Z., Nugroho, D. A., Pembangkitan, P. T., & Bali, J. (2021). *Analisa Karakteristik Biomasa untuk Cofiring pada Pembangkit Batubara di Indonesia*.

Novita, S. A., Santosa, S., Nofialdi, N., Andasuryani, A., & Fudholi, A. (2021). Artikel Review: Parameter Operasional Pirolisis Biomassa. *Agroteknika*, *4*(1). https://doi.org/10.32530/agroteknika.v4i1.105

Nurhasanah, R., & Firdaus, O. (n.d.). *Perbandingan Efisiensi Boiler Awal Operasi Dan Setelah Overhaul Terakhir Di Unit 5 PLTU Suralaya*.

Nyoman, I., Winaya, S., Agung, I. B., & Susila, D. (2010). Co-Firing Sistem Fludized Bed Berbahan Bakar Batubara dan Ampas Tebu. In *Jurnal Ilmiah Teknik Mesin* (Vol. 4, Issue 2).

Palupi, D. N., Sundari, S., Syahtaria, M. I., & Sianipar, L. (2024). *Analisis Dampak Lingkungan dan Keekonomian Pembangkit Listrik Tenaga Co-firing Biomassa dan Baru bara sebagai Upaya Bauran Energi Terbarukan*. *5*(3).

Parinduri, L., Parinduri, T., Kunci, K., Fosil, E., Biomassa, E., & Energi, K. (2020). Konversi Biomassa Sebagai Sumber Energi Terbarukan. In *Journal of Electrical Technology* (Vol. 5, Issue 2). https://www.dosenpendidikan.

Sidiq, A. N. (2022). Pengaruh Co-Firing Biomassa terhadap Efisiensi Boiler PLTU Batubara. *KILAT*, *11*(1), 21–31. https://doi.org/10.33322/kilat.v11i1.1553

Sidiq, A. N., & Suwardi. (2022). *CALCULATION OF CARBON EMISSIONS AND CAP AND TRADE/TAX SCHEMES AT CO-FIRING COAL POWER PLANTS*. *22*(2), 273–293. https://doi.org/10.26714/traksi.22.2.2022

Sudarmaji, W., Pramono, W. B., Eng, M., & Suyamto, I. H. (n.d.). *STUDI DAN ANALIS HEAT RATE PEMBANGKIT LISTRIK TENAGA UAP (PLTU) BATUBARA*.

Suhendra Permana dan Agung Wahyudi Bintoro, D. (2021). Analisis Pengaruh Perubahan Beban Boiler Terhadap Konservasi Energi di PLTU SU5. *Jurnal Teknik Mesin*, *10*(3).

Sutanto, H., Suyitno, S., Juwana, W. E., & Nurrohim, T. G. (2021). Design, Production Cost, and Air Flow Distribution of Biomass Pellet Furnace. *Mekanika: Majalah Ilmiah Mekanika*, *20*(2), 68. https://doi.org/10.20961/mekanika.v20i2.49232

Utomo, R., & Bambang Suwignyo, dan. (2015). *PRODUKTIVITAS TANAMAN KALIANDRA (Calliandra calothyrsus) SEBAGAI HIJAUAN PAKAN PADA UMUR PEMOTONGAN YANG BERBEDA PRODUCTIVITY OF CALLIANDRA (Calliandra calothyrsus) AS A FORAGE IN THE DIFFERENT DEFOLIATION TIME*. *39*(2), 103–108.

Winarno, I. D. (n.d.). *Pengembangan Energi Biomassa (Tantangan Dan Peluang Bisnis Menuju Net Zero Emmission) Chairman of Indonesian Biomass Energy Society (MEBI).*

Zhang, T. (2020). Methods of Improving the Efficiency of Thermal Power Plants. *Journal of Physics: Conference Series*, *1449*(1). https://doi.org/10.1088/1742-6596/1449/1/012001