ASTONJADRO

pISSN 2302-4240
eISSN 2655-2086

Volume 14, Issue 1, February 2025, pp.0339-0348
DOI: http://dx.doi.org/10.32832/astonjadro.v14i1 http://ejournal.uika-bogor.ac.id/index.php/ASTONJADRO

The Analysis of Changes in Calorific Value of Coal in the Coal Flow Coal Feeder and Net Plant Heat Rate (NPHR)

Mohammad Djaeni, Jaka Windarta, Rifqi Muqorrobin

Master of Energy Study Program, Diponegoro University, Semarang, INDONESIA

E-mail: rifqimuqorrobin@students.undip.ac.id

| Submitted: November 07, 2024 | Revised: November 14, 2024 | Accepted: December 22, 2024 |

| Published: January 03, 2025 |

ABSTRACT

This study to determine the effect in the difference of coal calori value on power plants. Currently, coal-fired power plants dominate power plants in Indonesia with 42.38%. With the dominance of coal-fired power plants, the need for coal in Indonesia remains high. In the electricity production process, calori value is an important in the electricity production process. This study discusses the effect of coal on power plants. In this study, coal received two types of treatment, namely by heating with sunlight and oven. Then in this study, research was conduct on the calori value of coal on several parameters such as Specific fuel consumption (SFC), coal flow, boiler efficiency and NPHR. From the results of the research conduct, the drying process in the sun for 10 days can reduce the water content by 28% and reduce the weight of coal from 150 grams to 108 grams. Changes in calories due to a reduction in the water content value in coal by 28% to 5414 kcal / kg. In the coal combustion test, the calorific value of coal is inversely proportional to the NPHR value and coalflow of the PLTU.

Keywords: coal calories; NPHR; moisture content; coal flow; efficiency.

INTRODUCTION

The coal requirement of a power plant with a production of 600 MW can reach two million tons in 2023. According by data, 39% of the causes of derating in power plants from the coal, with 24% by the coal flow value in the coal feeder and 15% by coal filling disturbances. This results in a power plant is not able to operate optimally. The low calorific value of coal also has an impact for Net Plant Heat Rate (NPHR) value in a power plant (A; Niu et al., 2023; Prodi et al., 2015; Tirumala Srinivas, 2017). The NPHR value is one of the references in determining the efficiency value of a power plant (Ariyanto & Soekardi, 2023; Pengaruh et al., 2014). In the production process, the PLTU mixes coal with various qualities to ensure sustainable operation of the power plant (Biaya et al., 2020; Marlina et al., 2019; Niu et al., 2023; Prodi et al., 2015; Putra et al., 2019; Xu et al., 2024).

In power plants, the largest production costs are associated with fuel, which is 80% to 88% of the total operational cost (Kumar & Kumar Nandi, 2021) . One of the parameters for measuring power plant efficiency is the Net Plant Heat Rate (NPHR). Evaluating the quality of coal from the thermal structure is very important to control the quality of coal in the ash composition and element distribution (Wu et al., 2024) . The installed electricity capacity in 2022 is 83.8 GW. With the dominance of coal-fired power plants of 42.38% is consider less environmentally friendly. There are still many technologies that are more environmentally friendly and efficient to national energy and prepare for a more sustainable in the future (Akbar, 2023.).

NPHR is one of the efficiency indicators of a power plant (Kumar & Kumar Nandi, 2021) .One of the things that affects NPHR is the calorific value of coal (Alfonso Nainggolan et al., 2021) .The water content of coal is one of the contents studied (Lingkungan et al., n.d.) (Dafa Arifki et al.). Various studies discuss the efficiency of power plants and production costs, but low attention to coal flow in coal feeders. Inability Coal feeders to repons the coal requirements in power plants causes derating. Derating is the inability of a power plant to meet 98% of P2B demand for 30 minutes. Low calorific value is also a factor in the power plant not available to operate optimally

Coal feeder is a tool that regulates coal requirements in power plants (Buku Saku, n.d.). The amount of coal flow regulated by the coal feeder on the electricity production requirements. In the steam production process in the PLTU by the boiler. To measure the level of boiler efficiency) is use Specific fuel consumption (SFC) (Yetri, 2017) . SFC is a comparison of the amount of coal burned (kg) with the electricity produced (kWh). So far, there has been very little research discussing SFC in a power plant.

This study presents various effect caused by the calorific value of coal. The research studied is its influence on coal flow, NPHR value, and coal requirements in the power plant. This study also examines the effect of water content on the weight and calorific value of coal.

RESEARCH METHODS
Methods

In this study, the coal treatment process with 2 methods, namely with a 90^0 C oven with a variance between 10 to 120 minutes (the oven specifications can be seen in table 1). The second method is dry the coal in the sun for 1 to 10 days of the drying process. From the two treatments, the reduction moisture content in the reduction in coal weight, and its relationship to the calorific value of coal will be compare. This study also conduct research on the effect of coal calorific value on coal flow coal feeder, NPHR value, SFC, and coal requirements at production loads.

Table 1. Oven Specification

No	Parameter	Value	Unit
1	Capacity	9	Liters
2	Power	175-350	Watt
3	Heating Element	9	Pcs

Table 2. Coal Feeder specification

No	Parameter	value	Unit
1	Coal feeder performance	62,9	Ton/hour
2	Primary Air temperature	357	Celcius
3	Primary air pressure	1778	Mmwg
4	Primary Air flow	107	Ton/hour
5	Motor power	400	Volt
6	Motor ambient temperature	40	Celcius
7	Rise temperature	80	Celcius

Table 3. Boiler Specification

No	Parameter	value	Unit
1	Main steam flow	1.953.866	Ton/hour
2	Reheat steam flow	1.758.500	Kg/hour
3	Main steam pressure	174	Kg/cm^2
4	Main Steam temperature	540	Celcius
5	Reheat steam pressure	39,8	Kg/cm^2
6	Reheat steam temperature	540	Celcius
7	Number of burners	36	Sets
8	Main Fuel	Coal	
9	Initial ignition fuel	Solar	
10	Furnace area	8.529	m^2
11	Economizer area	10.629	m^2
12	Primary Super Heater area	14.634	m^2
13	Secondary Superheater area	4.643	m^2
14	Reheater area	17.092	m^2

For get coalflow coal feeder value:

$$\text{Coal flow} = \frac{coal\ usage\ (kg)}{time\ (hour)} \quad (1)$$

pISSN 2302-4240
eISSN 2655-2086
Volume 14, Issue 1, February 2025, pp.0339-0348
DOI: http://dx.doi.org/10.32832/astonjadro.v14i1 http://ejournal.uika-bogor.ac.id/index.php/ASTONJADRO

For get specific fuel consumpion (SFC)

$$SFC_{bruto} = \frac{qf}{kWh\ bruto}\ \text{kg/kWh} \quad (2)$$

$$SFC_{netto} = \frac{qf}{kWh\ netto}\ \text{kg/kWh} \quad (3)$$

SFC = Specific Fuel Consumption (kg/kWh)
qf = coal usage (kg)
kWh bruto = Gross electricity production (kWh)
kWh netto = Netto electricity production (kWh)

for get boiler efficiency

$$\text{boiler efficiency} = \frac{Output\ energy}{Input\ Energy} \times 100\ \% \quad (4)$$

$$= \frac{Q\ (hg - hf)}{q\ GCV} \times 100\ \% \quad (5)$$

Q = Steam capacity produced (kg/hour)
hg = Steam enthalpy (kcal/kg)
hf = Initial water enthalpy (kcal/kg)
q = Fuel quantity (kg/hour)
GCV = Gross calorific value (kcal/kg)

For get net plat heat rate value

$$NPHR = \frac{coal\ calorific\ value\ x\ coal\ usage}{Netto\ \ production\ electricity} \quad (6)$$

Data Analysis

This study begin with a coal calorie test, then two coal treatments with an oven and sunlight. After that comparison the decrease in water content by weighing of the coal for every treatment process and testing the calorific value of the coal. Table 3 explains the results of the coal treatment process. The table explains the change in calorific value and weight reduction in coal. The reduction in coal weight is caused by the loss of water content in the coal. The water content in coal is too much will certainly be a loss and disrupt combustion process. The amount of water content allowed in coal varies, from 10% to 70%. The mosture content in coal will affect several things, such as the price of coal, the calorific value of coal, and the efficiency of coal. In a PLTU to maintain combustion efficiency, the water content in coal is limit from 10% to 30% of the total weight of coal.

RESULT AND DISCUSSION

Figure 1 explains that the weight of is decreased after the ovening process. The initial wight sample in this study is150 grams share in 12 samples. The ovening process in stages by ovening for 10 to 120 minutes. In the oven for 120 minutes, the weight of the coal decreased from 150 grams to 136 grams, meaning that the coal lost 14 grams or 9.3% of water. Figure 1 explains that the moisture content decreases with the long of the ovening process.

Table 3. Result for oven treatment

No	Heating Time (min)	Initial weight (grams)	Final weight (grams)	Weigth difference (grams)	Weight difference (percent)	Initial calories (kcal/kg)	Final Calories (kcal/kg)	Calorie difference (kcal/kg)	Calorie difference (percent)
1	0	150	150	0	0 %	4233	4233	0	0%
2	10	150	149	1	0,7 %	4233	4240	7	0%
3	20	150	149	1	0,7 %	4233	4329	96	2%
4	30	150	148	2	1,3 %	4233	4210	-23	-1%
5	40	150	147	3	2 %	4233	3993	-240	-6%
6	50	150	147	3	2 %	4233	4171	-62	-1%
7	60	150	146	4	2,7 %	4233	4153	-80	-2%
8	70	150	144	6	4 %	4233	4253	20	0%
9	80	150	144	6	4 %	4233	4280	47	1%

No	Heating Time (min)	Initial weight (grams)	Final weight (grams)	Weigth difference (grams)	Weight difference (percent)	Initial calories (kcal/kg)	Final Calories (kcal/kg)	Calorie difference (kcal/kg)	Calorie difference (percent)
10	90	150	141	9	6 %	4233	4390	157	4%
11	100	150	141	9	6 %	4233	4319	86	2%
12	110	150	139	11	7,3 %	4233	4463	230	5%
13	120	150	136	14	9,3 %	4233	4346	113	3%

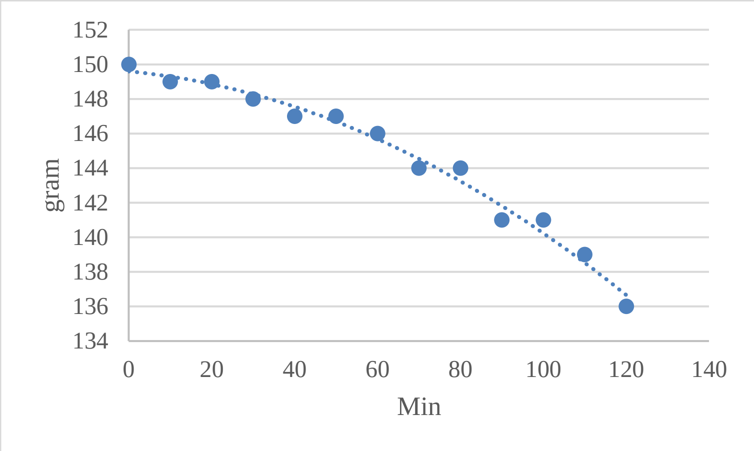

Figure 1. Weight changes in the ovening process

Figure 1 explains the relationship between the calorific value of coal after oven process. In this study, the coal calorie is 4233 kcal/kg. From the graph, the increase in the calorific value of coal is not too significant with the decrease in moisture in the coal. It could be that the coal have a high calorific value initially. In the heating time on 110 and 120 minutes, the calorific value of coal change to 4463 kcal/kg and 4346 kcal/kg or increase in calorific value at 5% and 3% when compare to the previous calorific value of coal. In this study, it is limit only 2 hours of heating or oven time because it consider the large energy use in heating coal on an industrial scale, but the results for the increase in calories not significantly. So in graphs 1 it is explaine the decrease in moisture content in coal is increase the calorific value, but not increase significantly, many factors for the calorific value of coal such as carbon content, ash content, volatile content, sulfur content, and type of coal.

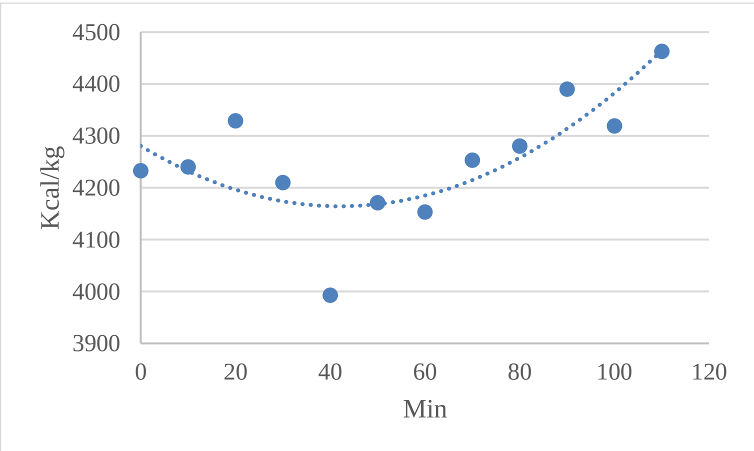

Figure 2. Changes in calories during the baking process

Figure 1 explains the graph of coal weight loss during the direct drying process with the sun. From Figure 1, it can be seen that the sun weight loss is very large at the beginning and stable at the end. Because the water content in the initial drying process is high. The coal drying method is same in PLTU, especially colyard, by drying coal the water content will decrease, and increase in the

pISSN 2302-4240
eISSN 2655-2086
Volume 14, Issue 1, February 2025, pp.0339-0348
DOI: http://dx.doi.org/10.32832/astonjadro.v14i1 http://ejournal.uika-bogor.ac.id/index.php/ASTONJADRO

calorific value of the coal as seen in Figure 2. Figure 2 shows that the calorific value increases when the water content in the coal decreases. This increase in calorific value will benefit the PLTU, because the increase in the calorific value of coal have an impact on several parameters in the PLTU such as SFC, NPHR, coal flow, and coal usage.

Table 5. Result for sun treatment

No	Heating Time (days)	Initial weight (grams)	Final weight (grams)	Weigth difference (grams)	Weight difference (percent)	Initial calories (kcal/kg)	Final Calories (kcal/kg)	Calorie difference (kcal/kg)	Calorie difference (percent)
1	0	150	150	0	0%	4233	4233	0	0%
2	1	150	138	12	8%	4233	4490	257	6%
3	2	150	127	23	15%	4233	4876	643	15%
4	3	150	121	29	19%	4233	4934	701	17%
5	4	150	115	35	23%	4233	5079	846	20%
6	5	150	112	38	25%	4233	5180	947	22%
7	6	150	109	41	27%	4233	5323	1090	26%
8	7	150	109	41	27%	4233	5357	1124	27%
9	8	150	108	42	28%	4233	5414	1181	28%
10	9	150	107	43	29%	4233	5378	1145	27%
11	10	150	107	43	29%	4233	5269	1036	24%

In the graph in Figure 3, it can be seen that the calorific value of coal is inversely proportional to the SFC value of the power plant. The higher the calorific value of coal, the lower the specific fuel consumption value of the power plant. It can conclude that the higher calorific value of coal is lower coal requirements to produce electricity. So that the higher calorific value of coal will increase the efficiency of electricity production. The high calorific value cannot always using by a power plant, because a power plant will consider several factors, such as the cost of buying coal and the availability of coal in the market. Buying expensive coal with high calories is not a solution to increasing efficiency, companies or power plants must also consider the initial design of the type of coal requirementa in the operating process

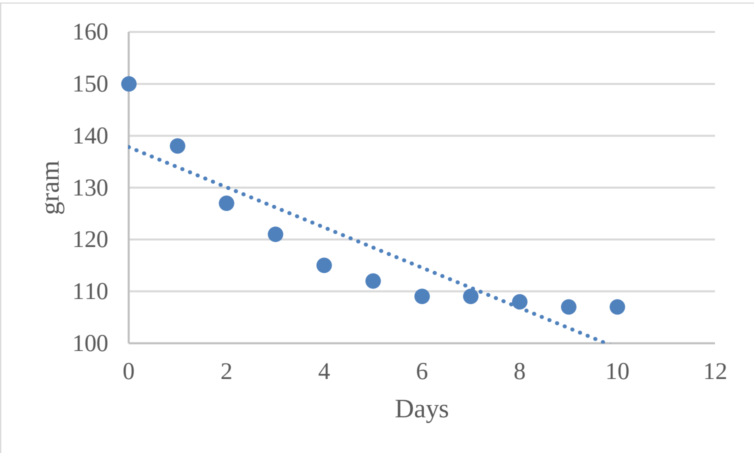

Figure 3. changes in weight during sun drying process

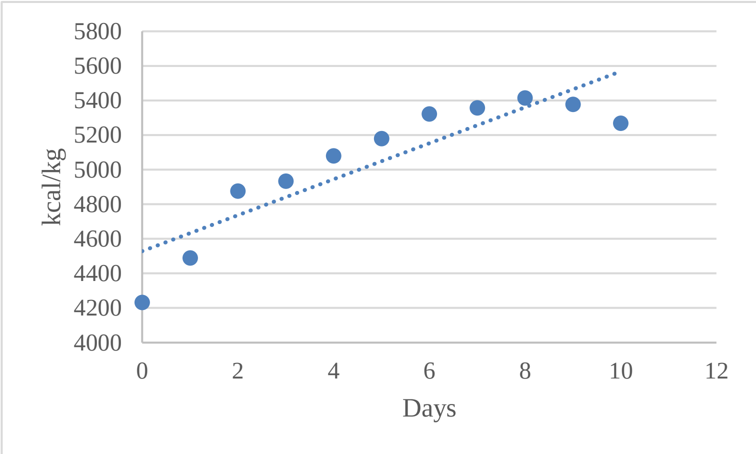

Figure 4. changes in calories during sun drying process

Figure 5 explains the relationship between the Net Plant Heat Rate (NPHR) value and the calorific value of coal. The NPHR value of a power plant is inversely proportional to the calorific value of coal. The higher the calorific value of coal, the lower the NIPHR value, and vice versa. So that the high calorific value of coal will increase the efficiency level of a power plant. The NPHR value is very important as a reference for the efficiency of a power plant, because the NPHR value is the amount of calorific value of coal to electricity production. The selection of the calorific value of coal cannot be chosen at will, because it must consider the design specifications of the equipment and the availability of coal on the market. Purchasing coal with high calories certainly has a more expensive price, so choosing coal with high calories will increase the capital in the cost of purchasing coal.

Figure 6 explains the relationship between the calorific value of coal and boiler efficiency when producing 570 MW. From Figure 7 above, it can be seen that the calorific value of coal and boiler efficiency have a trendline that is proportional. The greater the calorific value of coal, the greater the efficiency of the boiler, and vice versa. Increasing the boiler efficiency value will certainly benefit the power plant because it will reduce the reqirement for coal and also save the energy in electricity production. The more efficient the energy will benefit the company because not much coal and energy is waste in electricity production. However, the selection of coal must also consider the specifications of the boiler against the coal requirements.

From Figure 8, it can be seen that the relationship between the value of coal flow coal feeder and the calorific value of coal has an inverse relationship. The higher calorific value of coal, the lower the coal flow required and the lower the calorific value of coal, the higher the value of coal flow coal feeder. This shows the importance of maintaining the calorific value of coal, because the calorific value of coal is affects the requirements for coal in the electricity production process. The higher the calorific value of coal, the lower the requirements for coal, because it is more efficient. The value of coal flow in equipment also has a limit if at the time of electricity production the coal flow value has reached the maximum, then electricity production cannot be achieved and will not achieve the target, if this happens then the electricity production load will be reduced, and the power plant will derating, so it will reduce the EAF value of the power plant and disadvantages for the company because the production target is not achieve.

Figure 9 explains the relationship between coal usage and coal calorific value when the production load is 570 MW. From the graph 9 the relationship between coal usage and coal calorific value is inversely proportional. The higher the calorific value of coal, the lower the coal usage and vice versa. The higher the calorific value of coal and suitable to the equipment specifications will provide benefits to the power plant, such as increasing equipment efficiency, reducing coal requirements, because with a high calorific value, coal requirements will decrease. If the calorific value of coal is

ASTONJADRO

pISSN 2302-4240
eISSN 2655-2086

Volume 14, Issue 1, February 2025, pp.0339-0348
DOI: http://dx.doi.org/10.32832/astonjadro.v14i1 http://ejournal.uika-bogor.ac.id/index.php/ASTONJADRO

suitable to the equipment, the production process will be maximized and the power plant equipment will be more reliable in achieve production targets.

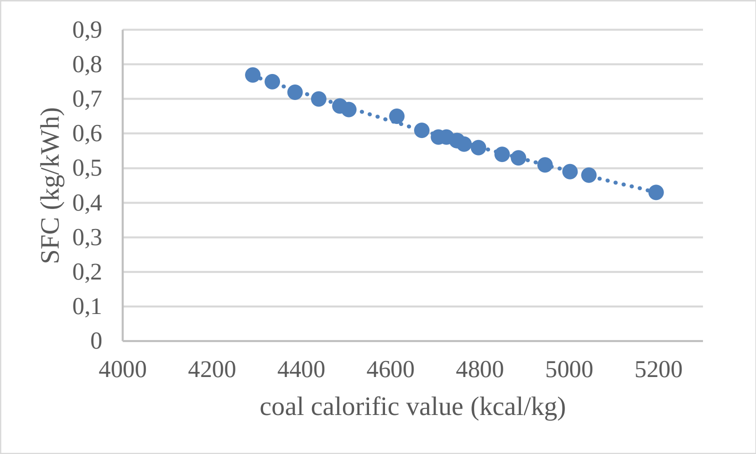

Figure 5. Relationship between Coal Calorific Value and SFC

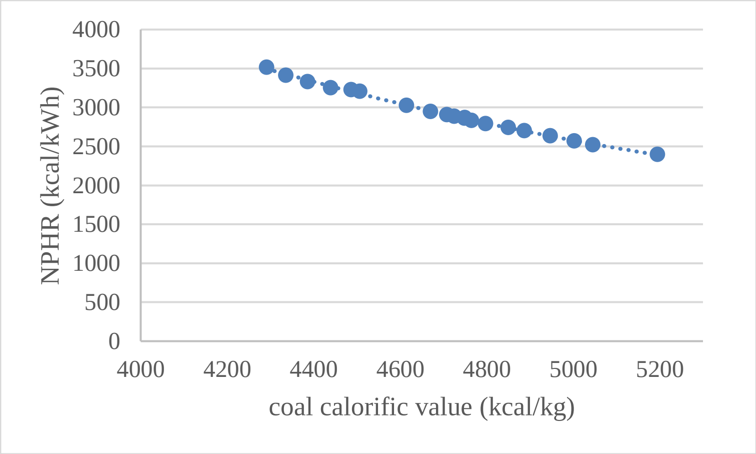

Figure 6. Relationship between NPHR value and coal calorific value

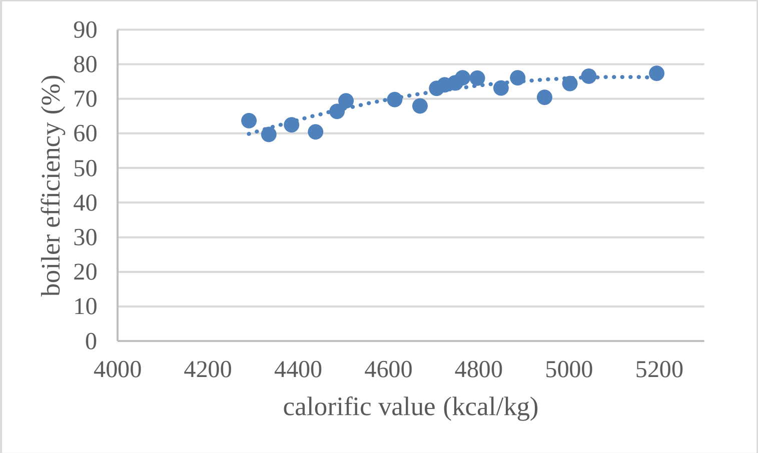

Figure 7. Relationship between boiler efficiency value and coal calorific value

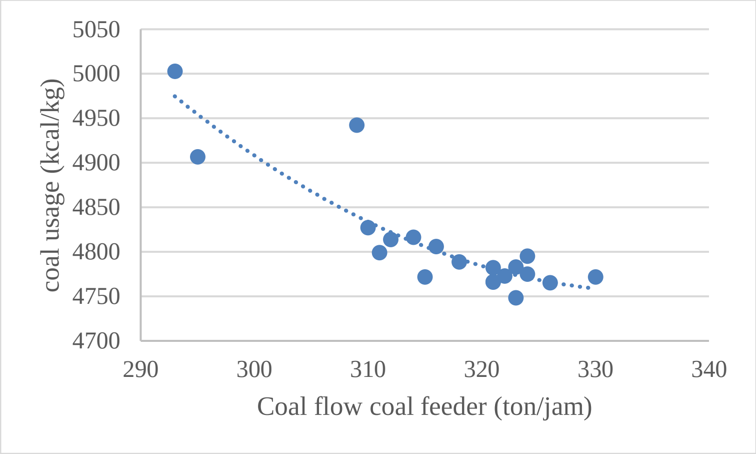

Figure 8. Relationship between coal flow coal feeder with coal calorific value in production load 570 MW

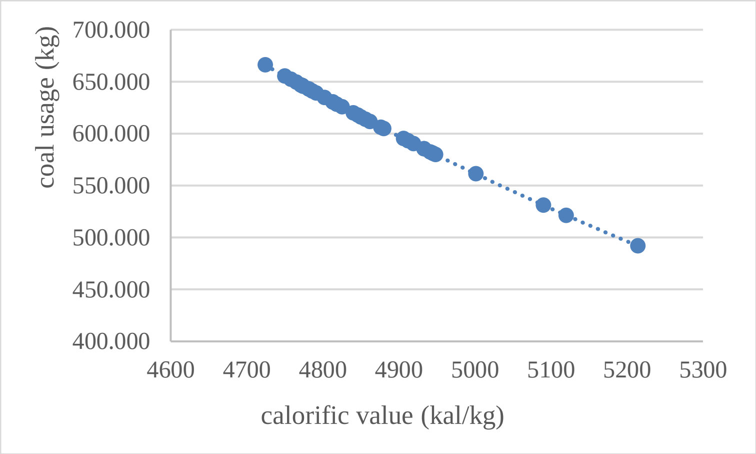

Figure 9. Comparison graph of coal usage with coal calorific value at producton load 570 MW

CONCLUSION

The process of drying coal with the sun for 10 days can remove water content by 29%, and can increase the calorific value of coal by 28% due to the disappearance of water content in coal. The drying process with an oven (constrained by limited oven capacity) can remove water content by 9% and increase the calorific value of coal by 5% with an oven process for 2 hours. The greater the calorific value of coal, the smaller the NPHR value of the generator and the efficiency of the power plant increases. Conversely, the smaller the calorific value of coal, the greater the NPHR value of the power plant and the efficiency decreases. The greater of calorific value of coal, the smaller the SFC value obtained, reducing the cost of electricity per kwh. The smaller the calorific value of coal, the greater the SFC value, so that the electricity cost per kwh is greater. In the electricity production process with the same load, the greater the calorific value of coal, the smaller the coal flow in the coal feeder, reducing coal usage. Meanwhile, the smaller the calorific value of coal, the greater the coal flow value in the coal feeder increasing coal usage.

ACKNOWLEDGEMENT

The author would like to thank UNDIP for its participation and support in this research.

REFERENCES

Alfonso Nainggolan Program Studi Teknik Elektro Sekolah Tinggi Teknologi Pekanbaru Jl Dirgantara No, S., Tim, S., Marpoyan Damai, K., & Pekanbaru, K. (2021). *Analisa Peningkatan Nilai Net Plant Heat Rate (NPHR) pada Unit 1 PLTU Tenayan 2 x 110 MW*. *8*(1), 259–264.

Ariyanto, A. E., & Soekardi, C. (2023). PLTU MERAK ENERGI INDONESIA. *Jurnal Teknik Mesin*, *12*(3), 216.

AUDIT ENERGI DETAIL PADA PLTU BATUBARA DENGAN. (n.d.).

Biaya, M., Bakar, B., Suriyan, P., Wibowo, A., & Windarta, J. (2020). *Pemanfaatan Batubara Kalori Rendah Pada PLTU untuk*. *1*(3), 100–110. https://doi.org/10.14710/jebt.2021.10029

BUKU SAKU. (n.d.).

Dafa Arifki, R., Ghony, M. A., & Belatri, N. (n.d.). *Bidang: Teknik dan Analisis Kimia Mineral Topik: Kimia Analisis, Kimia Mineral & Kimia Terapan PERBANDINGAN METODE BS TERHADAP METODE ASTM DALAM ANALISIS PROKSIMAT BATUBARA*.

Kumar, P., & Kumar Nandi, B. (2021). Combustion characteristics of high ash Indian coal, wheat straw, wheat husk and their blends. *Materials Science for Energy Technologies*, *4*, 274–281. https://doi.org/10.1016/j.mset.2021.08.001

Lingkungan, J. R., Ardinata, S., Herniti, D., & Pranajati, A. (n.d.). *ANALISIS PROKSIMAT BATUBARA MENGGUNAKAN STANDAR ASTM PADA PT. CAHAYA BUMI PERDANA KABUPATEN SAWAHLUNTO PROVINSI SUMATERA BARAT*.

Marlina, R., Pelita, R., Pertambangan, T., Tinggi, S., & Padang, T. (2019). MODEL COAL BLENDING BEDA KUALITAS UNTUK MEMENUHI PERMINTAAN BUYER. *Jurnal Sains Dan Teknologi*, *19*(1).

Niu, J., Jia, J., Zhang, H., Guo, Y., Li, L., & Cheng, F. (2023). Insights on the dual role of low-rank coal with high mineral catalysis index (LRC-HMCI) during blending coal for activated carbon production and low-temperature NH3-SCR of NO. *Fuel*, *349*. https://doi.org/10.1016/j.fuel.2023.128591

Pengaruh, A., Batubara, K., & Nugroho, A. A. (2014). ANALISA PENGARUH KUALITAS BATUBARA TERHADAP BIAYA PEMBANGKITAN (STUDI KASUS DI PLTU REMBANG). *Media Elektrika*, *7*(1).

PENGARUH JUMLAH PLUGGING TUBE HIGH PRESSURE FEEDWATER HEATER TERHADAP EFISIENSI PLTU 400 MW. (n.d.).

Prodi, D., Konversi, T., Jurusan, E., Mesin, T., Semarang, P. N., Teknik, J., Politeknik, M., Semarang, N., & Sudarto, J. H. (2015). PENGGUNAAN MIX COAL TERHADAP EFISIENSI PEMBANGKIT DAN BIAYA PRODUKSI LISTRIK (BPL) DI PLTU TANJUNG JATI B UNIT 3 Wahyono (1) , Teguh HM (2) (1) Dosen Prodi Teknik Konversi Energi Jurusan Teknik Mesin Politeknik Negeri Semarang. In *EKSERGI Jurnal Teknik Energi* (Vol. 11, Issue 2). http://www.polines.ac.id,

Putra, Y. R., Harminuke, R., Handayani, E., Syarifuddin, D., & Pertambangan, J. T. (2019). *OPTIMALISASI PENCAMPURAN BATUBARA UNTUK MEMENUHI KRITERIA PERMINTAAN PLTU DI MUSI RAWAS OPTIMIZATION OF COAL BLENDING TO MEET THE DEMAND CRITERIA PLTU IN MUSI RAWAS* (Vol. 3, Issue 1).

Tirumala Srinivas, G. (2017). Efficiency of a Coal Fired Boiler in a Typical Thermal Power Plant. *American Journal of Mechanical and Industrial Engineering*, *2*(1), 32. https://doi.org/10.11648/j.ajmie.20170201.15

Wu, Y., Wang, Z., Shi, C., Jin, X., & Xu, Z. (2024). A novel data-driven approach for coal-fired boiler under deep peak shaving to predict and optimize NOx emission and heat exchange performance. *Energy*, *304*. https://doi.org/10.1016/j.energy.2024.132106

Xu, W., Zhong, W., Zhou, G., Chen, X., Liu, X., & Shi, J. (2024). Optimization of air distribution and coal blending in pulverized coal boilers for high-temperature corrosion prevention based on POD reduced-order modeling. *Applied Thermal Engineering*, 123705. https://doi.org/10.1016/j.applthermaleng.2024.123705

Yetri, M. (2017). Estimasi SFC (Spesific Fuel Consumption) pada penggunaan Batubara di PT. Indonesia Power Pangkalan Susu Menggunakan Metode Regresi Linear Berganda. *Jurnal Sains Manajemen Informatika Dan Komputer*, *16*(2), 1–9. https://ojs.trigunadharma.ac.id/