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ADAPTATION TO CHANGES IN COAL QUALITY: CASE STUDY AT PT PAITON ENERGI (PE)

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ABSTRACT

This study discusses the coal conversion project undertaken by Paiton Energy (PE) in Indonesia in response to changes in coal supply. The root cause analysis method is used to systematically map PE case studies. The results show that PE has successfully adapted to changes in coal quality through the coal conversion project, but faces new challenges with the increasingly limited reserves of high-quality coal in the future. Therefore, further adaptation measures are needed to ensure the sustainability of power plant operations in the future.

KEYWORDS *Coal, Quality, Production.*

INTRODUCTION

Global coal production and consumption have tripled over the past 50 years. Coal is the second-largest energy source after petroleum, accounting for 27% of primary energy consumption (BP, 2020), and is also a major source of electricity generation (EIA, 2020). Despite increasing climate awareness and progressive climate policies in some countries, the fastest growth in coal consumption occurred in the 2020s (Figure 1). This "coal renaissance" is led by China, but is also evident in many rapidly developing countries (Jiang & Guan, 2016; Steckel et al., 2015, 2020). However, the majority of coal production and consumption is still concentrated in a few countries. When looking at coal production distribution, seven countries contribute almost 90% of global production: China, Indonesia, the United States, Australia, India, Russia, the Commonwealth, and South Africa (Figure 2).

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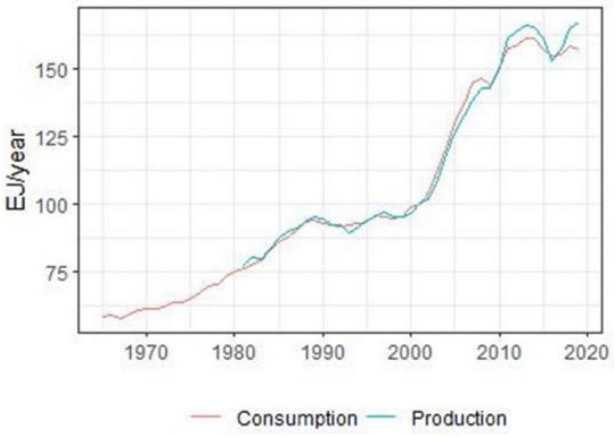

Figure 1. Global Coal Production and Consumption

Production refers only to commercial solid fuels, which include hard coal and anthracite (bituminous), lignite and brown coal (subbituminous), as well as other commercial solid fuels. This includes coal produced for conversion into liquid and gas fuels.

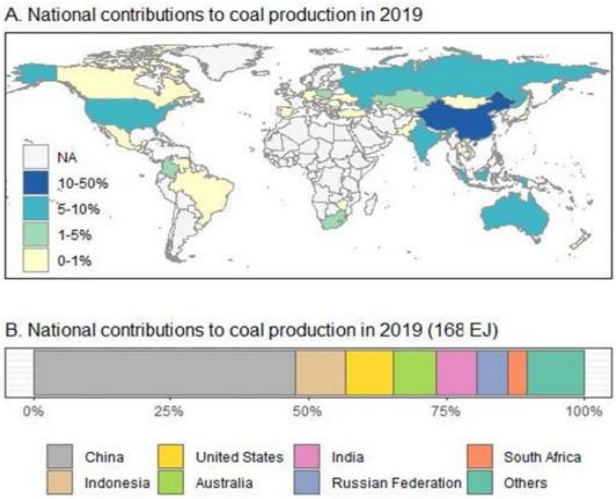

Figure 2. Coal Production Worldwide

Panel (A) shows the coverage of countries and their contribution (in %) to global coal production. Panel (B) lists countries that contribute more than 90% of global coal production. Data source: BP (2020). Production only concerns commercial solid fuels, namely hard coal and anthracite (bituminous), lignite and brown coal (subbituminous), and other commercial solid fuels. This includes coal produced for conversion into liquid and gas fuels. While NA values in Panel A do not necessarily indicate zero coal production, there is no data to suggest grouping small-

scale producers into a "different" category, so values for each country cannot be distinguished.

Coal consumption is also concentrated, with China being the largest consumer, followed by India and the United States, which together with Japan, South Africa, and the Russian Federation account for 80% of total consumption (Figure 3).

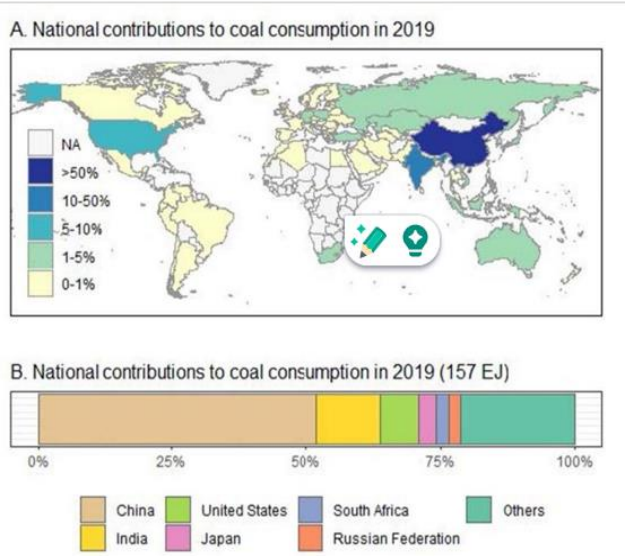

Figure 3. Global Coal Consumption

Panel (A) shows the coverage of countries and their contribution (in %) to global coal consumption. Panel (B) lists countries responsible for more than 80% of global coal consumption. Consumption only refers to commercial solid fuels, namely hard coal and anthracite (bituminous), lignite and brown coal (subbituminous), as well as other commercial solid fuels. While NA values in Panel A do not always indicate zero coal consumption, missing data suggests that BP groups small consumers into the "Other" category, making it impossible to distinguish values for each country.

High coal demand in Asia benefits Pacific exporters: Looking at the coal trade balance, Australia and Indonesia account for more than half of total coal exports, with China being the largest coal importer, followed by India (EIA, 2020). Global coal production and consumption growth remained stable from 2010 to 2019 (Figure 1). This has led to much speculation about whether this is a global phenomenon or not. CO2 emissions may have peaked around 2016, but this proved too early as emissions began to increase thereafter (Figueres et al., 2018; Jackson et al., 2016; Peters et al., 2020). This underlying trend is heavily driven by coal dynamics, particularly in China, which has experienced slowing economic growth and limited investment in new coal capacity since 2010 (Gregor & Gruber, 2020; Peters et al., 2020).

Coal production and consumption trends have been declining in the United States and most European countries this year, but these declines are offset by

increases in production and consumption in Asian economies, particularly Indonesia. Europe is rapidly reducing its dependence on coal consumption. The UK, once the 'king of coal', was one of the first countries to make a clear announcement in 2015. These six countries, along with South Korea, Indonesia, Germany, Vietnam, Poland, Australia, Turkey, and Kazakhstan (in order of consumption) account for 90% of global coal consumption.

In Indonesia, Paiton Energy (PE) is the first and largest independent power producer (IPP) operating in Indonesia, currently operating three coal-fired power plants at the Paiton Power Plant in East Java, supplying 2,045MW of electricity to the government. The State Electricity Company (PLN) property under the terms of the Power Purchase Agreement (PPA). Units 7 and 8 are subcritical coal-fired power plants with an output of 2 x 615 MW and have been operating since July 1999. Units 7 and 8 are designed to burn medium-calorific value (CV), sub-bituminous, low-ash, low-sulfur coal. On average, about 4.5 million tons of coal per year is needed for normal operation of Units 7 and 8.

Maintaining coal production at the quantitative and qualitative levels required by customers is very important for the company. The main issue is to obtain and maintain certain coal quality parameters required by the company. Therefore, coal quality issues can be viewed from the perspective of the company and the producer.

Paiton Energy (PE) is currently carrying out procurement procedures to secure long-term coal supply for Units 7 and 8. After the coal contract expired in 2016, the original coal supplier could no longer supply coal of the same quality and quantity. The coal supply contract period is from 2017 to 2021. Therefore, coal supply procurement will be carried out from 2022 to 2042, and new coal suppliers will be introduced and considered. However, coal that meets the plant's initial design specifications is no longer available in economically viable quantities and prices. Paiton Energy also requires this coal to meet the PPA coal requirements but will have a lower calorific value, potentially higher moisture content, higher ash content, and higher sulfur content than the coal currently being burned. To support procurement efforts and understand the nature and extent of plant modifications that may be required to accommodate off-design coal, Paiton Energy has launched a coal conversion project (N. R. Haddaway et al., 2018, 2020).

At the same time, quality parameters determine the production costs of the final product for customers, the selling price achieved, and production costs for producers. The Ministry of Energy and Mineral Resources (ESDM) set the October 2023 Coal Base Price (HBA) at $123.96 per ton. This is a decrease of $67.64 compared to July ($191.60 per ton) and a decrease of $181.25 compared to the previous month. This corresponds to January 2023 and amounts to $305.21. The September HBA was $159.33 per ton and August was $149.41 per ton. Coal prices are expected to continue to decline. PT PLN announced its intention to list on the Indonesia Carbon Exchange (IDXCarbon) and become the largest carbon trader in Indonesia. Indonesia has set a target to reduce greenhouse gas emissions by 31.89% by 2030. IDXCarbon was opened on the Indonesia Stock Exchange on September 26, 2023, by the President of Indonesia. As of October 2023, Indonesia's coal production reached 617.53 million tons, or 88.92% of the planned production target of

694.5 million tons. In addition, the volume of domestic market obligation (DMO) fulfillment was 132.6 million tons, or 75% of the DMO plan of 176.8 million tons.

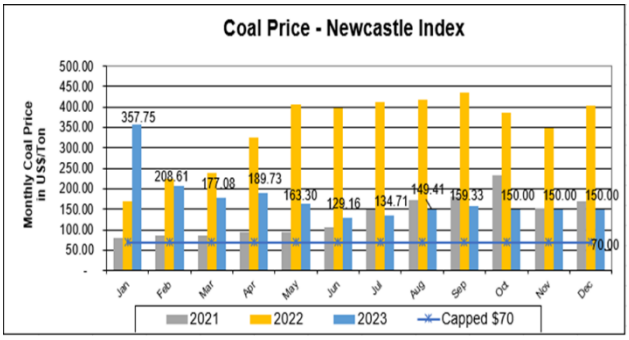

Figure 4. Coal Price-Newcastle Index

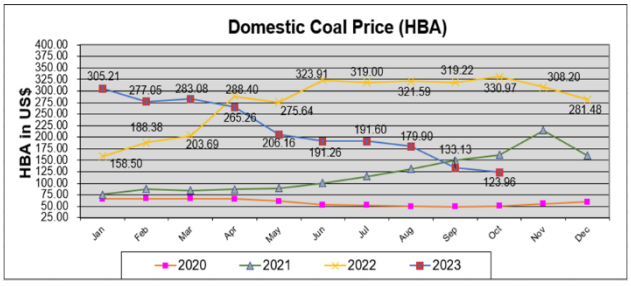

Figure 5. Domestic Coal Price (HBA)

Therefore, mining must be planned in such a way that the mined coal meets the required quality parameters so that it is not stockpiled awaiting sale. Coking coal quality issues are also felt in other countries and are the subject of scientific research there. The Czech company, OKD, published the impact of its research on this topic in 2013 (Danel et al., 2013). Therefore, PT Paiton Energy must take steps to build a modern production planning and scheduling system based on demand and quality-driven management. Furthermore, this research covers coal quality adjustment methods, especially research at PT Paiton Energy, forecasts to predict future coal quality, and appropriate strategies for the future.

Figure 6. Paiton Energy

RESEARCH METHOD

This research methodology involves root case analysis, a long-standing approach, and systematic case study mapping of PT Paiton Energy. The aim is to determine the future quality of coal in the region through sequential predictions and to develop appropriate strategies for the future. The method is descriptive and quantitative. The data obtained are case studies conducted during work at PT Paiton Energy, including:

- Coal market and regulation data
- Engineering study of coal switch (boiler) for Paiton units 3, 7, and 8
- Geological studies of coal suppliers
- Coal switch project phase 1
- Coal switch project phase 2

These data are collected and systematically mapped. Systematic mapping is a methodology for the systematic synthesis of evidence that organizes, describes, and catalogs existing research evidence (N. Haddaway, 2016; James et al., 2016). Systematic mapping is carried out in a transparent and iterative process to maximize the objectivity and completeness of the review process and minimize biases that can affect traditional literature reviews. When applying systematic mapping, sequential phases can usually be identified.

RESULT AND DISCUSSION

Brief History/Coal Supply Issues for the Paiton Project

Coal Design, COD - 2016

Paiton Units 7 & 8 are designed using Adaro coal. As a primary coal supplier, Adaro supplies the majority of PE coal needs. Kideco is a secondary coal that complements the quantity needs of PE coal. Both types of coal can be burned separately or mixed.

As Adaro and Kideco are coal designs, Paiton Units 7 &8 did not experience significant problems when using the coal. The term of Adaro and Kideco's Coal contracts is not in line with PPA PE. PE's coal supply agreements (CSAs) with both coal providers expire in 2016, while PE's PPAs expire in 2042. After the coal

contract period expires, the initial coal supplier cannot continue to supply coal of the same quality and quantity. Thus, new coal suppliers were introduced and studied.

Table 1. COD coal supply – 2016

COD to 2016		**Annual Tonnage**
1	Adaro (U7/8 & U3)	5.0 MTA
2	Kideco (U7/8 & U3)	2.0 MTA
	Total	7.0 MTA

Trends 2017– 2021

Table 2. Coal Supply 2017-2021

2017 to 2021		**Annual Tonnage**
1	Adaro (U7/8 & U3)	4.0 MTA
2	Kideco (U3)	1.0 MTA
3	Jembayan (U7/8)	1.0 MTA
4	Titan (U7/8)	0.7 MTA
5	Baramulti (U7/8)	0.3 MTA
	Total	7.0 MTA

The new CSA duration with coal suppliers is only five years and can be extended twice depending on PE's preferences. The coal quality available in the market differs from the design coal. Jembayan and Baramulti have high slagging indices and high sodium content, while Titan has lower calorific value, higher moisture, and higher ash content compared to the design coal. Overall, the average calorific value of the blended coal has decreased, the sulfur content has remained the same, and the ash content has increased. This has led to increased sulfur and ash content per calorie (mg/kcal) in the coal. This situation causes slagging issues in the boiler and a decrease in the pH of seawater in the flue gas desulfurization system.

According to the Ministry of Energy and Mineral Resources Decree No. 23K/30/MEM/2018, since 2018, the domestic coal price for power plants is capped at a maximum of USD 70/ton. Entering 2021, international coal prices have risen significantly above domestic prices. Although the same decree requires coal suppliers to supply 25% of their total production to the domestic market, PE and power plants in Indonesia generally still struggle to obtain coal in both quantity and quality.

Adaro indicated that after the first term (2017–2021), their coal supply would be reduced by 50%. To adapt to the changing quality of available coal and future coal, Paiton Energy initiated the coal conversion project. The main objectives of the coal conversion project are:

1. To identify a pool of potential coal candidates that meet PPA requirements.
2. To conduct front-end engineering and design (FEED) studies to identify the type of coal to begin the procurement process and optimize the level of plant modifications required to accommodate the new coal type.
3. To conduct a series of combustion trials.

4. To implement the necessary plant modifications based on EPC and complete the work by the start date of the new coal contract.

The first Coal Conversion Project began in 2017 with feasibility and FEED studies conducted by PE and GE, the equipment manufacturer for Paiton Units 7&8. The studies indicated that plant modifications were necessary to make Paiton U7&8 more flexible in accepting different coal qualities. The modifications included:

1. Plant rehabilitation.
2. Additional soot blowers.
3. Water cannons for the furnace.
4. Coal additives.
5. ESP rehabilitation.
6. Increased ash transport capacity.
7. Addition of a NaOH injection system.

In addition to modifications, the coal conversion project also studied coal blending to manage slagging index, sulfur content, and ash content effectively. Modifications to Paiton Units 7&8 began in 2021 and are expected to be completed by the end of 2024. Modifications related to slagging (projects No. 2, 3, and 4) have been completed. As a result of the modifications and coal blending studies, disruptions in plant readiness due to coal quality decreased from 9% in 2020 to 2% in 2022. In 2023, there were no disruptions in plant readiness due to coal quality.

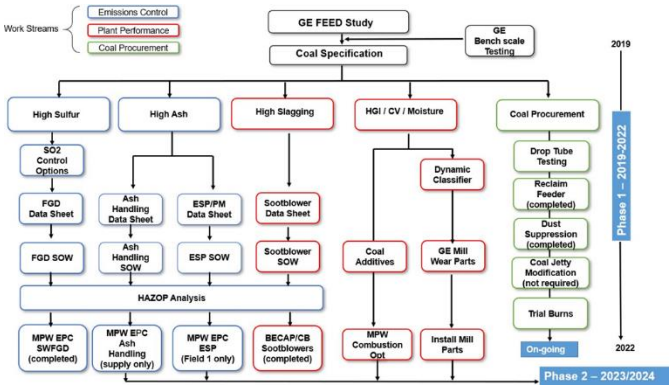

Figure 7. Workflow Implemented

Trends 2022 - 2024

Table 3. Coal Supply 2022 - 2024

2024		Annual Tonnage
1	Adaro (U3)	2.1 MTA
2	Kideco (U3)	1.0 MTA
3	KPC (U7/8)	1.5 MTA
4	Jembayan (U7/8)	0.4 MTA
5	Titan (U7/8)	0.3 MTA
6	Baramulti (U7/8)	0.35 MTA
7	Dizamatra (U7/8)	0.5 MTA

8	ABK/MSA (Spot Contract)	0.1 MTA
9	Alhasanie (Spot Contract)	0.1 MTA
10	MIP (Spot Contract)	0.4 MTA
11	KMIA (Spot Contract)	0.2 MTA
12	GBU (Spot Contract)	0.3 MTA
	Total	7.0 MTA

In 2022, the coal supply from Adaro, Jembayan, and Titan drastically decreased. PE had to seek replacement coal again. The disparity between domestic and international prices made some suppliers reluctant to enter into long-term contracts, preferring one-year spot contracts instead.

The new coal was directed to be burned in Units 7&8, which had undergone the coal conversion project. Along with an optimal coal blending strategy, the coal conversion project successfully accommodated the new types of coal without significant disruptions.

In 2023, some major coal suppliers reported changes in coal quality. Kideco's Roto 4800 kcal/kg coal will be depleted by the end of 2025, leaving only Kideco SM coal with a lower calorific value of 4150 kcal/kg. KPC coal's calorific value will decrease from 4900 kcal/kg to 4700 kcal/kg.

This situation necessitates a second phase of the coal conversion project. PE plans to undertake the final coal conversion project to prepare for future coal quality changes. Therefore, PE is conducting geological tests on all major coal suppliers to determine the trends in coal quality and quantity until the end of the PPA in 2042.

The study confirmed the predictions of Kideco and KPC. Additionally, Adaro's production will significantly decrease by 2030. Jembayan's coal reserves will be exhausted by 2032, Titan's by 2027, Baramulti and ABK's by 2025, Alhasanie's by 2026, and MIP's by 2029.

The study indicates that PE's future coal will consist of 50% medium-calorific (Adaro, KPC, Dizamatra) and 50% low-calorific (KIDECO SM, Bara Tabang) coal. The main issues with this coal quality are:

1. Decreased calorific value.
2. Increased total moisture content.
3. Increased total sulfur content.
4. Increased ash content.

Therefore, the second coal conversion project started in 2023 to prepare the units for future coal. This second coal conversion project includes feasibility studies, initial engineering design (FEED), and modifications to Paiton Unit 3. The target for these modifications is 2025, before the anticipated changes in coal quality.

The feasibility and FEED studies recommended the following modifications:

1. Changes to the dimensions and profile of the air heater.
2. Changing the ESP transformer from single-phase to high-frequency three-phase.
3. Increasing ash transport capacity.
4. Adding an ash silo.
5. Adding a NaOH injection system.
6. Modifying the nozzles in the flue gas desulfurization system.

7. Changing the water source for the flue gas desulfurization system from treated seawater to treated wastewater.

In addition to modifications, the operational pattern of the coal mills will also be changed. Currently, each Paiton PLTU unit has six coal mills. With the design coal, each unit can reach the plant's maximum capacity with five mills. With the future low-calorific coal, all mills must operate to reach the plant's maximum capacity, leaving no mills in reserve. A new maintenance strategy for the mills has been developed, adjusting the operation pattern and coal quality available in the coal yard.

Table 5. Data on Coal Suppliers and Potential Candidates

No	Coal Supplier	CV (kcal/kg)	Sulfur loading (mg/kcal)	Ash Loading (mg/kcal)	2024	2026	2032	2042
1	Adaro 4700	4700	0.226	4.22	2,100,000.00	2,100,000.00	1,000,000.00	1,000,000.00
2	Kideco Roto 4800	4800	0.223	6.83	1,000,000.00	-	-	-
3	Kideco SM 4150	4150	0.223	6.06	-	1,000,000.00	3,500,000.00	3,500,000.00
4	KPC 4700	4700	1.04	12.1	1,500,000.00	1,500,000.00	1,500,000.00	1,500,000.00
5	Dizamatra / Priamanaya	4600	0.36	9.67	500,000.00	500,000.00	1,000,000.00	1,000,000.00
6	Baramulti	5700	0.199	5.92	350,000.00	-	-	-
7	Titan	4600	0.707	10.11	300,000.00	300,000.00	-	-
8	Jembayan	5285	0.491	10.36	300,000.00	400,000.00	-	-
9	MSA/ABK	4700	0.629	10.2	100,000.00	-	-	-
10	Alhasanie	5113	1.163	8.89	100,000.00	100,000.00	-	-
11	Mandiri Intiperkasa (MIP)	4700	1.039	12.13	250,000.00	500,000.00	-	-
12	KMIA	5100	0.35	5.92	200,000.00	200,000.00	-	-
13	Gunung Bara Utama	5200	1.04	12.1	300,000.00	400,000.00	-	-
	Bara Tabang	4200	0.24	8.1	-	-	-	-
total					7,000,000.00	7,000,000.00	7,000,000.00	7,000,000.00

CONCLUSION

The types of coal received by PE have expanded from two design coals in late 2016 to 12 types of coal by 2024. This change is due to the misalignment between the durations of the CSA and the PPA, business decisions of major coal suppliers, and the quantity and quality of remaining coal reserves.

To adapt to the new types of coal, PE has undertaken two coal conversion projects. The first project started in 2017, aiming to enable Paiton Units 7&8 to adapt to the new coal types. With no disruptions in Paiton Units 7&8 due to coal quality in 2023, this project is considered successful.

However, in the same year, several coal suppliers reported that their coal reserves would soon be depleted. In response, PE plans to carry out a second and final coal conversion project. To prepare for this, PE conducted geological studies on all coal suppliers to determine the types and quantities of coal available until the end of the PPA in 2042.

The study results indicate that future coal will consist of low-calorific coal with high moisture content and medium-calorific coal with high ash and sulfur content. The feasibility and FEED studies focused on how PE can adapt to these two types of coal. The modifications will be implemented in 2025.

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