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Coal Downstream Potential in Central Kalimantan

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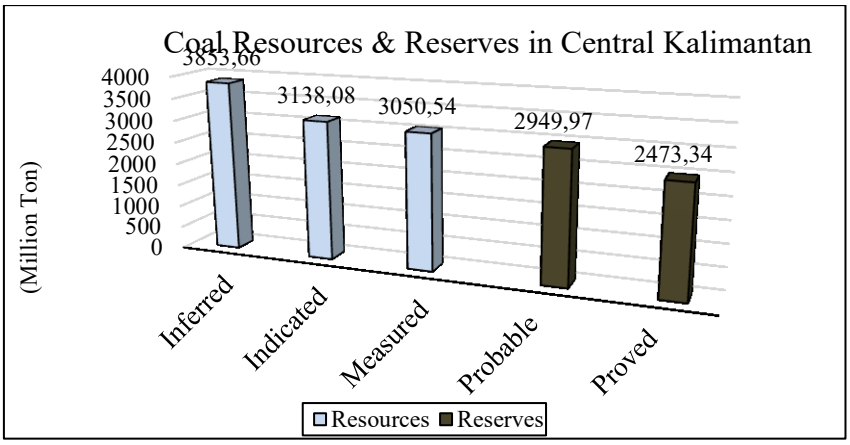
ABSTRACT
The management and utilization of coal raise new environmental challenges, such as deforestation and land degradation. The issue of global decarbonization requires that coal utilization operate within permitted capacity limits. Based on its diverse characteristics, coal can be utilized as a processed product. Downstream development through advanced coal processing can increase economic value and optimize land use more efficiently. Data were collected from various references, including scientific journals, research reports, government regulations, and related agency documents. The results provide recommendations for coal downstream development, such as optimizing the use of coal as a processed product for the production of methanol and dimethyl ether (DME), which function as alternative fuels and industrial raw materials, as well as synthetic natural gas (SNG) as a substitute for natural gas in various sectors. Coal liquefaction can convert coal into liquid hydrocarbons or fuel oil, thereby increasing its added value. Coal–biomass briquettes can produce smokeless fuel and be used for co-firing in steam power plants (PLTU). Extraction of rare earth elements (LTJ) from coal combustion residues also presents potential, as LTJ have high economic value and are fundamental to modern industries. The application of clean coal technologies, including Integrated Gasification Combined Cycle (IGCC) and Carbon Capture and Storage (CCS), can reduce carbon emissions from coal utilization. Based on these results, diversification of coal utilization through downstream development and clean technologies represents a strategic effort to address environmental challenges and respond to global decarbonization issues in Central Kalimantan Province.
Keywords: Coal Management; Environmental Issues; Deforestation; Land Degradation; Global Decarbonization

INTRODUCTION

Central Kalimantan Province has a diverse range of natural resources, one of which is coal (Kartikasari et al., 2019; Monica et al., 2023). The presence of these abundant coal reserves is utilized through mining activities that not only increase national and regional revenue but also create employment opportunities, enabling the surrounding communities to participate in advancing the regional economy.



(Source : *Geological Agency : Handbook-of-Energy-and-Economic-Statistics-of-Indonesia-2024*)

Figure 1. Graph of Coal Resources and Reserves in Central Kalimantan Province As of December 2024

The novelty of this research lies in its comprehensive mapping of coal downstream technologies against the specific geological formations of Central Kalimantan, as presented in Table 1. Unlike previous studies that focus on either geological characterization or technological options in isolation, this research integrates both dimensions to provide location-specific recommendations (Ansari et al., 2025; Bao et al., 2025; Contreras et al., 2025; Nwala et al., 2025). Furthermore, it considers the current state of implementation in Central Kalimantan, identifying both existing initiatives and gaps that require attention from policymakers and industry stakeholders (Ramadhan et al., 2025; Saining et al., 2025).

The primary purpose of this research is to identify and analyze potential downstream processing options for coal in Central Kalimantan based on its diverse characteristics, while considering environmental sustainability and global decarbonization trends (Zhang et al., 2021; Liu & Zhang, 2020). The research contributes to academic knowledge by providing a systematic framework for assessing coal downstream potential that integrates geological, technological, and policy considerations (Wang et al., 2020; Agustino et al., 2021). Practically, it offers evidence-based recommendations for government and industry stakeholders seeking to develop value-added coal processing in the province (Rachmat et al., 2021; Supriyadi & Susanto, 2022). The specific objectives include: (1) characterizing the coal formations in Central Kalimantan and their suitability for various downstream technologies; (2) assessing the current state of downstream implementation in the province; and (3) formulating strategic recommendations for coal downstream development that align with environmental sustainability (Hidayat & Putra, 2021; Santoso & Wijaya, 2022). The benefits of this research extend to policymakers responsible for regional development planning, industry investors seeking opportunities in coal processing, and communities that may benefit from sustainable resource utilization (Kurniawan et al., 2022).

Based on the graph above, the amount of measurable coal resources reaches 3,050.54 million tons, with proven coal reserves of 2,473.34 million tons. Coal utilization faces challenges related to environmental issues, as coal mining activities are often associated with land-use change, deforestation, and environmental degradation. Criticism of coal mining activities is also frequently linked to global decarbonization efforts that aim to limit the use of coal. The characteristics of Central Kalimantan coal are highly diverse, consisting of sub-

bituminous, bituminous, and metallurgical coal. This diversity in coal characteristics represents a potential advantage for various downstream applications that respond to environmental concerns. Such potential includes its use as feedstock for the briquette industry, methanol and ethanol production through coal conversion processes, and coke production. By utilizing coal for industrial purposes through further processing, significantly higher economic value can be achieved, while large-scale land clearing and excessive coal extraction can be minimized.

Simply put, given the existing characteristics of Central Kalimantan coal, there is an opportunity for these resources not only to be mined and sold outside the region but also to be further developed at the locations where they are found. Therefore, understanding the potential of coal processing in Central Kalimantan based on its characteristics needs to be prioritized. This study is urgent in terms of reviewing the coal prospects in Central Kalimantan, in line with the growing need for environmental protection and global demands for decarbonization.

METHOD

The presentation and analysis of data in this policy brief was carried out using a qualitative approach. This analysis is used to evaluate energy policies, decarbonization issues, and affected environmental conditions. The process involved a review of policy documents, academic reports, and media information, with content analysis techniques to capture dominant themes such as space conflicts, ecological pressures, and the direction of the green energy transition. Data were collected through literature studies, field observations, interviews, and Focus Group Discussions (FGD).

RESULT AND DISCUSSION

Coal in Central Kalimantan Province has diverse characteristics, from sub-bituminous, bituminous to metallurgical coal with coal-carrying formations found in the Tanjung, Batu Ayau and Warukin formations. The diversity of coal characteristics of Central Kalimantan Province certainly brings blessings in the form of potential opportunities for its use with activities that can be in line with environmental issues, where Central Kalimantan coal has potential and opportunities as a material for the briquettes, methanol-ethanol, and coke industries, with the use of coal for industry through further processing, a much higher economic value can be achieved, as well as land clearing and coal extraction in large quantities can be massively reduced. Simply put, with the existing characteristics of Central Kalimantan coal, it has the opportunity not to be mined and sold outside the region, but has the possibility to be further developed at the location where it is found (Table 1 and Table 2).

Table 1. The Suitability of Central Kalimantan Coal Formations to Coal Downstream Technology

Technology/Purpose	Final Products	Suitable Coal Formations in Central Kalimantan
Coal Gasification	Methanol, DME	**Warukin**, **Tanjung**, **Batu Ayau**, **Montalat** (requires pretreatment)
Coal Gasification	SNG, Ammonia, Hydrogen	**Warukin**, **Tanjung**, **Montalat**, **Lahei**

	(H_2)	
Coal Liquefaction	Gasoline, Solar	**Tanjung**, **Warukin**, **Gunung Timang**
Coal Briquette	Biomass Briquettes, Carbonized	**Batu Ayau**, **Montalat**, **Lahei**, **South Hamlet**
Coke Making	Metallurgical Coal	**Tanjung** (potential bituminus), **Mount Timang** (if VM levels are suitable)
Coal Upgrading	Coal for Electricity & Industry	**Batu Ayau**, **Montalat**, **Lahei**, **South Hamlet**
Extraction	Advanced Materials & Rare Earth Metals	**Batu Ayau**, **Warukin** (if containing REE), needs geochemical study
Extraction	Humic Acid and Fulvic Acid	**Montalat**, **Batu Ayau**, **Lahei**, **South Hamlet**, **Warukin**
Blending, Cofiring, IGCC	Electricity (CCT)	**Batu Ayau**, **Montalat**, **Warukin**, **Lahei**, **Tanjung**
Implementation of CCS/CCUS	Reduction of CO_2 Emissions	**Warukin**, **Tanjung** (gasification & oxyfuel suitable); need geological data for storage

Table 2. Recommendations for Coal Downstreaming in Central Kalimantan

No	Coal Downstream Efforts	Technology	Products
1	Development of coal to produce methanol and DME through gasification	Coal Gasification	Methanol & DME
	Import substitution of LPG and Methanol for industrial needs		
2	Development of coal to produce SNG, ammonia, and hydrogen (H2)	Coal Gasification	SNG, ammonia
	Contribution to meeting the needs of natural gas, syngas, ammonia and hydrogen from coal		Hydrogen (H2)
3	Development of coal for fuel through Coal Liquefaction	Coal Liquefaction	Gasoline and Solar
	Contribution to meet the needs of energy fuel (gasoline) from coal		
4	Coal development through coal-biomass briquettes and carbonized coal briquettes	Coal Briquette	Carbonized Briquettes
	Supporting the achievement of New Renewable Energy through the implementation of Bio-Coal briquette cofiring		Metallurgical Coal
5	Coal development for metallurgical industry	Cokes Making	Metallurgical Coal
	Optimization of domestic coal utilization in smelter industry		
6	Coal development through Coal Upgrading	Coal Upgrading	Coal Electricity and Industry
	Optimization of low calorie coal utilization for domestic needs		
7	Coal development through rare earth metals	Extraction	Advanced Materials and rare earth metals
	Optimization of coal utilization as a component of rare earth metal elements		
8	Coal development for Agro-industrial materials	Extraction	Humic acid and Fulvic Acid
	Contribution in meeting the needs of domestic fertilizer from coal		
9	Coal utilization for electricity: Blending Facility, biomass Cofiring and application of IGCC	Blending Facility Cofiring & IGCC Implementation	Electricity & Application Of Clean Coal Technology
	Optimization of coal utilization to national electricity		
10	Application of CCS / CCUS on Coal Development and utilization facilities	Implementation of CCS/CCUS	Decrease in CO2 emissions
	Implementation of clean coal technology in the		

	form of CSS / CCUS in power plants and coal downstream projects

Methanol and Dimethyl Ether (DME) Products Through Coal Gasification Technology

Through gasification technology, coal can be converted into methanol. Methanol itself is an important petrochemical compound that plays a major role in the development of various derivative products. This compound is needed as a basic material in various industries, such as textiles, plastics, synthetic resins, pharmaceuticals, insecticides, and the plywood industry. In addition, methanol is also used as an antifreeze and inhibitor in the downstream process of oil and gas, and is one of the main ingredients in biodiesel production. Methanol can be further processed into Dimethyl Ether (DME) which can be used as an alternative fuel as a mixture of other fuels or as pure DME. The use of Dimethyl Ether (DME) has wide potential for use in the industrial sector, including as a substitute for LPG and kerosene, fuel for transportation (diesel vehicles and fuel cell technology), power plants, raw materials for the chemical industry and as a solvent.

Until now, Central Kalimantan Province does not have a facility or project specifically directed to produce methanol from coal through a downstream process. In contrast, the initiative to downstream coal to methanol has been developed in the East Kalimantan region and is being developed in South Kalimantan. Although Central Kalimantan has no less large coal reserves, there have been no concrete plans or initiation of similar projects in the province to date.

Synthetic Natural Gas (SNG), Ammonia and Hydrogen ($H2_)$ Products Through Coal Gasification Technology

Synthetic Natural Gas (SNG), Ammonia and Hydrogen (H2) is a mixture of hydrocarbon gases that have similar characteristics to natural gas and can be produced through the gasification process of coal and biomass. SNG has the potential to be used as a substitute for natural gas in various sectors, including as an urban gas for household needs, fuel in gas and steam-based power plants, fuel in industrial processes, as well as as an alternative fuel for motor vehicles, such as Gas Fuel (BBG) or Natural Gas Vehicle (NGV).

In Central Kalimantan, so far, there has been no coal gasification project to produce Synthetic Natural Gas (SNG), Ammonia and Hydrogen (H2). However, there are similar initiatives developed in South Sumatra.

Gasoline and Diesel Products Through Coal Liquefaction Technology

Coal liquefaction is the process of converting coal into liquid hydrocarbons in the form of fuel oil and petrochemical materials. However, generally the main product desired from coal liquefaction is in the form of fuel oil, so the term "Coal to Liquid Fuels" or CTL is famous. Coal liquefaction through pyrolysis is carried out through heating coal without the presence of air at a temperature of 400°C and produces gases, hydrocarbon liquids and char. Coal pyrolysis is also called the destructive distillation process. This process involves breaking carbon bonds in the macromolecular structure of coal. The carbon bond breaking reaction causes a decrease in the molecular weight in the coal hydrocarbons thus turning the solid coal into a liquid or gas.

The implementation of coal downstream projects that focus on coal liquefaction technology is still concentrated in certain regions, especially in the provinces of South

Sumatra, East Kalimantan, and South Kalimantan. The three regions were chosen because they have abundant coal reserves and supporting infrastructure that is relatively more ready for the development of coal-based downstream industries.

Coal-Biomass Briquette Products (Bio-coal) and Carbonized Coal Briquettes Through Coal Briquette Technology

Briquettes are a type of solid fuel that is produced through a pressing or molding process to obtain a uniform shape and size according to the standard of use. Coal briquettes specifically refer to coal that has been processed and molded so that it has a uniform particle size, usually in the range of 3 to 5 centimeters in diameter. Non-carbonized coal briquettes are a type of briquette that is produced without going through a carbonization process beforehand. The manufacturing process is relatively simple, including the stages of coal grinding, mixing with binders, and printing. It is different from carbonized coal briquettes, where the raw materials used are coal that has undergone a carbonization process or is pre-fermented. The purpose of this carbonization process is to reduce the content of volatile matter, so that it can minimize the formation of smoke during combustion. The function of the development of coal-biomass briquettes is as cofiring coal-fired power plants and carbonized coal briquettes as an alternative fuel for small industries/MSMEs.

Until now, Central Kalimantan Province does not have a commercial-scale coal briquette production facility that is actively operating. However, there are several local-scale initiatives and limited research studies that have been conducted to explore the potential use of coal as a raw material for making briquettes in the region. Although Central Kalimantan has considerable potential for coal reserves, the implementation of its use in the form of coal briquettes has not yet reached the operational and commercial stages. Most of the initiatives carried out to date are still limited to small-scale socialization and research activities. These efforts have not developed into sustainable briquette production activities or are widely used by the community and the industrial sector.

Metallurgical Coal Products Through Cokes Making Technology

In general, products such as coke, coke briquettes, carbon raiser, and pulverized coal injection (PCI) are solid materials resulting from the carbonization process of coal or other carbon-rich materials. The process of making metallurgical coke can be carried out with raw materials in the form of coking coal mixed with several types of non-coking coal or non-premium coking coal to the specifications of coal as a blending material. In industrial practice, both coke and semi-coke are widely used in the refining process of metals, especially nickel and iron. The use of coal for the metallurgical industry in Central Kalimantan Province has not shown development at the operational or commercial level. Although this area is known to have potential metallurgical coal reserves, one of which was identified in Lahei I Village, North Barito Regency, with an estimated reach of around 3.9 million tons, its utilization is still in the initial exploration stage. The development process has not proceeded to a comprehensive technical and economic feasibility study stage. The metallurgical industry, such as the production of coke for steel smelting, demands the use of high-quality coal as well as the availability of adequate and complex supporting infrastructure.

Until now, there has been no construction of processing facilities or smelters specifically intended for metallurgical coal in Central Kalimantan. Although in recent years there has been a discourse on the establishment of coal processing plants in this region, its

implementation has not been realized. On the other hand, the development of the metallurgical industry in Indonesia is more focused on areas that have larger metallurgical coal reserves and more mature industrial ecosystems, such as East Kalimantan and South Sumatra. Thus, although geologically Central Kalimantan holds the potential of coal for the metallurgical sector, until now there has been no real application in the field in the form of large-scale industrial activities.

Coal Development Products Through Coal Upgrading Technology

Low-grade coal such as lignite and sub-bituminous generally have a low calorific value (< 5,100 cal/g air dried base, adb) and a fairly high moisture content (30%-50%). Due to the high moisture content, the calorific value of the coal becomes low so that it is less in demand and difficult to market. Even though there are quite a lot of coal resources of this type in Indonesia. One way to improve the quality of coal is through the process of upgrading coal by drying to reduce its moisture content. In Indonesia, the drying process with the intention of reducing water content has not been applied commercially because until now coal consumers, both coal-fired power plants, cement factories, and other industries still use bituminous coal which has a water content of between 13% and 20%. However, bituminous coal reserves are starting to deplete so that improving the quality (upgrading) of low-ranking coal in Indonesia is considered very important because the reserves are quite large.

Upgraded Brown Coal (UBC) is a low-ranking coal quality improvement technology jointly developed between the Center for Research and Development of Mineral and Coal Technology (tekMIRA) and the technology owner, Kobe Steel Ltd. Japan. A pilot plant with a capacity of 5 tons/day has been built in Palimanan and started operating since 2003 and a demonstration plant in Satui, South Kalimantan from 2006 to 2011 and there is no facility or initiation in Central Kalimantan.

Advanced Material Products and Rare Earth Metals Through Extraction Technology

Rare Earth Elements (REEs) are 17 elements in the Earth's crust consisting of 15 metal elements lanthanides (La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu) plus scandiun and yitrium. This rare earth metal/LTJ is commonly found in some minerals such as monacytes, xenotime, and bastnaesite. However, some recent studies have shown that coal can also contain LTJ with levels equivalent to the levels of LTJ found in LTJ-carrying minerals (Geological Agency's LTJ Potential Study Team).

Coal is made up of organic and non-organic components. The presence of LTJ in coal is associated with its inorganic components. The coal burning process at coal-fired power plants will eliminate organic components and leave non-organic components. This process can result in the enrichment of LTJ content in coal burning ash (FABA-Fly Ash and Bottom Ash). The LTJ level in coal fly ash has been proven to increase 10 times greater than in the coal itself (Geological Agency's LTJ Potential Study Team).

Currently, the main focus in Central Kalimantan is coal mining and managing its environmental impact. The development of technologies to extract advanced minerals and rare earth metals from coal in the region does not appear to be a priority and there is no documented information on its development.

Agro-Industrial Material Products Through Extraction Technology

Agroindustry is an industry that utilizes agricultural products as raw materials or products used in the agricultural industry, this includes many things, especially in crop

management, food and beverage production, biopharmaceuticals and bioenergy. The use of coal for agro-industrial material needs in Central Kalimantan has not yet reached the commercial stage, but it has shown promising potential through research conducted by the Geological Agency, especially the Center for Mineral, Coal, and Geothermal Resources (PSDMBP).

One of the focuses of the research is the extraction of humic acid and fulvic acid from low-calorie coal, including from the Dahor Formation in the Central Kalimantan region. Humic acid and fulvic acid are natural organic compounds that are very useful in the agricultural sector because they are able to improve soil structure, increase the availability of nutrients, and support plant growth. In the Geological Agency's portal, it is stated that humic acid extraction has been carried out on 48 coal samples from various formations including the dahor formation, testing of coal samples of the Dahor Formation in Central Kalimantan has a humic compound content of 45.51% making it feasible to be developed as a raw material for organic fertilizers.

Although there are no industrial facilities in Central Kalimantan that produce humic acid and fulvic acid in bulk, this study opens up great opportunities for coal downstream in the form of environmentally friendly agro-materials. If it continues to be developed, this technology will not only increase the added value of local coal, but can also support food security and productivity of the agricultural sector in Central Kalimantan.

Power Plant Optimization Through Blending Facility, Cofiring & IGCC Technology

Coal blending is a process of mixing medium calorie coal with low-calorie coal, so that specified coal is used according to the needs of coal. The Blending Facility is a superior alternative because it has several benefits, including the quality of the coal products produced can be adjusted to the required specifications. Blending products certainly have provisions in the environmental field with sulfur levels below the threshold according to the provisions of the law.

Biomass cofiring at coal-fired power plants is an alternative effort to reduce coal consumption (in line with the global coal phase out trend) by utilizing biomass fuel as a substitute for part of coal while still paying attention to the quality of fuel as needed. In addition, the application of biomass in coal-fired power plants can optimize the potential for abundant biomass utilization.

Integrated Gasification Combined Cycle (IGCC) is a technology that implements an integrated coal gasification combination cycle that uses gas and steam turbines as its generator. The main component of this IGCC technology is the coal gasification process. Its efficiency can reach 35-48% or about 5-10% higher than conventional plants. Likewise, from the environmental side, the emissions produced are also lower. The gases produced from the gasification process are cleaned first before burning, so that the exhaust gases have lower SO2, particulates, and mercury contents.

In Central Kalimantan, efforts to optimize power plants through Cofiring technology have been carried out in Pulang Pisau Regency through the PLN EPI unit in collaboration with the local government and the University of Palangka Raya in the form of planting gamal trees (Gliricidia sepium) as biomass to be used for cofiring at PLTU Pulang Pisau, Central Kalimantan. This program also includes planting on an area of 100 hectares, namely 80 ha in Rawa Subur Village (Kapuas Murung) and 20 ha in Buntoi Village (Pulang Pisau). However,

regarding alternative blending facility technology and IGCC in power plants, the procurement has not been facilitated and the program needs to be initiated.

Optimization of Power Plants Through CCS&CCUS Technology

With increasing electricity demand and the demand for reducing CO_2 emissions, coal-fired power plants in the future must include Carbon Capture and Storage (CSS) units. In 2015, Indonesia conducted a study to determine the readiness of power plants using CCS technology. The study was conducted for the West Java and South Sumatra areas. From these two areas, the annual CO2 emissions released reached 16.2 million tons, with the composition of West Java contributing 12.1 million tons of CO_2 and South Sumatra 4.1 million tons of CO_2. The process of capturing CO_2 is carried out by retrofitting existing plants by adding CO2 absorbing units. The most suitable method for this purpose is Post Combustion CO2 Capture.

Reducing CO2 emissions using CCS will make coal-fired power plants have greenhouse gas emissions relatively comparable to those that use new-renewable energy. Until now, CCS & CCUS technology has not been applied to power plants in Central Kalimantan, but it is an initiative of a new alternative as an effort to reduce $CO_{2\ \text{emissions}}$ from burning coal-fired power plants.

CONCLUSION

Coal in Central Kalimantan is mainly found in the Warukin, Tanjung, and Batu Ayau formations and is predominantly used in the Steam Power Plant (PLTU) sector, with smaller contributions to the cement, textile, and metallurgy industries. Despite its economic importance, coal utilization raises significant environmental concerns, including water and ecosystem pollution, topographic and biodiversity degradation, land subsidence, and greenhouse gas emissions such as CO_2 and methane, which contribute to global climate change. Nevertheless, coal also presents opportunities for higher-value and potentially lower-impact utilization through downstream conversion into products such as methanol, dimethyl ether (DME), synthetic natural gas (SNG), ammonia, hydrogen, gasoline, biodiesel, briquettes, metallurgical coke, and rare earth components. The optimization of these downstream potentials in Central Kalimantan can be supported by technologies such as coal gasification, coal liquefaction, coal briquetting, coke making, and coal upgrading, particularly when integrated with Carbon Capture Storage (CCS) and Integrated Gasification Combined Cycle (IGCC) systems to reduce CO_2 emissions and support cleaner energy transitions. Future research should focus on evaluating the techno-economic feasibility, environmental impacts, and regional policy frameworks needed to implement these coal downstream technologies sustainably in Central Kalimantan.

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