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Coal Gasification Technology to Support the Energy Transition: Opportunities and Challenges

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Abstract

Indonesia is a country that has quite abundant coal reserves. Coal reserves are most widely spread in Kalimantan and Sumatra and several other areas. When the production of other fossil energy such as petroleum decreases, the use of coal energy sources actually increases. However, coal is also known as a dirty fossil fuel because its use has a negative impact on the environment. This needs to be paid attention to in order to develop innovations in using coal that are more environmentally friendly, so that they can also support the energy transition to achieve the Net Zero Emission (NZE) target. The energy transition is a process that must be carried out by countries in the world to reduce carbon emissions which can cause climate change and global warming. The agreement on the energy transition aims to increase the use of clean energy. The energy transition does not have to eliminate coal. However, coal requires innovation for more environmentally friendly use. One of the environmentally friendly coal utilization technologies is coal gasification. In the road map for the development and utilization of coal by applying environmentally friendly technology through coal gasification, one of which is the coal development program to produce methanol and DME.

Keywords: Coal, Fossil Energy, Gasification, Energy Transition, Methanol, DME

INTRODUCTION

Coal is a natural resource that is quite abundant in Indonesia, with coal reserves as of January 2022 of 31.7 billion tonnes and resources totaling 91.6 billion tonnes. This makes Indonesia the largest coal producer and exporter in the world. Indonesia has low-calorie coal reserves of 10.9 billion tons. Then, medium calorie coal was 18.8 billion tons. Then, high-calorie coal is 1.5 billion tons and very high-calorie coal is not so much, 0.6 billion tons (CNN Indonesia, 2022).

Based on information provided by the Ministry of Energy and Mineral Resources, Indonesia's coal reserves are estimated to last for the next 65 years if production continues and no new reserves are discovered. About 60% of Indonesia's total coal reserves consist of cheaper, lower quality coal. Therefore, this type of coal is sold at competitive prices on the international market (Afin et al., 2021). But on the other hand, low quality coal can be used to encourage coal downstream policies to create diversification of coal as an alternative energy source.

Currently, coal still has a very important strategic role for Indonesia. As an energy source, coal is projected to still make a significant contribution to the energy mix to support Indonesia's national energy security. Coal is also seen as national development capital because its uses are very diverse, not only limited to its function as an energy source. Currently, the largest use of domestic coal is as conventionally burned thermal coal, reaching around 71% for PLTUs with a total of around 99 million tons (Ditjen Minerba, 2020). Apart from that, coal is used in various sectors such as the cement, textile, paper, steel, smelter industries, and so on in smaller quantities.

However, coal faces significant challenges, especially related to environmental issues due to direct use of coal. This challenge will become increasingly prominent in the future, especially as we move towards the Net Zero Emission (NZE) target. Environmental issues that always haunt the use of coal must remain the main focus, so that future use of coal must be balanced with

environmentally friendly technology to reduce CO2 emissions to support the energy transition towards achieving the Net Zero Emission (NZE) target. With abundant resources and reserves, Indonesia needs to develop the right strategy for developing and utilizing coal in the future.

Non-conventional use of coal can be an attractive option to support national energy supplies. Coal can still be used as an energy source but it must be much more environmentally friendly than its current use. Coal can play a role in helping the government reduce dependence on energy imports through coal conversion programs, such as coal gasification.

Coal gasification has considerable potential to help the country's foreign exchange reserves, where products from coal gasification such as dimethyl ether (DME) and methanol can reduce imports and substitute fuel oil (BBM), gas fuel (BBG) and raw materials for the chemical industry. (Afin et al., 2021). Several companies and institutions have started pioneering gasification projects, including underground coal gasification, in several locations in Indonesia. However, the non-conventional use of coal which is more environmentally friendly raises challenges and opportunities for developing it in the future (Widayat et al., 2021). Therefore, researchers aim to analyze the development and utilization of coal through coal gasification technology to produce methanol and dimethyl ether (DME) as well as future opportunities and challenges.

RESEARCH METHODS

The method used in this article is a qualitative method with a literature study approach. Literature study is the process of collecting, compiling, analyzing and synthesizing literature that is relevant to the research topic being studied (Sugiyono, 2019). The steps in using qualitative research methods with a literature study approach are searching for literature relevant to the research topic, evaluating and selecting sources, organizing literature, creating a framework, compiling a literature review (McCombes, 2023). In this journal the author uses data collection techniques from scientific books, articles, government policies and publications that are relevant to the research topic.

RESULT AND DISCUSSION

Coal Resources and Reserves in Indonesia

Indonesia is the main coal producing country in the Asia Pacific region, with resources and reserves spread throughout almost all regions, especially Kalimantan and Sumatra as shown in Figure 1.

Figure 1. Map of Distribution of Indonesian Coal Resources and Reserves
Source: PSDMBP (2019)

Resources and reserves are potential that is still stored in the earth that has not been utilized. Resources are parts of coal in a certain form and quality that make it possible to mine them economically. Coal resources are divided according to the level of geological confidence into inferred, indicated and measured categories. Meanwhile, reserves are part of indicated and/or measurable coal resources that are economical to mine.

In 2021, Indonesia has 97,196.1 million tonnes of resources and 33,610.31 million tonnes of low and medium calorie coal reserves (≤ 6100 cal/g). Meanwhile, high and very high calorie coal (> 6100 cal/g) Indonesia only has 12,873.81 million tons of resources and 2,668.54 million tons of reserves. Medium and high calorie coal is generally the main coal mining commodity in Indonesia. The number of coal resources and reserves in Indonesia can be seen in Table 1.

Table 1. Coal Resources and Reserves Based on Calories in 2021

Quality	**Resources (million tons)**					**Reserves (million tons)**			
	Guessed	**Appointed**	**Measurable**	**Total**	**Total Verified**	**Estimated**	**Proven**	**Total**	**Total Verified**
Low calories	14,961.91	11,979.49	10,402.32	37,343.72	29,703.20	7,523.85	5,401.22	12,925.07	10,869.81
Medium calories	14,625.47	18,356.99	26,869.92	59,852.38	51,868.94	9,464.74	11,220.50	20,685.24	18,811.62
High calories	3,368.46	3,135.27	3,228.12	9,731.85	7,246.56	1,139.99	855.96	2,025.95	1,456.17
Very high calories	1,394.31	878.63	869.02	3,141.96	2,787.34	246.34	396.25	642.59	558.02
Amount	34,350.15	34,350.38	41,369.38	110,069.91	91,606.04	18,374.92	17,903.92	36,278.85	31,695.63

Source: Badan Geologi (2021)

In the road map for the development and utilization of coal by applying environmentally friendly technology through coal gasification, namely in the form of a coal development program to produce methanol and DME and coal development to produce SNG, ammonia and hydrogen.

Coal Gasification

The coal gasification process is the process of converting coal from solid fuel to gas fuel. By converting coal into gas, unwanted materials contained in coal, such as sulfur compounds and ash, can be removed from the gas using certain methods so that clean gas can be produced and can be used as an energy source (Iswanto et al., 2015).

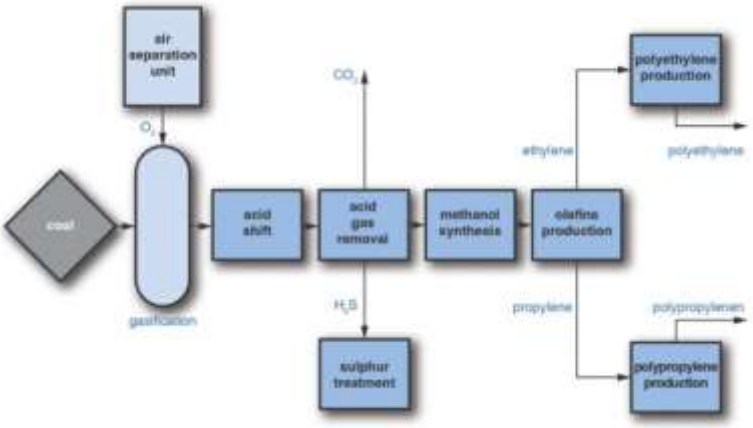

Figure 2. Coal Gasification Process
Source: Habibie Razak (2019)

Gasification is a process where coal can be converted into syngas which is a mixed gas whose main components are carbon monoxide (CO) and hydrogen (H2), then it can be used as fuel and can produce various chemicals, either directly or through intermediaries such as methanol. (Afin et al., 2021).

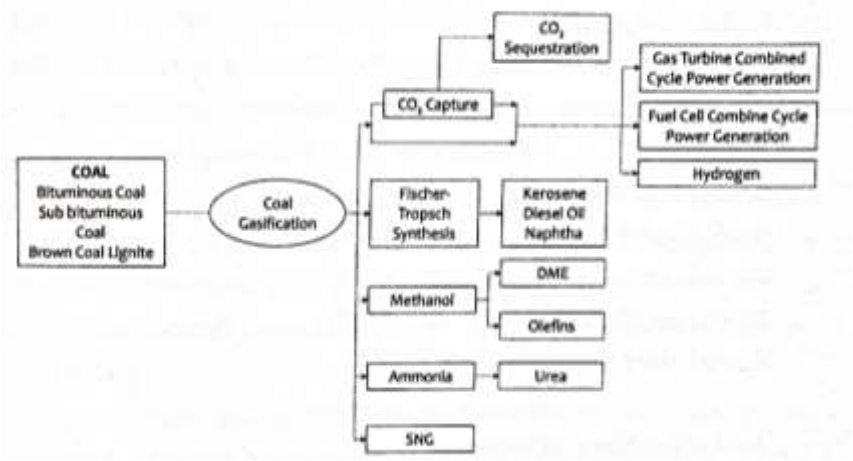

Figure 3. Coal Gasification Technology
Source: Toyo Engineering Corporation (2021)

Coal gasification is a method that can produce electrical power, fuel, chemicals and hydrogen. Based on Figure 3. Coal gasification can produce kerosene, diesel oil and naphtha through Fischer-Tropsch synthesis, and can produce methanol which can be further processed into DME and olefins, and can produce ammonia which can be processed into urea.

The development of gasification technology is growing rapidly in China. Almost all coal producing provinces have built gasification plants, especially at mine mouths. Compared to China, which has been using gasification technology for a long time, in Indonesia gasification has only just started because fuel oil is increasingly expensive due to restrictions on subsidies (Sasongko et al., 2011). Of course, products produced from the efficient and clean coal gasification process can help meet national energy needs and maintain national energy security. Research and development related to the coal gasification process in Indonesia has only been actively carried out by several institutions such as BPPT, Tekmira and PLN.

Development of Coal to Produce Methanol

Through gasification, coal can be used to produce methanol. Methanol is a petrochemical product which has a very important role in the development of downstream products. The raw material methanol is needed in the textile, plastic, synthetic resin, pharmaceutical, insecticide and plywood industries. Methanol also acts as an antifreeze and inhibitor in downstream oil and gas activities and is one of the raw materials for making biodiesel (Ditjen Minerba, 2021).

In general, methanol is made from syngas. Most methanol syntheses are based on natural gas as a raw material, but syngas from coal can also be used. Coal was used to make up 9% of global methanol production in 2003. In 2003, China's methanol production reached 6 million metric tons. In 2010, production capacity in China reached 38.4 million tons and consumed 22.7 million metric tons of methanol or around 40% of the global market (Methanol Institute, 2020). Currently, China is the largest consumer of methanol production in the world. China accounts for approximately 58% of world methanol use (Khalafalla et al., 2020).

According to the Ministry of Energy and Mineral Resources, demand for methanol in Indonesia is projected to increase from year to year. The need for methanol is estimated to reach 2.1 million tonnes per year with imports reaching 1.6 million tonnes. With the increase in demand for methanol, coal to methanol technology is needed as a means of increasing the added value of coal and an effort to reduce methanol imports (Arif, 2022). The process of making methanol from coal goes through several stages which can be seen in Figure 4.

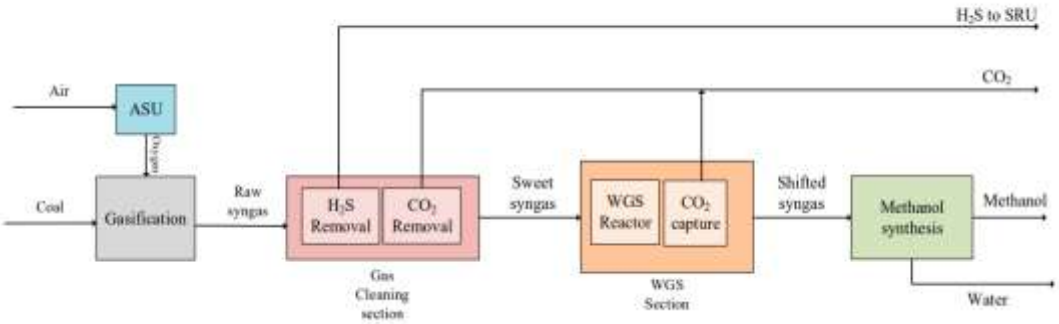

Figure 4. Process of Forming Methanol from Coal
Source: Khalafalla et al. (2020)

Coal Development to Produce Dimethyl Ether (DME)

DME is a source of clean energy that can be produced from various raw materials such as petroleum residues, biomass, natural gas and coal (IHS Markit, 2009). Utilization of DME as fuel produces low environmental impacts. Where, combustion does not produce sulfur oxides (SOx) and smoke at all because DME does not contain sulfur or ash and DME produces very low NOx and CO (Toyo Engineering Corporation, 2021) (Ditjen Minerba, 2021).

Although basically DME can be produced from various energy sources, currently low-calorie coal is considered the most ideal raw material for developing DME. The discovery of coal gasification technology to produce DME was driven by the increasing need for LPG (Arif, 2022). Utilization of DME can replace or reduce the use of diesel oil and LPG in Indonesia. Apart from being able to be used in industry and transportation as well as power plants as a substitute for diesel oil, DME also has the opportunity to replace LPG as a fuel in the household, commercial and industrial sectors, which is currently mostly imported (Boedoyo, 2010). LPG consumption in 2019 was around 7.64 million tons, and 75% of total consumption was imported or reached IDR 80 trillion. In 2021, as much as 75-78% of domestic LPG consumption will still be covered by imports (Industri Kontan, 2021).

DME is currently widely used as fuel in China. With a capacity of 3 million tons per year, this country is the largest producer and user of DME in the world. DME has been used in the housing sector in a number of cities and provinces in China. Meanwhile, DME has been used as a transportation fuel as a substitute for diesel in Austria, America, Denmark, Sweden, Korea, China and Russia. DME has been used as a gas turbine fuel in the industrial sector in Japan, South Korea, China and India(Director General of Oil and Gas, 2010; ogindonesia, 2018).

In general, there are two DME production process technologies that have been developed to date, namely: Indirect process and direct process. Figure 5. DME can be produced through two process stages, namely methanol synthesis from syngas and DME synthesis process from methanol. DME production using the indirect process is currently the most widely used and has reached a refinery scale/capacity above 1 million tons/year. Meanwhile, DME production using a direct process is currently generally still in the development stage on a pilot plant scale (Ditjen Minerba, 2021).

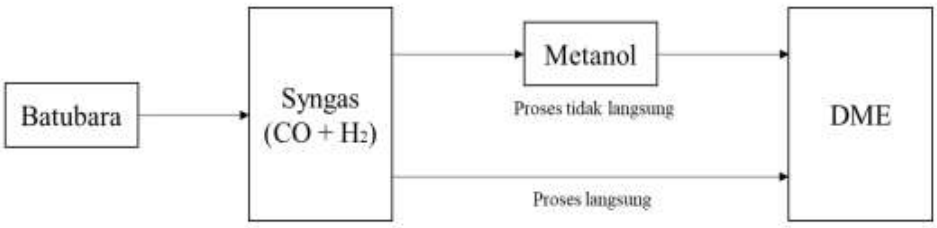

Figure 5. DME Synthesis Method
Source: Fadhilla et al. (2023)

Opportunities and Challenges of Coal Gasification

Gasification technology is suitable for application in Indonesia, considering that coal resources and reserves in Indonesia are dominated by low to medium rank coal. Low rank coal tends to have better reactivity than high rank coal. This is caused by low rank coal having a higher concentration in active sites, higher porosity, and a more uniform dispersion of alkaline impurities which act as a built-in catalyst. Thus, low rank coal can be used as a better alternative fuel for gasification. The excess reactivity allows the use of low rank coal more efficiently to produce synthetic gas, as required in the gasification process. With gasification technology, Indonesia can maximize the potential of its low rank coal as a more environmentally friendly energy source. (Gasifier et al., 2014).

Syngas from coal gasification has promising prospects for three reasons. First, syngas products are very commercial and are widely used in various industries, both as chemicals, energy sources and transportation fuels. Second, syngas is more environmentally friendly compared to natural gas or petroleum with low CO2, SOx and NOx emissions. Third, the abundance of coal resources in Indonesia. Apart from its quite large reserves, coal gasification can also utilize young coal, the amount of which in Indonesia reaches 70% (KESDM, 2013) (Iswanto et al., 2015).

To support increasing the added value of coal, the Government has issued several regulations. One of them is Government Regulation Number 96 of 2021 concerning the Implementation of Mineral and Coal Mining Business Activities. Through this regulation, Special Mining Business Permit (IUPK) holders as a continuation of the government's Coal Mining Concession Work Agreement (PKP2B) are encouraged to carry out domestic coal development and utilization activities. In addition, through Government Regulation Number 25 of 2021 concerning the Implementation of the Energy and Mineral Resources Sector, the Government provides incentive support for companies that carry out activities to increase added value, including incentives for coal royalties of up to 0% for gasification, setting special coal prices to increase added value. (gasification) which is carried out at the mouth of the mine, as well as

granting a special period of Mining Business Permit (IUP) for coal which is used as a coal supply for gasification according to its economic life (KESDM, 2021) (Fadhilla et al., 2023).

However, increasing the added value of coal through coal gasification in Indonesia has not yet reached the commercial stage. The development of gasification technology in Indonesia is still slow due to several factors, apart from the technological side, including the lack of investment in this sector, unclear regulations regarding DME prices, and guarantees of domestic coal supplies (Sasongko et al., 2011). The energy sector is synonymous with large investment values. As we know, the mining sector is one of the economic sectors that requires quite a large investment value in Indonesia. This investment is used for general investigations, exploration activities, construction activities and operational activities (Rosyid, 2020). As for the problem of gasification technology, it is actually not a problem considering that gasification technology has been implemented on a commercial scale throughout the world. Gasification technology has also been known for quite a long time in Indonesia, where various studies leading to gasification technology have been developed to suit the specifications and characteristics of coal in Indonesia (Sasongko et al., 2011).

Apart from that, it cannot be denied that the use of fossil energy (coal as raw material for the gasification process) is also closely related to various environmental problems, especially increasing global warming due to the release of greenhouse gas emissions in the form of CO2 into the atmosphere, both in the process of obtaining coal raw materials and in the process of the production. Several studies have been carried out to determine the potential for greenhouse gas emissions from the DME production process through coal gasification compared to LPG. It is known that the emission factor for LPG production is around 5 times lower than DME. This is quite rational because DME production involves more extensive chemical and energy reactions (Felixius et al., 2021). In order to reduce the potential for the release of greenhouse gases into the atmosphere, it is necessary to develop clean gasification technology, as well as implement methods for capturing CO2 produced during the gasification process. Many technologies have been developed to capture CO2, including absorption, adsorption, membranes, rectification at low temperatures (Li et al., 2022), and the most recently developed is Carbon Capture and Storage (CCS). The coal gasification process can be combined with CCS technology to capture CO2 emissions before they are released into the atmosphere. The captured CO2 is then recycled to be used as raw material to produce DME through two approaches, namely methanol synthesis followed by a dehydration reaction (indirect synthesis) and direct hydrogenation of CO2 into DME (direct synthesis) (Centi et al., 2013), or further utilized through IGCC technology to be utilized as electrical energy.

CONCLUSION

The use of coal gasification technology has opportunities and is suitable for application in Indonesia because coal reserves are quite abundant and dominated by medium and low calorie coal. In addition to increasing energy security, coal gasification can also play a role in the new energy mix according to the targets set in the KEN and contribute to reducing greenhouse gas emissions in Indonesia. However, the challenges faced in the form of investment costs for coal gasification projects are very large so cooperation is needed to invite investors and it cannot be denied that the use of fossil energy such as coal still produces greenhouse gas emissions in the form of CO2 so the resulting emissions need to be managed well. Coal gasification with carbon capture technology such as absorption, adsorption, membranes, rectification at low temperatures and most recently CCS/CCUS technology is one solution to minimize pollutants and greenhouse gas emissions produced.

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