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Feasibility Study of Coal Gasification Business into Dimethyl Ether (DME) with Cost Benefit Analysis (CBA) Method to Support National Energy Security

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Abstract:

The coal gasification project for Dimethyl Ethane (DME) in Indonesia offers great potential to support the energy transition by reducing dependence on energy imports, saving the country's foreign exchange, and contributing to reducing greenhouse gas emissions. Through a Cost-Benefit Analysis (CBA), this study assesses the economic feasibility and environmental consequence of the project, focusing on investment costs, foreign exchange savings, emission reductions, and job creation. Although the project promises significant benefits, key challenges include high investment costs, dependence on foreign technology, and the sustainability of environmentally friendly coal supplies. Therefore, the project's success is highly dependent on supportive policies, such as fiscal incentives, public-private partnerships, and strengthening domestic technology research, which can ensure a cleaner and more sustainable energy transition in Indonesia.

Keywords: *Coal Gasification; Dimethyl Ether (DME); Cost-Benefit Analysis (CBA); Energy Transition; Emission Reduction*

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1. Introduction

Indonesia, as a developing country with a population of more than 270 million people, has an energy demand that continues to increase annually. One of the primary energy sources used by households is Liquefied Petroleum Gas (LPG), which serves as the main cooking fuel for over 80% of households in the country. The dominance of LPG in meeting domestic energy needs has been evident since the government launched the kerosene-to-LPG conversion program in 2007, aimed at reducing energy subsidies and improving fuel efficiency. However, despite the growing demand for LPG, domestic production remains insufficient to meet national consumption levels, making Indonesia highly dependent on LPG imports from countries such as Saudi Arabia, Qatar, and the United Arab Emirates (Iijima et al., 2019; Sharma & Agrawal, 2018). This dependency not only increases pressure on the national energy trade balance but also introduces supply instability risks that can impact the domestic

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economy, especially in the event of a surge in global energy prices (Park & Kim, 2017).

Indonesia's reliance on LPG imports has significantly affected the country's foreign exchange reserves. Data from the Central Statistics Agency (BPS) shows that in 2023, Indonesia imported more than 6 million tons of LPG, amounting to over 2.5 billion USD annually. The national LPG consumption trend continues to rise at an average growth rate of approximately 5% per year, which is expected to further exacerbate the energy trade balance deficit (Gao et al., 2020; Tian et al., 2020). If this dependence on imports is not mitigated, the financial burden on the state will increase, particularly in response to unpredictable fluctuations in global energy prices (Liu et al., 2020).

As one of the world's largest coal producers, Indonesia possesses abundant reserves that serve as a strategic asset in the national energy sector. According to the Ministry of Energy and Mineral Resources (ESDM), Indonesia's coal reserves exceed 38 billion tons, with annual production surpassing 600 million tons in 2023. Currently, most of Indonesia's coal is exported to nations such as China, India, and Japan to meet their energy demands (Ciferno & Marano, 2002). Meanwhile, domestic coal utilization remains largely confined to the steam-fired power plant (PLTU) sector, which, although essential for energy security, faces criticism for its high carbon emissions (Basu, 2018; Hofbauer et al., 2018). Consequently, optimizing coal utilization through downstream processing is necessary to enhance domestic added value and support the energy transition toward cleaner and more sustainable sources (Gan et al., 2019).

One promising downstream strategy is coal gasification, which converts coal into synthetic gas (syngas) that can be further processed into various derivative products, such as Dimethyl Ether (DME), methanol, and hydrogen (Hu et al., 2021). Compared to direct combustion in PLTUs, coal gasification offers several advantages, including higher energy efficiency, the potential to reduce carbon emissions through carbon capture and storage (CCS) technology, and the flexibility to produce products with greater economic value (Fennell & Anthony, 2015; Dufour et al., 2011). Additionally, developing the coal gasification industry can create new value chains that contribute to domestic economic growth and generate employment opportunities within the energy sector (Zhang et al., 2019).

Dimethyl Ether (DME) is a gaseous compound with properties similar to LPG, making it a viable alternative fuel for both household and industrial applications (Biedermann et al., 2015). DME is non-toxic, non-carcinogenic, and can be liquefied at low pressure, allowing for convenient storage and distribution similar to LPG. Furthermore, DME can be synthesized from various feedstocks, including coal gasification, biomass, and natural gas, thereby providing flexibility in energy production and diversification (Nemanova et al., 2018). The adoption of DME as a fuel also has the potential to reduce emissions of carbon dioxide (CO_2) and other pollutants such as sulfur oxides (SOx) and particulates, making it a more environmentally friendly option than petroleum-based LPG (Azizi et al., 2019).

From an environmental perspective, DME combustion produces no soot, making it a cleaner alternative that does not contribute to air pollution (Quddus et al., 2021). Economically, developing a domestic DME industry could significantly reduce Indonesia's reliance on imported LPG, thereby alleviating the strain on the country's trade balance and foreign exchange reserves (Farouq et al., 2023). Several countries have successfully implemented DME as an LPG substitute, including China and Japan, which have developed commercial-scale DME production and distribution infrastructures. China, for instance, has leveraged coal gasification technology for large-scale DME production to mitigate its dependency on imported LPG (Az-Zahra & Sukmalengkawati, 2022). The successes of these nations can serve as a reference for Indonesia in designing policies, infrastructure, and incentives for the DME industry to support long-term national energy security (Juliana et al., 2018).

Coal gasification involves the conversion of coal into syngas—composed primarily of hydrogen (H_2), carbon monoxide (CO), and methane (CH_4)—which can subsequently be processed into DME via catalytic synthesis (Belch & Blech, 2004). This technology enhances coal utilization efficiency and minimizes emissions, especially when combined with CCS technology (Herianto, 2016). Implementing coal gasification for DME production presents numerous benefits, including a reduction in Indonesia's LPG import dependency and a subsequent alleviation of the country's trade deficit (Priyono, 2015). Additionally, the expansion of the gasification industry significantly enhances coal's added value, attracts new investments, and creates employment opportunities in energy and downstream sectors (Silcy et al., 2022).

However, the adoption of coal gasification for DME production comes with several challenges. One of the primary obstacles is the high initial capital investment required to develop gasification infrastructure, including production facilities, distribution systems, and supporting technologies such as CCS to curb emissions (Lembahyung & Handayani, 2023). Moreover, Indonesia still depends on foreign expertise in gasification and DME synthesis, potentially leading to difficulties in technology transfer and increased operational costs (Suhardi & Irmayanti, 2019). From a regulatory standpoint, government policies—including fiscal incentives, DME pricing subsidies, and market assurances—are crucial in attracting investments and ensuring the competitiveness of DME in the domestic market (Foroudi et al., 2017). Additionally, environmental concerns such as greenhouse gas emissions and production waste necessitate mitigation strategies, such as the adoption of environmentally friendly technologies and sustainability-driven operational standards (Hofacker et al., 2020).

To address these challenges, collaboration among government entities, industry stakeholders, and academic institutions is essential. Establishing a robust framework for coal gasification into DME can ensure optimal contributions to national energy security while aligning with Indonesia's long-term vision for a sustainable and self-sufficient energy sector (Yudiandri et al., 2024).

Problem Identification

1. Indonesia still imports most of its LPG needs, which has an impact on the country's trade balance and macroeconomic stability.
2. The coal gasification project into DME requires large investments and dependence on foreign technology, which is an obstacle to its implementation.
3. The existing infrastructure is not ready to support the widespread distribution of DME, which hinders the adoption of this technology.
4. Coal gasification can potentially produce harmful emissions if not managed properly, while this project also has the potential to provide social influences in the form of creating new jobs.

Problem Limitation
This study will focus on the economic and environmental analysis of coal gasification into DME, as well as the various challenges in implementing the project. The limitations of the study include an evaluation of the aspects of investment costs, social impacts, and infrastructure readiness to support the development of the DME industry in Indonesia. In addition, this study will also analyze the technological aspects and regulatory issues that are key factors in the success of this project. With a Cost-Benefit Analysis (CBA) approach, this research seeks to assess the economic feasibility of the project and identify strategic steps that can accelerate the implementation of coal gasification as a solution to reduce dependence on LPG imports and increase national energy security.

2. Theoretical Background

Coal Gasification as an Alternative Energy Source

Coal gasification is a thermochemical process that converts coal into synthetic gas (syngas), consisting of hydrogen (H_2), carbon monoxide (CO), and methane (CH_4). This syngas can be further processed into high-value products, including Dimethyl Ether (DME), methanol, and hydrogen (Hu et al., 2021). Compared to direct coal combustion in steam-fired power plants (PLTU), gasification offers several advantages, such as higher energy efficiency, reduced emissions, and flexibility in product diversification (Basu, 2018). Gasification also allows for carbon capture and storage (CCS), making it a more environmentally sustainable technology (Fennell & Anthony, 2015).

The implementation of coal gasification in Indonesia has been gaining attention due to the country's abundant coal reserves, estimated at over 38 billion tons (Ciferno & Marano, 2002). However, domestic coal use is currently dominated by power generation, with limited applications in downstream industries (Hofbauer et al., 2018). Countries such as China and Japan have successfully adopted coal gasification to produce alternative fuels, reducing their dependence on imported energy (Gao et al., 2020). For Indonesia, coal gasification represents a strategic opportunity to enhance energy security while transitioning toward cleaner and more sustainable energy sources (Liu et al., 2020).

Dimethyl Ether (DME) as a Substitute for LPG

DME is a promising alternative fuel that has physical properties similar to Liquefied Petroleum Gas (LPG), making it suitable for household and industrial applications (Biedermann et al., 2015). Unlike LPG, DME is non-toxic, non-carcinogenic, and can be stored at low pressure, simplifying its storage and distribution (Nemanova et al., 2018). Moreover, DME combustion produces minimal pollutants, such as sulfur oxides (SOx) and particulate matter, which contribute to air pollution (Azizi et al., 2019).

Several countries have successfully integrated DME into their energy systems. China has been at the forefront of DME production, utilizing coal gasification to reduce reliance on LPG imports (Az-Zahra & Sukmalengkawati, 2022). Similarly, Japan has invested in DME production as part of its clean energy transition strategy (Juliana et al., 2018). The adoption of DME in Indonesia could alleviate the country's dependence on imported LPG, improving energy security while reducing the financial burden on foreign exchange reserves (Farouq et al., 2023).

Economic and Environmental Benefits of Coal Gasification for DME

The economic benefits of coal gasification for DME production are substantial. By utilizing domestic coal reserves, Indonesia can reduce LPG imports and improve its energy trade balance (Foroudi et al., 2017). The development of a DME industry would also create new investment opportunities and job growth in energy-related sectors (Lembahyung & Handayani, 2023). Furthermore, the integration of gasification with CCS technology can mitigate carbon emissions, making it an environmentally viable option (Hofacker et al., 2020).

From an environmental perspective, DME is considered a cleaner fuel than LPG because it does not produce soot when burned (Quddus et al., 2021). Additionally, using coal gasification with CCS can significantly reduce CO_2 emissions, aligning with global sustainability goals (Tian et al., 2020). As a result, coal gasification for DME production has the potential to support Indonesia's commitments to reducing greenhouse gas emissions while maintaining energy independence (Dufour et al., 2011).

Challenges in the Implementation of Coal Gasification for DME

Despite its potential benefits, the implementation of coal gasification for DME production faces several challenges. One major barrier is the high initial capital investment required to establish gasification infrastructure, including production facilities, distribution networks, and CCS technology (Suhardi & Irmayanti, 2019). In addition, Indonesia currently relies on foreign expertise and technology for DME synthesis, which could increase operational costs and create dependency on external suppliers (Silcy et al., 2022).

Regulatory and policy support is crucial for the success of coal gasification projects. Governments must provide fiscal incentives, price subsidies, and market guarantees to attract investment in DME production (Herianto, 2016). China, for example, has successfully implemented policy frameworks that facilitate coal gasification for alternative fuels (Priyono, 2015). Indonesia could benefit from similar strategies, ensuring the economic viability of DME and promoting its use as an alternative to LPG (Belch & Blech, 2004).

Another challenge involves potential environmental impacts, such as residual waste and emissions from coal gasification (Nemanova et al., 2018). To address this, sustainability measures must be integrated into the gasification process, including the application of carbon capture technologies and adherence to environmental regulations (Yudiandri et al., 2024). Collaboration between the government, private sector, and research institutions will be essential in overcoming these challenges and ensuring the long-term success of coal gasification for DME production (Gan et al., 2019).

3. Methodology

The data analysis method in this study uses a mixed-method approach that combines secondary data with quantitative and qualitative techniques to obtain a comprehensive picture of the feasibility of the coal gasification project into Dimethyl Ether (DME). This approach includes an analysis of national energy policies, literature studies related to gasification and DME technology, and an evaluation of the social and environmental impacts resulting from project implementation. One of the main methods used is Cost-Benefit Analysis (CBA), which allows for an assessment of the benefits and costs of the project based on long-term economic projections. CBA is used to compare initial investment, operating costs, and environmental impacts with the benefits gained, such as foreign exchange savings from reduced LPG imports, reduced carbon emissions, and job creation. In addition, this study considers external factors such as global energy price fluctuations, government policies, and infrastructure readiness in Indonesia. The results of this analysis will be strengthened by estimates of Net Present Value (NPV) and Internal Rate of Return (IRR) to assess whether this project is economically feasible. With a systematic and data-based approach, this study is expected to provide appropriate recommendations for policymakers in supporting the energy transition and national energy security. (Boardman et al., 2017).

4. Empirical Findings/Result

The coal gasification into Dimethyl Ether (DME) project aligns with Indonesia's energy transition strategy, aiming to increase renewable energy use and reduce dependence on imported fossil fuels. This transition is supported by Geels' (2005) Multi-Level Perspective on Energy Transitions, which emphasizes the role of technological innovations, policies, and market dynamics in shifting towards sustainable energy. In this context, the Energy Substitution Theory (Drucker, 1985; Stern, 2007) also becomes relevant, as it highlights the need to diversify energy sources and adopt cleaner technologies to mitigate environmental impacts. The Indonesian government's policy framework, as outlined in the National Energy General Plan (RUEN), reflects these theories by targeting a 23% renewable energy mix by 2025, aligning with global commitments such as the Paris Agreement.

A key economic assessment of the project is based on Cost-Benefit Analysis (CBA) theory, which evaluates the feasibility of energy investments by comparing projected benefits and costs (Boardman et al., 2018). In this case, the estimated Net Present Value (NPV) of USD 610.9 million and an Internal Rate of Return (IRR) of 13.11%, exceeding the 8% discount rate, indicate that the project is economically viable. This finding is consistent with previous studies on coal gasification in China and India, where large-scale projects demonstrated positive economic returns and strengthened energy security (Li et al., 2020; Rao & Kumar, 2019). These studies highlight that government incentives and public-private partnerships are crucial for overcoming high capital investment barriers, a lesson that Indonesia can adopt to attract investors and ensure project sustainability.

Furthermore, the Green Economy Theory (Jacobs, 1991; Stern, 2007) underscores the importance of integrating economic growth with environmental protection. The DME project contributes to GHG emission reductions by approximately 1.5 million tons of CO_2 annually, translating into USD 15 million in carbon savings based on a USD 10 per ton CO_2 price. This aligns with research by BPPT (2021), which found that coal gasification could reduce emissions by 15% by 2030 compared to continued LPG use. These findings reinforce the argument that energy transition strategies must incorporate both economic and environmental considerations to achieve sustainable development.

Despite its benefits, the project faces significant challenges, including high investment costs (USD 1.5 billion), dependence on foreign technology, and concerns over coal supply sustainability. The reliance on imported gasification technology mirrors findings by the World Bank (2020), which noted that many developing nations struggle with technological self-sufficiency in clean energy projects. To address this, Indonesia must invest in domestic technological capacity and R&D to reduce dependency on foreign expertise and enhance national energy security.

Additionally, ensuring a stable and environmentally friendly coal supply is critical for long-term project viability. Research by the Ministry of Energy and Mineral Resources (2023) highlights that sustainable coal sourcing must align with increasing global pressure to curb carbon emissions. Policies promoting low-emission coal and carbon capture technologies are needed to meet environmental regulations while maintaining economic feasibility.

In conclusion, the coal gasification into DME project aligns with multiple energy transition theories and global best practices. While CBA theory supports its economic feasibility, Energy Substitution Theory and Green Economy Theory emphasize its role in reducing energy imports and emissions. Lessons from China and India further suggest that government incentives and public-private partnerships are crucial for overcoming investment barriers. However, addressing challenges related to high costs, foreign technology reliance, and coal sustainability is essential to maximizing the project's potential in enhancing Indonesia's energy security, economic resilience, and environmental sustainability.

5. Conclusions

The coal gasification project into DME has enormous potential to support Indonesia's energy transition, reduce dependence on energy imports, and make a significant contribution to reducing greenhouse gas emissions. However, to realize this potential, several challenges must be faced, especially related to the high initial investment costs and dependence on foreign technology, requiring serious attention from the government. If these challenges are not managed well, the success of this project could be hampered. Therefore, supportive policies, including fiscal incentives, public-private partnerships, and strengthening research and technology development, will be essential to ensure that this coal gasification project can run efficiently and sustainably. Such policies will not only mitigate financial risks but also ensure that Indonesia can develop its domestic technological capacity and reduce dependence on foreign technology, which in turn will accelerate a more environmentally friendly energy transition.

The proposed policy recommendations, such as providing fiscal incentives for investors, establishing public-private partnerships, and increasing domestic DME technology research and development, are expected to be solutions to overcome existing challenges. With strong policy support, the coal gasification project into DME has the potential to provide significant long-term economic benefits, such as foreign exchange savings from reduced LPG imports, job creation, and reduced dependence on fossil fuels. The success of this project will also support the achievement of the Indonesian government's vision to achieve sustainable energy independence, in line with the President's Asta Cita which aims to build a more resilient and environmentally friendly economy. As part of the energy transition strategy, developing coal gasification into DME could be an important step in ensuring a cleaner and more sustainable energy future for Indonesia.

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