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Coal Downstreaming in the Form of Dimethyl Ether (DME) Will Increase Greenhouse Gas Emissions

Executive Summary

With various renewable energy policies in several destination countries for coal exports, The Indonesian government intends to increase its production capacity. One of the strategies undertaken by the government to absorb coal production is pursuing coal downstreaming in kind of the Dimethyl Ether (DME) manufacturing project. This coal gasification planned as a substitute fuel for LPG. This project will be undertaken by a consortium of PT Bukit Asam Tbk (PTBA) which requires an investment of 2.4 billion USD. This project will produce DME of 1.4 million tons per year with a 6 million tons coal demands.

The government claimed that this project has the potential to save up to IDR 8.7 trillion (617,6 billion USD) in state expenditure. In fact, a study report by the Institute for Energy Economics and Financial Analysis (IEEFA) revealed that this project has the potential to lose IDR 5.3 trillion per year. Not only in the financial sector, this DME project also has several environmental impacts, such as large greenhouse gas emissions.

Based on a study conducted by the Action for Ecology and Emancipation (AEER) it was found that the coal downstreaming with the DME production project resulted in several losses:

1. The DME production project with 1.4 million tons per year capacity would require 6 million tons of coal, which produces a high level of greenhouse gas emission of 4.26 million tons CO_2-eq per year mainly coming from the coal extraction as raw material and the DME production process itself.
2. The DME produced through coal gasification would result in emission five times more than the LPG production process with the same capacity, about 1.4 million tonnes per year. Besides, DME has a lower energy capacity than LPG.
3. Using DME as a substitute fuel for LPG has the potential to produce a greater rate of greenhouse gas emissions by 2050, with an estimated 12 million tonnes of CO_2-eq per year.

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Introduction

With an annual coal production of more than 400 million[1] tonnes per year (see table 1), Indonesia is one of the largest thermal coal exporters. Of 70-80% of total production has been exported while the rest is sold in the domestic market. With various renewable energy policies in several destination countries for coal exports as well as increased technological efficiency in the energy sector using coal, demand for coal is projected to slow down. Instead of reducing coal production, the government intends to increase production capacity. In 2020, Indonesia is targeting coal production of 550[2] million tonnes.

Table 1. RPJMN and Actual Coal Production

Description	2015	2016	2017	2018	2019
RPJMN (million tonnes)	425	419	413	406	400
Actual (million tonnes)	461	456	461	528	610

Source: RPJMN 2015-2019, ESDM Report 2019

One of the strategies undertaken by the government to absorb coal production in Indonesia is coal downstreaming project which produced Dimethyl Ether (DME) as a substitute fuel for LPG. This project will be undertaken by a consortium of PT Bukit Asam Tbk (PTBA) which is planned to operate in 2024[3]. The government's strategy to develop coal downstreaming into DME has several new problems[4]. Apart from the limited technological development in Indonesia, this project also has the potential to generate environmental impacts and financial losses.

Production DME is dirtier with less energy

With the implementation of the coal downstreaming project into DME, which costs an investment of USD 2.4 billion, DME is projected to be produced 1.4 million tonnes per year with 6 million tonnes coal demand per year. The government claimed that this project has the potential to save up to 8.7 trillion IDR in state expenditure. In fact, several reports from multiple institutions stated that this project presumably would harm the state finances. IEEFA in its document states that the DME project will lose 5.3 trillion IDR per year[5]. Not only in the

[1] AEER. 2019. China Investment in The Coal Power Plant Sector In Indonesia http://aeer.info/kajian-fdi-batubara-tiongkok/

[2] Ministry of Energy and Mineral Resources Republic Indonesia. Pers Release: Hingga Mei 2020, Realisasi Produksi Batubara Masih Sesuai Target. (Nomor:205. Pers/04/SJI/2020). https://www.esdm.go.id/id/media-center/arsip-berita/hingga-mei-2020-realisasi-produksi-batubara-masih-sesuai-target

[3] Press Release: *Sinergi Mewujudkan Hilirisasi Tambang Batubara: PTBA, Pertamina dan Air Products Sepakat Bentuk Perusahaan Clearn Energy Mulai dari Syngas Hingga DME*

[4] Arinaldo, Deon. (2020). Indonesia’s coal dynamic: Toward a Just Energy Transition. IESR

[5] Peh, Ghee. (2020). Proposed DME Project in Indonesia: Does Not Make Economic Sense. Institute for Energy Economics and Financial Analysis

financial sector, this DME project also generates greater emissions with less energy acquisition compared to the use of LPG as an energy provider for households.

The amount of greenhouse gas emissions in the DME production process is derived from the total amount of energy used for processes such as hot steam, heat, and electricity as well as greenhouse gas emissions directly generated by production processes such as carbon dioxide (CO_2), methane (CH_4), sulfur hexafluoride (SF_6), hydro fluorocarbons (HFCs) and nitrous oxide (N2O)[6]. These emissions are generated during the exploration and extraction stage of coal materials, the DME production process, product use, and product waste. In this document, emissions are only calculated for coal extraction, and the process of making. Gas emissions calculation is based on CO_2 equivalents. The emission factors have also considered the location of the factory in addition to the literature review. For example, the emission factor for the electricity used in the production of this DME is 0.877 tons CO_2-eq / MWh, with the power source coming from the coal power plant[7].

Based on the literature and simulations carried out using Aspen Hysis software, it is found that electricity and hot steam needs to produce 1.4 million tonnes of DME as shown in **Table B.2.** (Appendix B) for the coal into syngas and **Table B.3.** (Appendix B) for the syngas to DME.

To produce 1.4 million tonnes of DME per year from 6 million tonnes of coal, the resulting emissions are 4.26 million tonnes CO2-e / year *.

*AEER calculations using aspen hysis simulation and literature review from Yale University's coal to methanol technical report

Electricity and hot steam are required during coal gasification to produce syngas and DME purification for making the product match with the market specification. This process also produces CO2 from gasification and purification of DME. Based on the calculations, the results are listed in Table B.2. and Table B.3. (Appendix B), it obtained an emission of 3.68 million tonnes CO2-eq /year from the production process alone. In addition, the emission resulting from coal extraction of 6 million per year which is used as the main raw material for making DME is 580,000 tons CO2-eq per year

Therefore, the greenhouse gas emission for producing 1.4 million tons DME per year is 4.26 million tons CO2-eq / year. Of course, this should be a major concern for many stakeholders

[6] Suding, Paul H. (2013). Chemical plant GHG emissions: reconciling the financing of chemical plants with climate change objectives. *Inter-American Development Bank*, 2016.
[7] Rencana Usaha Penyediaan Tenaga Listrik (RUPTL) PT.PLN (Persero) 2019-2028.

considering that even a production activity that produces emissions of 1 million tonnes of CO2-e per year is considered as a very significant emitter category[8].

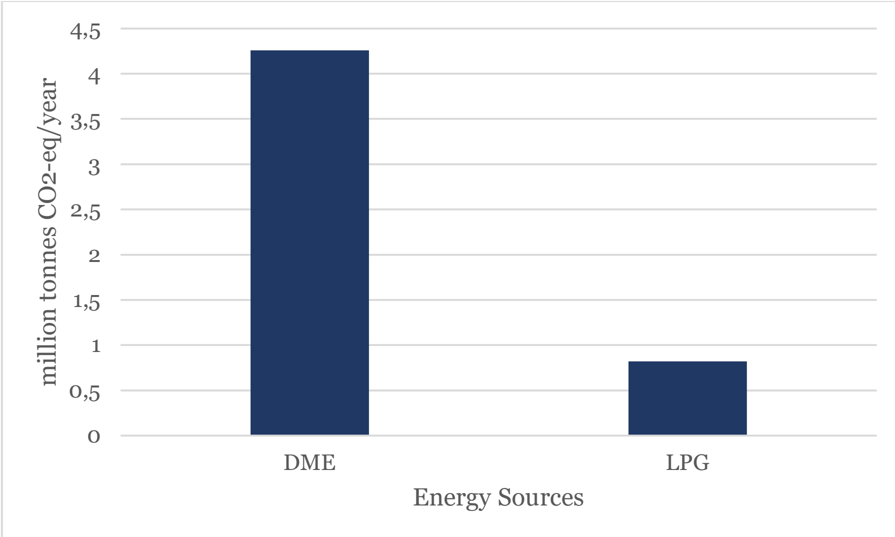
For additional information, emissions will increase if the selected process is to dehydrate methanol before it is converted into DME. This is due to the higher emission produced when dehydrating methanol from coal gasification, which is 2,965 kg CO2-eq per kg methanol[9] so that methanol production to continue to DME alone produces around 3 million tons CO2-eq / year emissions.

Compared to DME production (see **Figure 1**), the greenhouse gas emissions produced to produce LPG are much lower. The resulting emissions for producing LPG are 12,631 kg / GJ of energy. By calculating based on the LPG heat value of 46.6 MJ / kg LPG, it is obtained that greenhouse gas emissions are produced from LPG production with the same DME project capacity, namely 1.4 million tons per year of 824 thousand tons CO2-eq / year. The emissions produced by this DME production project are 5 times greater than the production of the same amount of LPG. Moreover, the amount of energy contained in LPG is 1.4 times greater than that of DME[10]. Therefore, it can be concluded that the policy for coal downstreaming in the form DME will likely to result more unfavourable impact as it produces larger emission with much less energy.

DME produces more carbon emissions for less energy content than LPG.

[8] Suding, Paul H. (2013). Chemical plant GHG emissions: reconciling the financing of chemical plants with climate change objectives. *Inter-American Development Bank*, 2016.
[9] Kajaste, Raili. (2018). Methanol-Managing greenhouse gas emissions in the production chain by optimizing the resource base. *Energy,*1074-1102.
[10] Muliahati, Annisa. (2018). Study of domestic coal-based dimethyl ether (DME) utilization to reduce LPG import. *Universitas Indonesia*.

Figure 1. Comparison of Emissions from Production Process of DME to LPG



Source: AEER calculations using a simulation with Aspen Hysis

Emission Increased from Using DME

Based on documents from the Indonesian Energy Outlook prepared by the National Energy Council (DEN) in 2019, it is estimated that household energy demand will increase. In 2050, energy demand in the commercial sector will be 47.7 million tonnes of oil equivalent (MTOE) under the business as usual scheme. Along with that, it can be ensured that the substitution of LPG with DME will also increase until 2050. The demand for DME and LPG in the years up to 2050 can be seen in **Table 2** (RUEN, 2019).

The substitution of LPG by DME will increase carbon emissions in the coming years*.

***Based on AEER calculation and literature review**

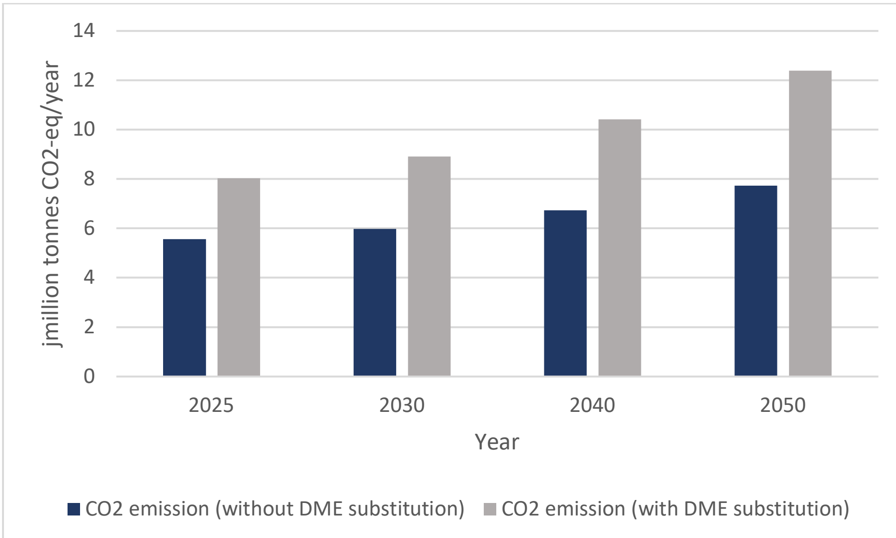
Table 2. Indonesia's LPG and DME demand in 2025-2030

Description (in million tonnes)	2025	2030	2040	2050
LPG demands (without DME substitution)	9,5	10,2	11,5	13,2
LPG demands (with DME substitution)	8,5	9	10	11,3
DME demands	1	1,2	1,5	1,9

Source: RUEN, 2019

Therefore, it can be ascertained that the greenhouse gas emissions resulting from supplying energy needs with LPG mixed with DME will be higher than the energy supply with LPG without being mixed with DME. (**Figure 2**).

Figure 2. Comparison of the rate of total emissions produced between LPG (without DME substitution) and LPG (with DME substitution)



Source: AEER calculations using data from RUEN, 2019

Conclusion

The coal downstreaming project by producing DME is certainly against Indonesia's commitment to make efforts to reduce greenhouse gas emissions and actively move to prevent climate change. Moreover, this project has the potential to experience losses of 5.3 trillion per year IDR. With this fact, it will be worthy for the government to revisit the policy of coal downstreaming project into DME.

In addition, the increasing target of using DME will also be followed by an increase in coal production both as a raw material for DME and for electricity needs. This also contradicts the government's efforts to reduce domestic coal production. Meanwhile, coal demand for this project potentially comes from coal mines around Tanjung Enim, where this project is being implemented[11]. This will exacerbate the ecological crisis that occurs in Muara Enim District, South Sumatera Province, such as annual flooding, land inequalities, wildlife versus local

[11] There are several Izin Usaha Pertambangan (IUP) dan Perjanjian Karya Pengusahaan Pertambangan Batubara (PKP2B) in Kabupaten Muara Enim. Three of them belong to PT Bukit Asam TBK with a total area of 30.000 hectares.

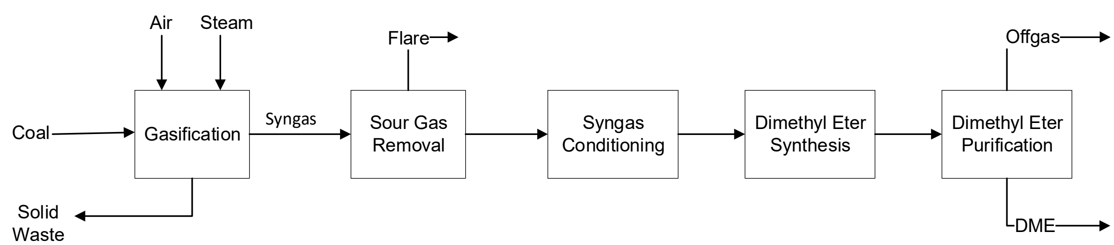
community conflicts. Futhermore, inequality access to land makes residents pushed towards unsafe employment, including unsafe artisanal coal mining in October 2020. (end)

Appendix A: Description of DME Production Process

Based on the press release delivered by PTBA, Pertamina, and Air Products on January 16, 2017, it is known that the coal gasification technology used for the production of dimethyl ether is a direct process. In this process, syngas is directly converted into DME in one reaction stage with syngas first obtained through coal gasification.

The process diagram can be seen with the scheme below.

Figure A.1 Flow Chart for Production DME.



Source: Larson, 2014

The coal gasification process is carried out with air and steam[12]. The reaction mechanism of the gasification process is shown in **Equation 1.**

$$C + H_2O \rightarrow H_2 + CO\ (syngas) \qquad (1)$$

The gasification process produces solid waste in the form of soot, fly ash, and slag, so it must be separated first. Meanwhile, the syngas is cleaned of impurity gases such as CO2, H2S, and other impurity gases. The impurity gas is directed to the flare to be burned and disposed of.

Before the DME synthesis is carried out, the syngas must first be conditioned by making a specification of the appropriate H_2/CO ratio. Then, the syngas is purified from CO_2 impurity by absorption using DEA. Then, the direct DME synthesis process from syngas is carried out in one reactor. The equation for the reaction is shown in **Equation 2** as follows.

$$3H_2 + 3CO \rightarrow DME + CO_2 \qquad (2)$$

The output products of the DME synthesis reactor still contain impurities, such as syngas, H_2, CO, and CO_2 gas, inert compounds (CH_2 and N_2), and H_2O. Therefore, it is necessary to carry out a refining process to obtain DME with a purity by the desired product specifications.

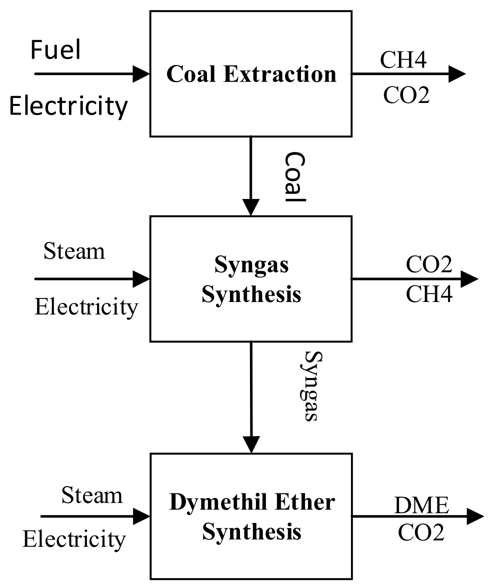
[12] Azizi, Zoha., Tohidian. (2014). Dimethyl ether: A review of technologies and production challenges. *Chemical Engineering and Processing: Process Internsification,* 82, 150-172.

Appendix B: Calculation of Greenhouse Gas Emission in DME Plant

B.1 Scope of Greenhouse Gas Emission Calculation

The scope used to calculate greenhouse gas (GHG) emissions is shown in **Figure B.1** below. This scope considers emissions in raw material extraction and factory processes.

Figure B.1. Scope of the GHG emission calculation on this document



Source: Guideline ADB, 2017 & Agrawal, 2014

greenhouse gas emissions by reviewing per unit in each process, which is the synthesis of syngas and dimethyl ether. From each process, the emission of energy input used is obtained, which is steam and electricity and CO2 from the reaction process. **Table B.1.** summarizes the emission factor of the energy input used.

The energy input in the form of hot steam is based on thermodynamic data from the High Pressure-steam used. Steam conditions are at a temperature of 460 ˚C and a pressure of 60 kg / cm2. So we get a specific enthalpy of 3,325 kJ / kg. It is stated by the GHG Protocol that the CO2 emission factor by steam is 98.40 kg CO_2 / GJ. Therefore the emission factor for tonnes of CO2 / tonne of steam is obtained, according to **Table B.1**

Table B.1 Input emission factor.

Input Energi	**CO2**		**CH4**		**N2O**	
Fuel Oil	3,096	ton/ton	0,00012	ton/ton	0,000024	ton/ton
Natural Gas	2,694	ton/ton	0,000048	ton/ton	0,0000048	ton/ton
Listrik	0,877	ton/MWh				
Steam	0,327	ton/ton				

Source: IPCC 2006, GHG Protocol, dan RUPTL 2019

It should be noted that this emission factor has been converted from tonnes of GHG / TJ and TJ / ton-BB and has been adjusted to the emission factor in Indonesia.

B.2 Calculation of emission in each process

B.2.1. Syngas Synthesis Process

The process of syngas synthesis consists of gasification of coal and cleaning of syngas from impurity gases. From the energy input as follows, it produces GHG emissions in accordance with the IPCC and also takes into account the CO_2 output of the reaction. The calculations are listed in **Table B.2** below

Tabel B.2 . GHG emission calculation for the syngas synthesis process.

Source	Amount		tonnes CO2-e/year
Electricity	$1{,}4\times10^6$	MWh/year	$1{,}2\times10^6$
Steam	$0{,}33\times10^6$	tonnes/year	$0{,}11\times10^6$
CO2 from process	$0{,}77\times10^6$	tonnes/year	$0{,}77\times10^6$
Sub total emission			$2{,}11\times10^6$

Source:AEER calculation using data from IPCC 2006, GHG Protocol, and RUPTL 2019.

B.2.2. DME Synthesis Process

The process of DME synthesis consists of conditioning the syngas feed before entering the system reactor then purifying the DME reaction results to adjust to demand conditions. From the energy input as follows, it produces GHG emissions in accordance with the IPCC and also takes into account the CO_2 output of the reaction. The calculations are listed in Table B.3 below.

Tabel B. 3. GHG emission calculation for DME synthesis process.

Source	Jumlah	tonnes CO2-e/year

Electricity	$0,34\times10^6$	MWh/year	$0,33\times10^6$
Steam	$1,99\times10^6$	ton/year	$0,65\times10^6$
CO2 from process	$0,62\times10^6$	ton/year	$0,62\times10^6$
Sub total emission			$1,57\times10^6$

Source:AEER calculation using data from IPCC 2006, GHG Protocol, and RUPTL 2019.

From the emissions in the coal gasification process to syngas then from syngas to methanol in the coal downstreaming project with a DME target of 1.4 million tons per year with a coal requirement of 6 million tons per year, total carbon emissions per year are 3.68 million tons of CO2 -e / year.

B.2.3. Emission from Coal Extraction

CO2 emissions in DME and LPG production start from mining/exploitation of the raw materials for each product, in this case coal and natural gas. First, calculating the emission from the acquisition of coal. Limits for coal recovery are coal mining, equipment preparation, transportation, chemical production, and other processes. The material and energy flowing in coal extraction and production of other materials as well as process wastes are also calculated. In general, the calculated greenhouse gas emissions are:

- Emission from fuel combustion
- Emission from *torch* combustion
- CH_4 and CO_2 fugitive emission
- CO_2 emission from electricity

CO_2 emissions in DME and LPG production start from mining / exploitation of the raw materials for each product, in this case coal and natural gas. First, calculating the emission from the acquisition of coal. Limits for coal recovery are coal mining, equipment preparation, transportation, chemical production and other processes. The material and energy flowing in coal extraction and production of other materials as well as process wastes are also calculated. In general, the calculated greenhouse gas emissions are:

Table B.4. GHG emission from coal extraction.

No	Source	Emission (tCO2e/year)
1	Fugitive emission	196×10^3
2	Fuel Combustion	132×10^3
3	Blasting	5×10^3

4	Electricity	105×10^3
5	Coal Handling	49×10^3
6	Coal Transportation	98×10^3
Total		585×10^3

Source: Pandey, 2017