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Techno-Economic Analysis of DME Implementation In Indonesia's Household Energy Sector

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ABSTRACT - Indonesia's increasing demand for Liquefied Petroleum Gas (LPG) projected to reach 13.2 million tonnes by 2050 and its heavy dependence on imports, require alternative and sustainable fuel solutions. Among the options under development, researchers and industry stakeholders consider Dimethyl Ether (DME) particularly from abundant domestic low-rank coal a viable and strategic substitute. DME has physicochemical properties similar to LPG, as well as its compatibility with existing storage and distribution infrastructure. This comprehensive study evaluates the techno-economic aspects of replacing LPG with coal-based DME in the household sector. The factors analyzed include energy equity, production and distribution costs, and projected fiscal impacts on the national economy. Assuming a production capacity of 1.4 million tons per year and an Internal Rate of Return (IRR) of 12%, analysts estimate DME's Free-On-Board (FOB) price at IDR 8.03 million per ton, with a benchmark price equivalent to LPG at IDR 16,666/kg. At this rate, replacing imported LPG with domestic DME can save the country's foreign exchange around IDR10.71 trillion per year, but has the potential to increase subsidies by IDR3.97 trillion. The government can use the foreign exchange savings to cover the potential increase in DME subsidies.

Keywords: DME, LPG substitution, techno-economic analysis, energy equity, subsidy savings.

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INTRODUCTION

Since the implementation of the kerosene to LPG conversion policy in 2007, LPG consumption in Indonesia has continued to increase significantly (Yuliarita et al. 2020), driven by economic development and increasing household energy demands. Total LPG requirement is expected to reach around 8.90 million tons, of which approximately 1.96 million tons (22.37%) come from domestic production and around 6.91 million tons (77.63%) are obtained from imports (Republik Indonesia, 2024). The most significant LPG consumption is in the household sector, accounting for 95.90%, followed by the commercial sector at 2.66%, and the industrial sector at 1.45% (Kementerian ESDM Republik Indonesia 2024), making Indonesia highly dependent on imports to cover the shortage. This dependence makes Indonesia vulnerable to fluctuations in global energy prices and burdens foreign exchange reserves and the state budget due to the need for subsidies (Undang-Undang Republik Indonesia Nomor 22 Tahun 2001 Tentang Minyak Dan Gas Bumi 2001; Peraturan Presiden Republik Indonesia Nomor 5 Tahun 2006 Tentang Kebijakan Energi Nasional 2006; Peraturan Presiden Republik Indonesia Nomor 104 Tahun 2007 Tentang Penyediaan, Pendistribusian, dan Penetapan Harga Liquefied Petroleum Gas Tabung 3 Kilogram 2007; Peraturan Menteri Energi dan Sumber Daya Mineral Nomor 26 Tahun 2009 Tentang Penyediaan dan Pendistribusian Liquefied Petroleum Gas 2009; Kementerian ESDM Republik Indonesia 2024).

Figure 1 shows that the demand trend is showing an alarming direction. In 2025, it is expected to rise to 9.5 million tons and reach 13.2 million tons by 2050 (Peraturan Presiden Republik Indonesia Nomor 22 Tahun 2017 Tentang Rencana Umum Energi Nasional 2017). This trajectory demonstrates the urgent need for diversification of energy sources to reduce import dependency and ensure energy equity and security. In response, the Government of Indonesia is actively looking for viable alternatives to LPG, with one of the most promising candidates being Dymethil Ether (DME) (Yuliarita et al. 2020).

DME is a clean-burning gas, non-toxic, and shares many properties with LPG, making it a strong candidate for a substitute. DME can be synthesized from a variety of raw materials, including natural gas, biomass, and coal. In the Indonesian context, coal reserves especially low rank coal are abundant but have not been optimally utilized, so coal-based DME is the most economical and practical solution. The household sector, which accounts for more than 95% of national LPG consumption, offers the highest potential for DME deployment (Rifki et al. 2023). This study examines the technical feasibility, economic viability, and policy implications of integrating coal-based DME as the primary household fuel in Indonesia.

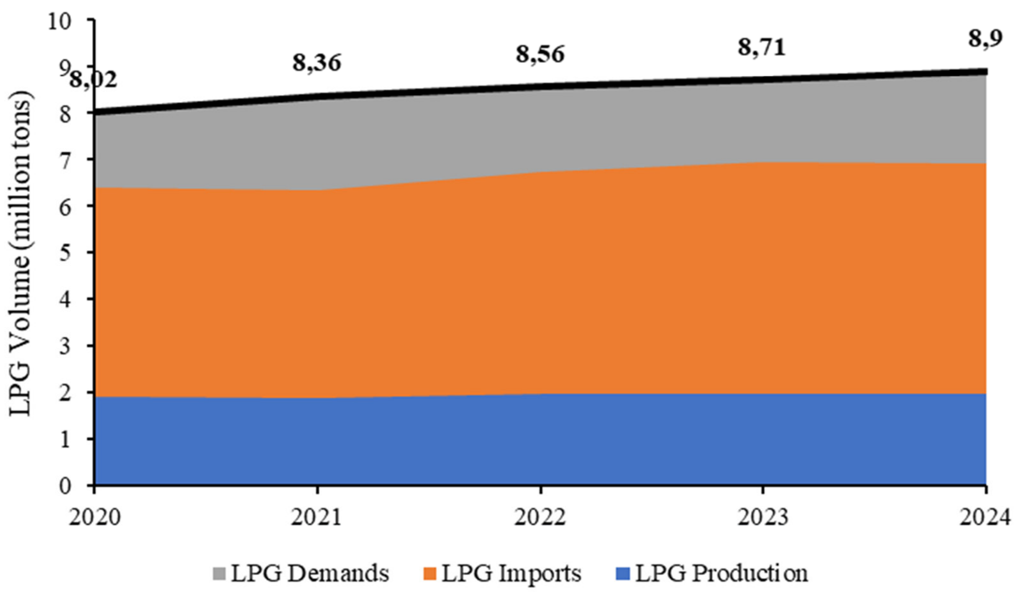

Figure 1. Modeling of LPG Supply Demands in 2015-2050 (Republik Indonesia 2024)

LPG and DME share a wide range of physical and chemical similarities (Anggarani et al. 2017), allowing the use of existing LPG infrastructure for DME distribution and consumption. LPG is a hydrocarbon fuel typically composed of propane (C_3H_8) and butane (C_4H_{10}) (Nofrizal et al. 2013), with a boiling point of -42°C for propane and -0.5°C for butane, a density of 0.49 kg/m³ in liquid form, and a lower calorific value (LHV) of about 46 MJ/kg. DME (CH_3OCH_3), on the other hand, is a colorless and odorless gas under environmental conditions, with a boiling point of -25°C, a density of 0.66 kg/m³, and an LHV of about 29.03 MJ/kg (Fitri Amalia et al. 2025; Murti et al. 2021).

Although the calorific value of DME is lower, its combustion properties provide advantages. DME produces very low NOx and particulate emissions, making it environmentally friendly. DME also has a high cetane number (55–60), which contributes to good combustion performance in household stoves and engines. Its physical characteristics such as pressure and liquefaction behavior are similar enough to LPG that they can be stored and transported in the same tubes and pipes, minimizing infrastructure conversion costs(Murti et al. 2021).

The main challenge is the lower calorific value, so it takes a larger volume to meet the exact energy needs than LPG. This factor is important in distribution logistics planning, pricing schemes, and user acceptance evaluation. Even so, its compatibility with existing household appliances (especially if using flexible stoves) and its clean emissions profile reinforce its position as a sustainable and safe alternative.

METHODOLOGY

The study uses a comprehensive and integrated methodology that combines experimental validation, literature analysis, and economic modeling to ensure precision and practical relevance. The process includes empirical testing using a modified stove (Flexy Gas Stove) in collaboration with PT Pertamina (Persero) and BBPMGB LEMIGAS to compare the combustion efficiency of DME and LPG under identical cooking conditions. The calculation of LPG and DME equivalence was obtained by testing the performance of LPG and DME-fueled household stoves. The test was carried out at the Oil and Gas Testing Center "LEMIGAS", by SNI 8660:2018, regarding "Low-pressure LPG and LNG/NG gas stoves for the household sector". The characteristics of LPG fuel, following the Decree of the Director General of Oil and Gas No.116.K/10/DJM/2020, and DME, following the Decree of the Director General of Oil and Gas No. 990.K/10/DJM.S/2013. To obtain the value of DME energy equivalent to LPG, use the following equation (Pusat Unggulan IPTEK Bahan Bakar Dimetil Eter (DME), 2020):

$$X = Y \times \frac{\eta_{DME} \times H_{DME}}{\eta_{LPG} \times H_{LPG}} \tag{1}$$

X = LPG Volume
Y = DME Volume
η_{DME} = DME Stove Efficiency
H_{DME} = DME Caloric Value
η_{LPG} = LPG Stove Efficiency
H_{LPG} = Caloric Value of LPG

Economic modeling is carried out by compiling the DME production cost structure, which includes capital expenditure (CAPEX), operating costs (OPEX), raw material prices, utility costs, and ancillary income (income from by-products in the form of electricity sales, which affects cash flow and FOB value). Discounted Cash Flow (DCF) and Return Period are used to calculate the optimal FOB price with an IRR of 12%. Distribution cost analysis was carried out by modeling transportation logistics from the production site in Muara Enim to the regional fuel terminal using ship cost data from the Baltic Dry Index and the AFRA class of ships. Infrastructure adaptation costs are also taken into account in the cost analysis. The fiscal impact assessment is carried out by calculating the impact of national-scale substitution, including foreign exchange savings, and reducing the allocation of LPG subsidies from the state budget. Sensitivity analysis was also conducted to test the model's resilience to coal price fluctuations, DME plant efficiency, and external market volatility.

RESULT AND DISCUSSION

Energy equivalence and usage efficiency

Before the performance test on the stove, a characteristic test of the properties of LPG fuel and DME fuel is first carried out to ensure that the fuel used meets the fuel specification as regulated in Indonesia. The test results can be seen in Table 1-4.

Table 1. LPG composition test results

No	Composition	Result LPG % mass	Result LPG %volliq	Method
1	Ethane	0.5869	0.8995	ASTM D2163:2014 (2019)
2	Propane	42.855	46.1435	
3	Propylene	zero	zero	
4	Dimethyl Ether		-	
5	Iso Butane	2.8854	2.7994	
6	N-Butane	53.3115	49.8365	
7	1-Butane	zero	zero	
8	Iso-Butylene	zero	zero	
9	Cis-2-Butane	zero	zero	
10	Trans-2-Butene	zero	zero	
11	Iso Pentane	0.2112	0.1845	
12	1.3 Butadiene	zero	zero	
13	N-Pentane	0.0189	0.0164	
14	Neopentane	0.1311	0.1201	
No	**Parameter**	**Result**		**Method**
1	Gross Heating Value (GHV), kcal/kg	11,935		IPK 2172:2019
2	Net Heating Value (NHV), kcal/kg	10,997		

Table 2. Results of LPG physical & chemical characteristics test

No	Component	Unit	Standard	Result	Method
1	Steam Pressure at 100°F	psig	Max. 145	111.5	ASTM D1267:2018
2	Corrosion of Copper Blades, 100°F	-	Max. No.1	1A	ASTM D1838:2016
3	Total Sulfur Content	Grain/100 feet	Max. 15	0.66	ASTM D6667:2014
4	Free Water Content	-	No free water	No free water	Visual
5	Relative Specific Gravity at 60/60°F		Reported	0.5462	ASTM D1657:2012
6	Residue on Evaporation 100 ml	ml	Max. 0.05	0.1	ASTM D2158:2016
7	Oil Stain Inspection	-	Pass*	Pass	ASTM D2158:2016
8	Ethyl/Butyl Mercaptan	lb/10000 AG	Min. 1.0	0.3	ASTM D5305:2012

Table 3. DME Composition test results

No	Composition	Result DME % mass	Result DME %volliq	Method
1	Ethane	zero	zero	ASTM D2163:2014 (2019)
2	Propane	0.1418	0.1874	
3	Propylene	zero	zero	
4	Dimethyl Ether	99.7419	99.6783	
5	Iso Butane	0.0198	0.0236	
6	N-Butane	0.0964	0.1107	
7	1-Butane	zero	zero	
8	Iso-Butylene	zero	zero	
9	Cis-2-Butane	zero	zero	
10	Trans-2-Butene	zero	zero	
11	Iso Pentane	zero	zero	
12	1.3 Butadiene	zero	zero	
13	N-Pentane	zero	zero	
14	Neopentane	zero	zero	
No	**Parameter**	**Result**		**Method**
1	Gross Heating Value (GHV), kcal/kg	7,582.47		GPA 2172:2019
2	Net Heating Value (NHV), kcal/kg	6,912.83		

Table 4. Results of the Chemical physics characteristics test of DME

No	Component	Unit	Limitation	Result	Method
1	Steam Pressure at 100°F	psig	Max. 145	109	ASTM D1267:2018
2	Corrosion of Copper Blades, 100°F	-	Max. No. 1	1	ASTM D1838:2016
3	Total Sulfur Content	Grain/100 feet	Max. 15	0.6	ASTM D6667:2014
4	Free Water Content	-	No free water	No free water	Visual
5	Relative Specific Gravity at 60/60°F	-	Reported	0.6706	ASTM D1657:2012
6	*Weathering Test* at 36°F	%vol	Min. 95	99.5	ASTM D1837:2011
7	Ethyl/Butyl Mercaptan	ml / 10000 HP	Max. 50	<0.01	ASTM D5305:2012

Table 5. DME and LPG efficiency test results on stoves

Fuel	Hs (MJ / kg)	Starting Weight (kg)	Final Weight (kg)	I (kg)	Early T (Celsius)	Final T (Celsius)	Early T - Final T (Celsius)	Mc (kg)	Efficiency (%)	Time (min)
DME	29.03	8.185	8.090	6.68	20	91.7	71.7	0.095	72.70	21.58
LPG	46.04	21.075	21.005	6.68	20	90.9	70.9	0.070	61.52	19.23

Table 6. Estimated LPG and DME demands in 2025

Province	LPG MT/Year	DME MT/Year
Lampung	250,755 (Tobing, 2024)	333,504
Riau	249,295 (Gunawan, 2025)	331,562
West Sumatra	131,400 (Nasution, 2023)	174,762
South Sumatra	366,370 (Baiduri, 2025)	487,272
Entire	**997,820**	**1,327,100**

Based on the test results in Table 1-4, all parameters of the LPG and DME fuel test results used in this study met the specifications.

Using the test results listed in Table 5 and applying the variables: η DME, η LPG, H DME, and H LPG into Eq.1, the energy equivalent of LPG to DME is as follows:

$$X = Y \times \frac{72.70 \times 29.03}{61.52 \times 46.04} \qquad (2)$$

$$\frac{X}{Y} = 0.75$$

LPG Volume : DME Volume = 1 : 1,33

The DME energy equity ratio is then used as the basis for calculating DME needs based on the ratio to LPG import needs as a substitution object.

LPG and DME demand

Based on the results of energy equity, the DME requirement for LPG import substitution of 6.9 million tons is 6.9 x 1.33 = 9.17 million tons/year. The calculation of LPG substitution to DME was carried out for the Sumatra region, as listed in Table 6. Based on data from the Ministry of Energy and Mineral Resources, the DME refinery to be built in Muara Enim has a capacity of 1.4 million tons/year. To absorb this production, the following markets are needed.

DME distribution pattern of muara enim plant

The distribution of DME produced by the Muara Enim DME Plant is designed to meet the demand for DME as a substitute for LPG in the regions of Lampung, Riau, West Sumatra, and South Sumatra. The distribution mechanism is carried out through a combination of land and sea transportation modes, supported by intermediate distribution terminals (hubs) strategically located in each of these regions, as illustrated in Figures 2 and 3. Land distribution is conducted using specialized tank truck fleets from the plant to fuel terminals within South Sumatra. In contrast, inter-provincial distribution is handled via tanker ships integrated with existing LPG fuel terminals, with necessary adjustments for DME handling.

Production and distribution cost

CAPEX

The calculation of the investment value of the DME refinery with coal raw materials requires an investment value of USD1,508 million for the capacity of the DME refinery of 3,520 tons/day (Yan et al. 2017). With the scaling factor of 0.6 and the price escalation, to determine the current investment value, a price correction in 2017 was made using the Chemical Engineering Plant Cost Index (CEPCI) in May 2025, so that the current investment value was obtained as shown in Table 7 (Jenkins 2025; Maxwell 2025).

Table 7. The Value of DME investment based on refinery Capacity

Factory capacity	Year	Index	Investment Value
3,520(Yan et al. 2017)	2017	585.7 (Maxwell 2025)	1,508 million(Yan et al. 2017)
4,200	2025	791.9 (Jenkins 2025)	2,300 million

Depreciation

The depreciation used in the calculation of the economics of the DME refinery is a straight line, where the life of the DME refinery project is 20 years, with the value of the asset at the end of the 20th year being zero, so that the depreciation value is obtained as follows (Aulia 2015).

$$Depreciation = \frac{Capex}{Year\ of\ Operation}$$

$$Depreciation = \frac{2{,}300\ million\ USD}{20\ year} = 115\ million\ USD/year \qquad (2)$$

As for Insurance costs in this study, it is assumed to be 0.8% of the *capital expenditure* (CAPEX) (Aulia 2015).

Figure 2. DME Distribution Pattern of Muara Enim Plant (Pertamina 2022; Kementerian Energi dan Sumber Daya Mineral Republik Indonesia 2021)

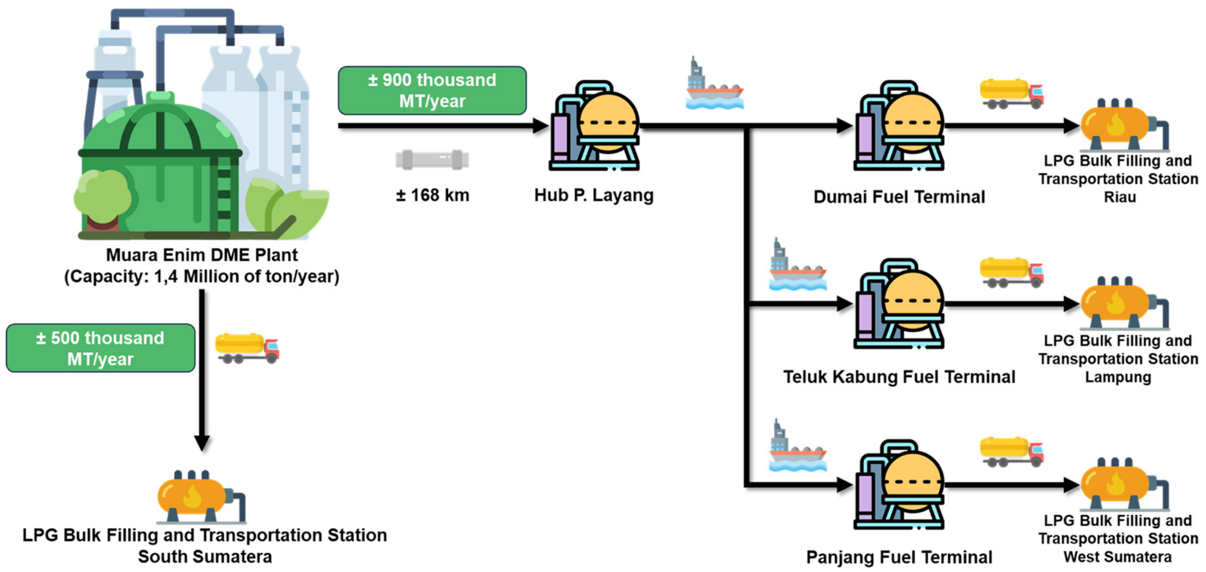

Figure 3. Distribution Mechanism of Muara Enim DME plant (Pertamina 2022; Kementerian Energi dan Sumber Daya Mineral Republik Indonesia 2021)

Cost of operating

Raw material efficiency is used to calculate the amount of coal required to produce a certain amount of DME. This efficiency value depends on the thermal efficiency of a process, commonly referred to as cold gas efficiency. According to the Central Coal Utilization (CCUJ) and the Japan Institute of Energy (JIE), the efficiency of DME production through coal gasification is around 60% or 46 MMBTU per ton of DME (Muliahati et al. 2018). This efficiency is used to calculate the electricity production generated during the gasification process. Then, the value of raw materials, namely the price of coal, refers to the Reference Coal Price (HBA) issued by the Ministry of Energy and Mineral Resources in May 2025, which is USD 35.42/ton. Based on data from the Ministry of Energy and Mineral Resources, 1 ton of Tanjung Enim coal is equivalent to 22,855,690 BTU, so the price value of coal raw materials is 1.55 USD/MMBTU(Kementerian ESDM Republik Indonesia 2024; Muliahati et al. 2018; Keputusan Menteri Energi dan Sumber Daya Mineral Nomor 175 Tahun 2025 2025).

Cost of utility

The utility cost of DME refinery production is one of the factors that can affect the FOB DME price. According to CCUJ data from 2003, the utility cost of DME refinery production from coal was USD 5.3/ton DME (Muliahati et al., 2018). Changes in the value of the equipment cost, labor, materials, construction, macroeconomic, and global market conditions can occur from 2003 to 2025. Due to this price correction, based on the CEPCI index from 2003 to 2025, the utility cost is USD 10.44/ton DME.

Cost of electricity

In the production process of DME from coal, electricity is obtained due to the gas efficiency of the coal gasification process as a by-product of the production process that can be sold to the area around the Muara Enim DME refinery. The efficiency value of the turbine thermal gas is assumed to be 49% with a heat rate value of 6,960 BTU/kWh (Winters 2023) and a capacity factor of 64%. Using Eq.3 of the formula below (Yan et al. 2017; Gas Turbine World 2024; Clarion Energy Content Directors 2023).

$$kWh = \frac{Mf \times LHV \times \eta}{HR} \times Cf \quad (3)$$

Where:

kWh = the number of kWh produced by the generator

Mf = fuel during testing (tons)

LHV = Fuel Bottom Calorific Value (kcal/kg)

HR = *Heat level* (BTU/kWh)

η = thermal efficiency in %

Cf = Capacity factor in %

Power obtained from the DME refinery

KWh=829 kWh/tDME

process is 829 kWh/ton DME; in this study, it is assumed that all the electricity produced can be sold around the location of the DME Muara Enim refinery with a purchase price from PLN according to the report, which is equal to 0.05 USD/kWh (Yustika, 2024).

From the results of the cash flow calculation based on Table 8, the FOB price was USD487/ton (IDR 8.03 million/ton).

Cost of Palembang pipeline and hub

DME distribution is strategically implemented through a pipeline network that transports the product from the refinery located in Muara Enim to a key distribution hub situated in Palembang, specifically at the Hub P. Layang facility. The total distance covered by this pipeline spans approximately 168 kilometers, traversing varying terrains and requiring robust infrastructure to ensure safe and efficient delivery. According to a detailed feasibility study conducted by PT Pertamina, the capital investment required for the construction and commissioning of the 168 km pipeline infrastructure is calculated to result in a fixed cost of approximately USD 27 per metric ton of DME transported (Pertamina 2022). In addition to the capital expenditure, the ongoing operational expenditure at the Palembang hub itself is estimated at USD 24 per ton. These operational costs encompass a range of essential activities, including the routine operation and maintenance (O&M) of the pipeline system, supervision and control mechanisms, safety management, and the comprehensive operation of the terminal and storage facilities within the hub. This cost structure reflects not only the physical transportation of DME but also the supporting infrastructure required to maintain supply chain reliability, ensure compliance with safety and environmental standards, and meet regional energy demands efficiently (Pertamina 2022).

Table 8. Estimated DME production cost conditions

No	Condition	Description	Unit	Value
1	Economic Analysis	Discounted Cash Flow		
2	Estimated Production Cost	IRR	%	12
3	DME Caloric Value		kcal/kg LHV	6,900(Murti et al. 2021)
4	Location	Muara Enim		
5	Exchange rate	Evaluated with USD	IDR	16,488
6	Project Age		Year	20
7	Load Factor (Djuningsih, 2016)	Year 1	%	50
		Year 2	%	60
		Year 3	%	70
		Year 4	%	85
		Year 5	%	100
8	Construction Period (Djuningsih, 2016)	Year 1	%	25
		Year 2	%	40
		Year 3	%	35
9	Operating Time		Daily/Year	333
10	Raw Materials			Coal
11	Raw Material Price		USD / Ton	35.42 (Keputusan Menteri Energi Dan Sumber Daya Mineral Nomor 175 Tahun 2025, 2025)
12	Non-Raw Material Opex		% Capex / Year	6
13	Escalation		% / Year	5
14	Electricity Generated		kWh/DME	480
15	Electricity Prices		USD/kWh	0.05(Yustika, 2024)
16	Production Capacity		Tons/Day	4,200
17	Depreciation	Firm Lines	USD Miles/Year	115
18	Insurance		% Book Value Capex/Year	0.8(Djuningsih 2016)

Cost of ship transportation

Based on Figure 4, ships with a DWT below 25 can be categorized as GP (General Purpose) with a maximum carrying capacity of 22.5 WT. To distribute DME from the refinery to the fuel terminal, the use of small vessels is assumed to be adequate. Based on a study by Muliahati A., the cost of renting a small vessel type is USD6,100/day. To estimate the cost of chartering a ship in 2025 based on 2017 rates, the Baltic Dry Index (BDI) change can be used as an indicator, as shown in Table 9. To calculate the rental rate using equation 4 and to calculate the transportation cost using equation5 (Muliahati 2018).

$$\text{Rental rate} = \frac{\text{Ship price} \times \text{Storage capacity}}{\text{Ship storage}} \tag{4}$$

$$\text{Transportation cost} = \frac{\text{Charter rate}}{\text{Daily DME production}} \tag{5}$$

Table 9. Cost of renting a boat using the baltic dry index

Price (USD/day)	Year	Baltic Dry Index
6,100 (Muliahati et al. 2018)	2017	959.0 (Fusion Media Limited 2025)
8,538	2025	1342.3 (Fusion Media Limited 2025)

Table 10. Calculation of transportation costs from the DME Muara Enim refinery to the dumai fuel terminal location

No	Description	Unit		Value
1	Ship Speed	nm/congestion	a	11 (Muliahati et al. 2018)
2	Distance	Nm	b	435 (Marine Traffic 2025)
3	Trip	day	$c = \frac{\left(\frac{b}{a}\right)}{24}$	1.65
4	Docking-Stopping(Muliahati et al. 2018)			
	Sleigh	Hours	d	3
	Connecting Hosts	Hours	e	0.5
	Cargo Calculation	Hours	f	2
	Cargo Pumping	Hours	g	6.72
	Disconnecting the Host	Hours	h	0.5
	Cargo & Ship Documentation	Hours	i	2
	ATD (Actual Time Departures)	Hours	j	0.5
5	The Time of the Dead - Untitled	Hours	$k = \frac{\text{sum}(d{:}j)}{24}$	1
6	**RTD (Day Trip)**	**Day**	**l=(c×2)+k**	**5**
7	Storage Capacity	MT	m	6,000
8	Rental Rate (USD/day)	USD/day	n	20,491
9	**Transportation Cost (USD/Ton)**	**USD/ton**	**o**	**22.56**

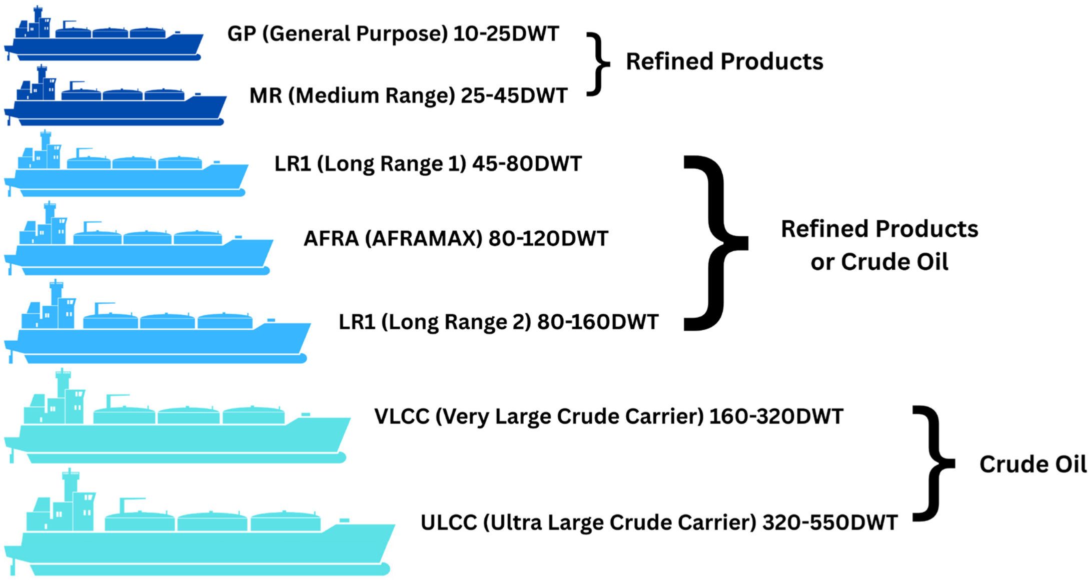

Figure 4. AFRA (Average Freight Rate Assessment) scale for ship classification based on carrying capacity (Hamilton 2014)

Table 11. Calculation of transportation costs from the DME muara enim refinery to the location of the teluk kabung fuel terminal

No	Description	Unit		Value
1	Ship Speed	nm/congestion	a	11(Muliahati et al. 2018)
2	Distance	Nm	b	435(Marine Traffic 2025)
3	Trip	day	$c = \frac{\left(\frac{b}{a}\right)}{24}$	1.65
4	Docking-Stopping(Muliahati et al., 2018)			
	Sleigh	Hours	d	3
	Connecting Hosts	Hours	e	0.5
	Cargo Calculation	Hours	f	2
	Cargo Pumping	Hours	g	6.72
	Disconnecting the Host	Hours	h	0.5
	Cargo & Ship Documentation	Hours	i	2
	ATD (Actual Time Departures)	Hours	j	0.5
5	The Time of the Dead - Untitled	Hours	$k=\frac{\text{sum(d:j)}}{24}$	1
6	**RTD (Day Trip)**	**Day**	**l=(c×2)+k**	**5**
7	Storage Capacity	MT	m	6,000
8	Rental Rate (USD/day)	USD/day	n	20,491
9	**Transportation Cost (USD/Ton)**	**USD/ton**	**o**	**22.56**

Table 12. Calculation of transportation costs from the DME Muara Enim refinery to the location of the panjang fuel terminal

No	Description	Unit		Value
1	Ship Speed	mm/Congestion	a	11(Muliahati et al. 2018)
2	Distance	Nm	b	367(Marine Traffic 2025)
3	Trip	Day	$c = \frac{\left(\frac{b}{a}\right)}{24}$	1.39
4	Docking-Stopping(Muliahati et al., 2018)			
	Sleigh	Hours	d	3
	Connecting Hosts	Hours	e	0.5
	Cargo Calculation	Hours	f	2
	Cargo Pumping	Hours	g	5.33
	Disconnecting the Host	Hours	h	0.5
	Cargo & Ship Documentation	Hours	i	2
	ATD (Actual Time Departures)	Hours	j	0.5
5	The Time of the Dead - Untitled	Hours	$k=\frac{\text{sum(d:j)}}{24}$	1
6	**RTD (Day Trip)**	**Day**	**l=(c×2)+k**	**4**
7	Storage Capacity	MT	m	5,000
8	Rental Rate (USD/day)	USD/day	n	17,076
9	**Transportation Cost (USD/Ton)**	**USD/ton**	**o**	**18.69**

Cost of operating fuel terminal and margins

Operating cost and margin components are taken into account in determining the DME benchmark price. Operational costs include fuel terminal operation, LPG bulk filling and transportation station transport fee and filling fee, tube maintenance, and agent transport fee. Meanwhile, the margin of business entities follows the provisions of PT Pertamina. Based on data from PT Pertamina's study, the operational cost of the DME Muara Enim refinery is USD177/ton, while the margin is set at USD24/ton (Pertamina 2022).

Foreign exchange and national budget savings

The calculation of foreign exchange savings is carried out by referring to the 3kg LPG HIP at CP Aramco in the last 5 years for 595,52 USD/MT. As stated above, if the equivalent of LPG with DME based on the calorific value and efficiency of the stove is 1:1.33. The total volume of DME that will be produced to replace LPG is 1.4 million tons/year, so the volume of LPG that DME will replace is 1.05 million tons/year. Therefore, foreign exchange savings are obtained as follows the equation 6:

$$\text{Foreign exchange saving} = 1.05\ million\ MT \times (100\% \times USD595{,}52/MT + USD21.34/MT) \quad (6)$$

Foreign exchange saving

= Rp10.71 trillion per year

exchange rate = Rp16,488

The potential savings in national energy subsidies can be more accurately quantified once the specific amount of subsidy required for DME, as a substitute fuel for LPG, has been calculated. This calculation becomes especially relevant in the context of policy planning and fiscal budgeting for energy diversification. To establish a meaningful comparison, an analogous approach to the existing 3 kg LPG subsidy calculation is employed. Under this methodology, the DME subsidy when positioned as an equivalent to subsidized LPG is defined as the difference between the Benchmark Price of DME (expressed in USD per metric ton) that yields an energy output equivalent to LPG, and the Retail Selling Price of 3 kg LPG currently in effect for Indonesian consumers (Pertamina, 2022). This definition assumes that the end-user energy utility provided by both fuels is relatively equal, ensuring an apples-to-apples economic comparison. As illustrated in Figure 5, the Benchmark Price for DME that is deemed equivalent to LPG is established at USD 760 per metric ton. This benchmark serves as a critical reference point for further fiscal analysis and policy discussions regarding the replacement of LPG with domestically produced DME and the resulting implications for long-term energy subsidy reform.

Based on the calculation results presented in Table 13, the potential additional subsidy that could be achieved by replacing conventional LPG with DME for an annual distribution volume of approximately 1.4 million tons is estimated at around IDR3.97 trillion per year. This significant figure reflects the economic benefits of shifting to DME as a cleaner, locally produced alternative energy source, which reduces the government's financial burden associated with subsidizing imported LPG. The calculation takes into account various cost components, including production, distribution, and infrastructure investments, as well as comparative subsidy levels between DME and LPG. A comprehensive breakdown and detailed summary of these cost elements including per-ton subsidy differentials, transport logistics, and operational efficiencies can be found in Table 13, which serves as a key reference point for evaluating the long-term fiscal impact of DME adoption within Indonesia's national energy strategy. The calculation of the value components in Table 13 is as follows:

$$g=\left(\left((b+c)\%\times a\right)+d+e\right)\times \text{exchange rate} \quad (7)$$

$$h=\left(\text{retail selling price with income tax}\times\frac{1}{(1+\text{income tax})}\right)-\text{agent margin} \quad (8)$$

$$i=g-h \quad (9)$$

$$k=i\times j\times 10^{9} \quad (10)$$

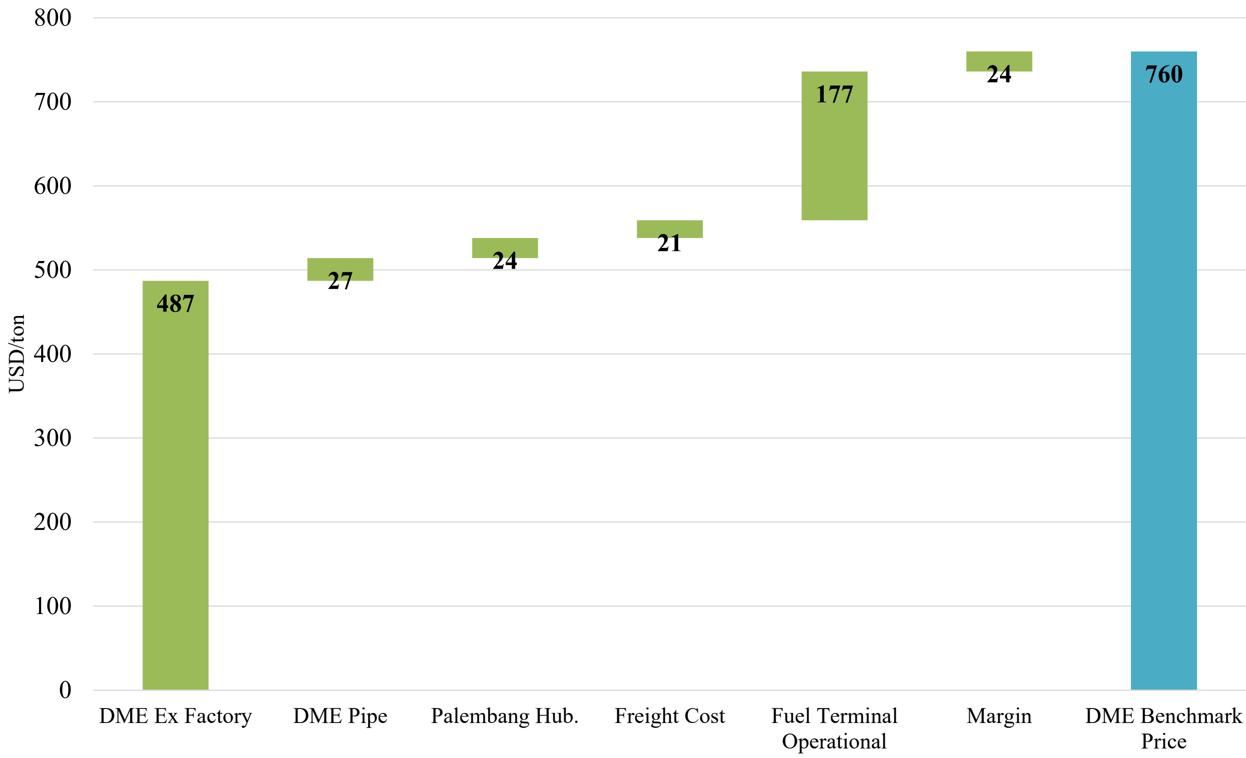

Figure 5. Calculation of DME benchmark price

$$s=sum(l:s)\times Exchange\ rate \quad (11)$$

$$t=\frac{1}{Energy\ equity}\times h \quad (12)$$

$$u=s-t \quad (13)$$

$$v=i-(s\times Energy\ equity)-h \quad (14)$$

$$x=w\times u\times 10^9 \quad (15)$$

$$y=k-x \quad (16)$$

Table 13. Cost components of DME subsidy potential savings for LPG

No	Component	Calculation Component	Value	Unit	No	Component	Calculation Component	Value	Unit
1	HIP LPG	a	595,52	USD/ ton	1	DME Ex-Factory	l	487	USD/ ton
2	Fees				2	Fees			
	a. Procurement	b	100	%		a. Procurement Costs	m	100	%
	b. Import Duties	c	3.85	%		b. Distribution Costs			
	c. Alpha Procurement	d	21.34	USD/ ton		DME Pipe	n	27	USD/ ton
	d. Domestic Freight Forwarding	e	28.77	USD/ ton		Hub Palembang	o	24	USD/ ton
	e. Distribution and Margin Costs	f	1,879	IDR/ kg		Freight Costs	p	21	USD/ ton
						c. Operation	q	177	USD/ ton
						d. Margin Pertamina	r	24	USD/ ton
3	LPG Benchmark Price	g	12,902	IDR/kg	3	DME Benchmark Price	s	12,531	IDR/ kg
4	Retail Selling Price of LPG 3kg	h	3,429	IDR/kg	4	Retail Selling Price of DME 3kg	t	2,578	IDR/ kg
5	Subsidies	i	9,473	IDR/kg	5	Subsidies	u	9,953	IDR/ kg
						Subsidy Addition	v	-3,765	IDR/ Equiv.Kg LPG
6	LPG Volume	j	1,052,632	Ton	6	DME Volume	w	1,400,000	Tone
7	Subsidies LPG 3kg	k	9.97	Trilli-on	7	DME subsidy	x	13.93	Trilli-on
					8	**Total Subsidy Addition**	y	**3.97**	**Trilli-on**
9	**Foreign Exchange Savings**		**10.71**	**Trill-ion**					

Table 14. Sensitivity of subsidy changes in DME prices

HIP LPG CP Aramco (USD/ton)	Ex-DME Plant (USD/ton)							
	300	**350**	**400**	**450**	**487**	**500**	**550**	**600**
300	-4,97	-6,13	-7,28	-8,43	-9,29	-9,59	-10,74	-11,9
400	-3,17	-4,32	-5,48	-6,63	-7,49	-7,79	-8,94	-10,09
450	-2,27	-3,42	-4,58	-5,73	-6,59	-6,89	-8,04	-9,19
500	-1,37	-2,52	-3,68	-4,83	-5,68	-5,98	-7,14	-8,29
528	-0,86	-2,02	-3,17	-4,33	-5,18	-5,48	-6,63	-7,79
595	0,34	-0,81	-1,96	-3,12	**-3,97**	-4,27	-5,43	-6,58
600	0,44	-0,72	-1,87	-3,03	-3,88	-4,18	-5,34	-6,49
650	1,34	0,18	-0,97	-2,13	-2,98	-3,28	-4,43	-5,59
700	2,24	1,08	-0,07	-1,23	-2,08	-2,38	-3,53	-4,69
750	3,14	1,98	0,83	-0,32	-1,18	-1,48	-2,63	-3,79
800	4,04	2,89	1,73	0,58	-0,28	-0,58	-1,73	-2,89
900	5,84	4,69	3,53	2,38	1,53	1,23	0,07	-1,08
1000	7,64	6,49	5,34	4,18	3,33	3,03	1,87	0,72

Based on the data displayed in Table 14, the higher the selling price of DME (the further to the right on the table), the higher the potential for additional savings. On the other hand, the higher the selling price of LPG (the lower it is in the table), the greater the potential for subsidy savings. In this study, CP Aramco's HIP value is USD595.52/ton based on the average price over the last 5 years, so that the LPG subsidy needs are IDR 9.97 trillion per year for an LPG volume of 1.05 million tons. In contrast, the DME Ex-Factory value is USD487/ton per year, so the DME subsidy needs are IDR 13.93 trillion for a DME volume of 1.4 million tons. Thus, the construction of the DME Muara Enim refinery has the potential for additional subsidies of IDR 3.97 trillion per year. However, the transition from LPG to DME can save foreign exchange of IDR10.71 trillion per year. The government can use foreign exchange savings to cover the potential increase in DME subsidies.

Sensitivity analysis of LPG vs DME subsidies

This sensitivity analysis aims to assess the impact of changes in key parameters on total subsidies and potential savings or increases. For LPG, sensitive parameters include LPG HIP, distribution costs and margins, and volume. For DME, the key parameters are ex-factory price, distribution costs (including pipelines), and volume. Figure 6 shows the impact of changes in four key variables LPG HIP, DME distribution costs, DME ex-factory price, rupiah exchange rate, and energy equivalent on subsidy savings (percentage of baseline) under scenarios ranging from 0% to 50%. The results indicate that an increase in LPG HIP has a positive impact, with subsidy savings increasing by up to +9% under the 50% increase scenario. This reflects that the higher the international LPG price, the more fiscally beneficial the substitution to DME is. Conversely, DME distribution costs exhibit a negative linear correlation, with savings decreasing by -6% under the 50% scenario. This means that the higher the logistics costs, the greater the subsidy burden.

The DME ex-factory price is the most sensitive factor to reduced savings. An increase of up to 50% can reduce savings by as much as -8.5%, emphasizing the importance of production efficiency. The weakening rupiah also reduces subsidy savings, although the impact is more moderate (-6.1%), as most DME costs are denominated in US dollars.

The energy equivalency adjustment between LPG and DME consistently increases the need for subsidies, as DME requires a larger volume to produce the equivalent energy of LPG. Overall, the LPG HIP and the ex-factory DME price are the most influential variables affecting subsidy changes in the state budget.

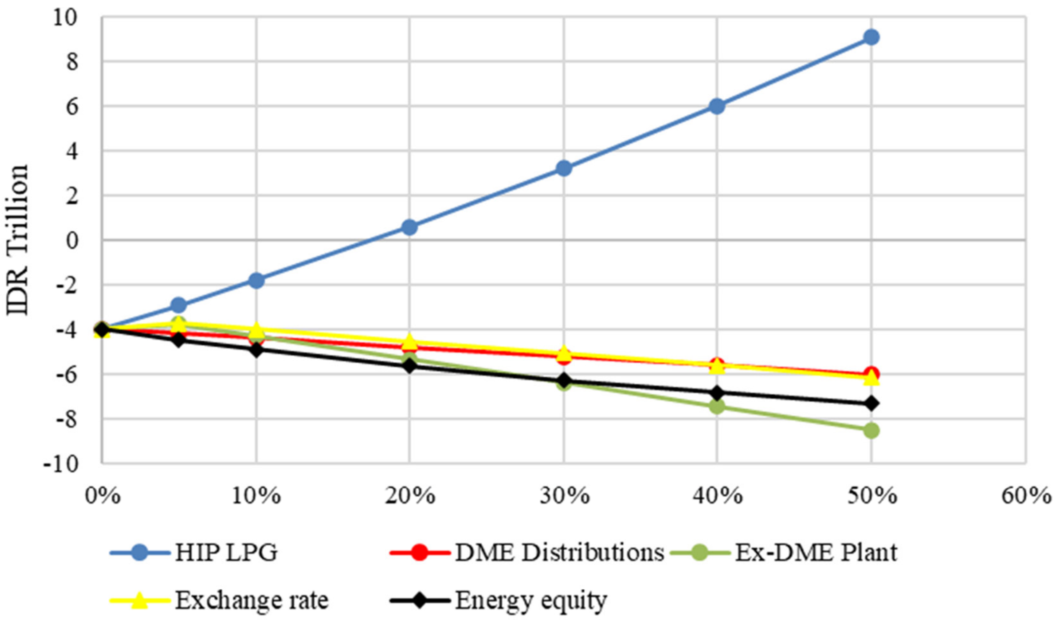

Figure 6. Sensitivity analysis graph against subsidy savings

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Based on the findings of this study, the energy equivalence ratio between DME and LPG is 1:1.33, derived from fuel efficiency tests using household stoves, where DME achieved an efficiency of 72.70% and LPG 61.52%.

Through the cost analysis, including FOB DME, transportation (DME pipelines, Palembang hub, freight), operational costs, and PT Pertamina (Persero)'s margin, the benchmark price for DME equivalent to LPG is estimated at IDR16,666/kg, using an exchange rate of IDR16,488/USD.

Replacing LPG with DME at a volume of 1.4 million tons per year could result in foreign exchange savings of approximately IDR10.71 trillion annually, based on the average price of 3 kg LPG over the last 5 years, as per CP Aramco. The additional potential subsidy from this substitution is IDR3.97 trillion per year. However, sensitivity analysis indicates that if the LPG HIP based on CP Aramco falls to ≥900 USD/ton, there is a potential subsidy savings of ≥1.53 USD/ton. The transition from LPG to DME can save foreign exchange of IDR10.71 trillion per year. The government can use foreign exchange savings to cover the potential increase in DME subsidies.

A sensitivity analysis shows that market conditions can influence this equilibrium. For example, if global LPG prices (HIP CP Aramco) increase, DME substitution becomes more economical. Conversely, if DME ex-factory prices increase or the rupiah depreciates, the subsidy burden will increase.

Based on the findings of this study, several recommendations are proposed to support the successful implementation of DME as an alternative to LPG. First, it is recommended that further in-depth studies be conducted, with a focus on detailed design, construction, and carbon tax assessments, especially in anticipation of future regulatory frameworks. Second, the application of DME as a substitute for LPG requires active government intervention, particularly in regulating the price of raw materials used in DME production, to ensure that DME remains economically competitive with the LPG currently used by households. Lastly, the government needs to establish appropriate policies and subsidy mechanisms for DME to promote its adoption and ensure affordability for consumers, aligning with national energy transition goals.

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GLOSSARY OF TERMS

Symbol	Definition	Unit
LPG	Liquefied Petroleum Gas	
DME	Dymethyl Ether	
IRR	Internal Rate Of Return	
FOB	Free-On-Board	
IDR	Indonesian Rupiah	
kg	Kilogram	
°C	Degree Celcius	
m^3	Cubic Meter	
MJ	Mega Joule	
LHV	Lower Heating Value	
SNI	Standar Nasional Indonesia (Indonesian National Standards)	
CAPEX	Capital Expenditure	
OPEX	Operating Expenditure	
DCF	Discounted Cash Flow	
°F	Degree Fahrenheit	
ASTM	American Standard Testing and Material	
ml	Milliliters	
lb	Pound	
AG	Air-Gallon	
HP	Hundred Pound	
η	Efficiency	
Hs	Calorific Value	
USD	United States Dollar	
CEPCI	Chemical Engineering Plant Cost Index	
BTU	British Thermal Unit	
kWh	Kilowatt Hour	
kcal	Kilocalories,	
kcal	Kilocalories,	
AFRA	Average Freight Rate Assessment	
DWT	Deadweight Tonnage	
Nm	Nautical Mile	
MT	Metric Tons	
HIP	Harga Indeks Pasar (Market Index Price)	

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