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Techno-Economic and Risk Assessment of Small-Scale LNG Distribution for Replacing Diesel Fuel in Nusa Tenggara Region

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ABSTRACT

The conversion of existing diesel-fuel power plants in remote areas of Indonesia to gas is a practical solution for the reduction of carbon emissions. However, the transportation of natural gas from its sources to plant gates across the vast and dispersed islands of the Indonesian archipelago using small-scale Liquefied Natural Gas (LNG) poses challenges in terms of economics and investment risks. Therefore, this study aims to analyze the techno-economic risks of converting diesel power plants spread across the Nusa Tenggara region to gas with acceptable prices. The real options method is applied to perform the economic evaluation based on a proposed cost-effective LNG distribution scheme. The gas demand from eight power plants with a total capacity of 347 MW across the region is 9,176 BBTU annually. The profitability analysis is carried out using Net Present Value (NPV), Internal Rate of Return (IRR), Payback Period (PBP), and Profitability Index (PI) values showing USD 56,876,674, 15.3%, 7.25 years, and 1.48, respectively. The risk analysis using the real options method suggests that the investment risk is lower if the program starts in the 1st year with 20 years of operation. The use of gas lowers the cost of generation per kilowatt-hour and reduces carbon emissions compared to diesel-fueled power plants.

Keywords: Binomial Lattice, Monte Carlo Simulation, Diesel to Gas Conversion, Small Scale LNG, Nusa Tenggara Region
JEL Classifications: G11, G12, D84

1. INTRODUCTION

Energy is an essential requirement for every country worldwide, and the most widely used sources are fossil fuels such as oil, gas, and coal. As of 2020, fossil fuel-based energy sources constituted over 80% of the global energy mix (International Energy Agency, 2021). Among the various products derived from fossil energy, diesel fuel is commonly used for various purposes such as powering vehicles and diesel-based electricity generation. In 2019, world diesel consumption reached 28 thousand barrels per day (Mordor Intelligence, 2021). Although diesel power plants are typically used in areas with low electricity demand averaging about 100 Mega Watts (MW). However, the diesel power plant has a fairly expensive operating price, which is represented by the expensive price of diesel fuel. In addition, the use of diesel fuel has a negative impact on the environment since it belongs to a class of fossil fuels, and its combustion process produces greenhouse gases (GHG) such as CO_2, CH_4, and N_2O. The accumulation of GHG in the atmosphere causes global warming and is a major factor in climate change. To prevent the adverse effects of climate change, all countries in the world reached a landmark agreement to combat GHG emissions and intensify the actions and investments needed for a sustainable low carbon future (Mcfarlan, 2018).

Indonesia, one of the world's largest archipelagic countries in the world, is one of the largest users of diesel power plants. In 2020, there were 5,400 diesel power plant units with a total electrical capacity of 3.043 Gigawatt hours (GWh) (PLN, 2021). The government has launched an initiative to reduce power plants to diesel through the implementation of de-dieselization, which will convert about 5,200 power plant units with a total capacity of 2.37 GW to diesel. The target of the initiative is centered on the development of three conversion strategic plans, one of the schemes is the conversion of diesel fuel to natural gas fuel with a total electricity capacity target of 1198 MW (Indonesia Ministry of Energy and Mineral Resources, 2022).

The use of natural gas fuel has many advantages over diesel fuel. In terms of emissions, natural gas fuel produces fewer emissions than diesel fuel (Kabeyi and Olanrewaju, 2022). Natural gas fuel produces less than 44.4% of diesel fuel emissions. In addition, converting diesel fuel from diesel to natural gas can reduce generator operating costs. A comparison of fuel costs between single fuel and diesel fuel with dual fuel with an LNG composition of 65% shows that dual fuel can save operational costs by 19%. (Santoso, 2014).

In Indonesia, natural gas is one of the most widely used primary energies after oil and coal. As a gas-producing country, Indonesia successfully produced 5282 BBTUD (Billion British Thermal Units Per Day) of gas products in various forms in 2021. Meanwhile, Liquefied Natural Gas (LNG) is a form of natural gas that has been liquefied through a cooling and expansion process to a temperature of about −162□. This process of liquefied natural gas into LNG is carried out to effectively reduce gas volume by up to 600 times in a way that gas can be stored and transported more economically (Rao et al., 2020). This method can be used for gas distribution processes to remote locations. For the distribution of LNG to remote areas, a small-scale LNG distribution method is usually applied, which involves the delivery mode through ships and storage tanks (International Gas Union, 2014).

The receiving terminal plays a crucial role in the LNG supply chain by acting as an important component between gas producers and consumers. This terminal receives LNG from ships, which will then be stored in a storage tank. The next step involves the vaporization of the LNG, after which the natural gas is distributed through distribution pipelines (Tarlowski and Sheffield, 2012). The terminal is designed to deliver gas at a certain speed and maintain LNG reserve capacity. To achieve this, the receiving terminal facilities will consist of LNG unloading systems, storage tanks, vaporizers, pumps, vapor handling systems, supporting utilities, and supporting infrastructure.

Due to the geographical and topographical challenges of the vast and scattered Indonesian archipelago, the use of LNG technology is necessary for the transportation of natural gas from its sources to the end users. This transportation system is comprised of numerous closed clusters, known as the small-scale LNG supply and distribution value chain (Budiyanto et al., 2020). To determine the feasibility of implementing the value chain, Otis important to consider both economic and risk perspectives (The Japan Research Institute, Limited, 2014). A study related to small-scale LNG techno-economic analysis for diesel conversion in remote areas of Northern Canada showed the potential for dedieselization movement, which is very feasible from a techno-economic aspect. The use of small-scale LNG systems with 5 types of clusters has been found to result in a reduction of investment costs of about 75%, while also reducing carbon costs by \$336–788/ton CO_2 (Mcfarlan, 2020). However, it should be noted that the risk aspect of small-scale LNG was excluded from the study.

This study further extended the techno-economic analysis and risk assessment of small-scale LNG networks for the conversion of diesel engines to natural gas. The results are intended to be of interest to policymakers, government agencies, project developers, and investors to help in decisions making.

2. METHODS

2.1. Small-Scale LNG Network

The Small-scale LNG distribution system mentioned is a network connecting the Bontang LNG Plant operated by PT Badak in East Kalimantan, Indonesia with the targeted power plants scattered in the Nusa Tenggara region covering West and East Nusa Tenggara provinces, Indonesia as shown in Figure 1 and Table 1. The natural gas processed at the Badak LNG Plant is produced from surrounding oil and gas blocks in the Mahakam Delta and the Makassar strait, which is managed by various operators. The estimated total gas reserves are capable to supply both the Bontang gas pipeline and LNG needs (Lemigas, 2018).

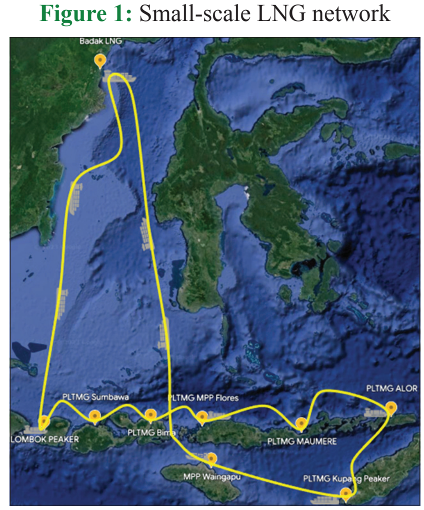
Since the Nusa Tenggara region is an archipelago area, the LNG distribution using small-scale LNG carriers becomes attractive. In this region, there are eight power plants with a capacity of 347 MW, which run on natural gas (Decree of the Minister of Energy and Mineral Resources No. 2.k/TL.01/MEM.L/2022). The average gas demand is expected to be about 9,151 BBTU per year. The capacity and estimated gas demand for these power plants are listed in Table 2.

By determining the quantity of natural gas at the site, the minimum volume of LNG vessels and the total storage tank capacity required can be ascertained (Turton et al., 2018).

2.2. Economic Evaluation

The economic evaluation consists of calculating the cash flows of the project, including capital and operational expenditures, total revenue, and economic feasibility calculation.

Figure 1: Small-scale LNG network



2.2.1. Expenditure and revenue calculation

The total capital expenditure comprises the total direct and indirect cost (TDIC), cost of contingency (C_{Con}), and land cost (C_{Land}). The TDIC included total installed cost (TIC) and indirect cost. The capital cost includes investment costs of LNG receiving terminals. Table 3 shows the detailed direct cost of the LNG receiving terminal (Tarlowski and Sheffield, 2012).

The fixed and variable costs of running a small-scale LNG are referred to as operating expenditures, which are divided into two parts consisting of terminal operations and maintenance costs, and LNG buying costs including free onboard (FOB) of LNG and shipping costs.

The main income of this project can be obtained from the LNG terminal receiver. It is produced from the amount of LNG that can be converted to gas for power plant supply. The gas price at a power plant can be determined by the total FOB of LNG cost, shipping cost, margin regasification cost, and revenue cost. The minimum revenue is obtained through trial and error to gain an internal rate of return value deemed acceptable.

2.2.2. Feasibility evaluation

The economic feasibility is indicated by net present value (NPV), internal rate of return (IRR), payback period (PBP), and profitability index (PI). These variables will determine whether a project is economically feasible or not.

Table 1: Distribution route

Route scheme	Total distance (nautical miles)
Badak – Lombok – Sumbawa – Bima – Flores – Maumere – Alor – Kupang -Waingapu - Badak	2107 Nautical miles

Table 2: Gas demand for the referenced power plants (Indonesia Ministry of Energy and Mineral Resources, 2022)

Power plant	Capacity (MW)	Annual gas demand (BBTU)
Lombok Peaker	124	7.77
PLTMG Sumbawa	50	4.75
PLTMG Bima	50	4.98
PLTMG MPP Flores	23	1.12
PLTMG Maumere	40	2.36
PLTMG Kupang Peaker	40	1.35
PLTMG Alor* (development)	10	1.67
MPP Waingapu* (development)	10	1.14
Total	347	25.14

Table 3: Direct cost LNG receiving terminal (Tarlowski and Sheffield, 2012)

Component cost	Percentage
Unloading facilities	11
Storage tank	45
Regasification	24
Utility equipment	16
Land and building cost	4
Total	100

- Net present value

Project profitability is measured by Net Present Value (NPV). This is the most effective way to decide whether to accept or reject an industrial or financial investment. The rule in this assessment is that if the NPV is greater than zero, the project would be accepted, otherwise, it would be rejected.

- Internal rate of return

The IRR of an investment project is the rate at which it is expected to generate profits. This is the rate at which the project's net cash inflows and outflows become equal. The rule is that if the IRR is greater than the weighted average cost of capital (WACC), the project would be accepted, and if IRR is less than WACC, it would be rejected (Sullivan, 2006).

- Payback period

The term payback period refers to the time it takes to recover the cost of an investment. In essence, the shorter payback an investment has, the more attractive it becomes. To determine the payback period, the initial investment is divided by the average cash flows.

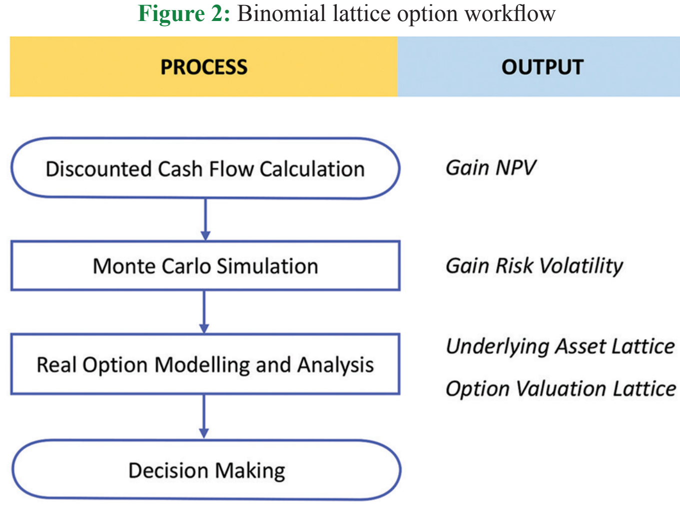
- Profitability Index

The profitability index (PI) describes an index that represents the relationship between the costs and benefits of a proposed project. This index is calculated by dividing the present value of future expected cash flows by the initial amount invested in the project. If PI is greater than 1, it is deemed as a good investment, with higher values corresponding to more attractive projects.

2.3. Risk Calculation

The real option (RO) applies the theory of choice to assess real assets in a dynamic condition and there is uncertainty, such a decision is needed. The decision has the characteristics of being flexible, having business opportunities, and being strategic (Mun, 2006; Doymus et al., 2022; Liu and Ronn, 2020; Mbolo et al., 2008). Integrating the standard NPV method with real options to evaluate a project is recommended by many researchers (Wang and Halal, 2010). When analyzing real options, a volatility value obtained through a Monte Carlo Simulation is needed, the value describes the level of risk (McLeish, 2005). The stages of real

Figure 2: Binomial lattice option workflow



options analysis using the binomial lattice method are presented in Figure 2.

The binomial lattice method required to calculate the supporting parameters includes the up factor (μ), the down factor (d), and the calculation of risk-neutral probabilities (p). Supporting factors are calculated using equations (1)-(3).

$$up = e^{volatility\sqrt{\delta t}} \quad (1)$$

$$down = e^{-volatility\sqrt{\delta t}} = \frac{1}{u} \quad (2)$$

$$p = \frac{e^{(risk\ free\ rate - dividend\ outflow)(\delta t)} - d}{u - d} \quad (3)$$

The first step of the binomial lattice is to determine the lattice of the underlying asset. The underlying assets known as stocks are a condition of developing asset values based on the up factor, the down factor, and risk-neutral probabilities parameter levels throughout a step period. For example, Figure 3a determines an underlying asset with 5 steps.

Having the values of the underlying assets, the next step is to calculate the option valuation lattice. Figure 3b shows an option valuation lattice with a 5-step lattice. The rightmost value or the last step is obtained from the maximum value between letting the option expire without being exercised or the option being exercised. Furthermore, the value for the fourth step up to the option value is obtained through backward induction using Equation (4).

$$option = \left[(p)u + (1-p)d\right]\exp\left[(-rf)(\delta t)\right] \quad (4)$$

3. RESULTS AND DISCUSSION

3.1. Small-Scale LNG Demand and Storage

The power plants selected for the dedieselisation program are listed in the decree of the Ministry of Energy and Mineral Resources Number 2.k/TL.01/MEM.L/2022 regarding the assignment of implementation of the supply provision and the LNG infrastructure construction along with the conversion of fuel oil use into LNG in the electricity supply. The list includes 33 power plants with a capacity of 1,198 MW, of which 1,018 MW are in operation and 180 MW are under construction.

Out of these, eight with a 347 MW of capacity are distributed within the Nusa Tenggara region, which was deliberately chosen for this case study. The location of the plants scattered across the archipelago of Nusa Tenggara has created challenges in the small-scale LNG supply chain leading to economic and investment risks.

The gas allocated to the eight power plants according to the ministry decree is around 25,140 MMBTU per day. This gas will be shipped from Bontang LNG Plant in East Kalimantan, Indonesia. Bontang's LNG specification is given in Table 4. Using a heat content of 1132.5 BTU/SCF, the demanded volume gas rate is approximately 22.2 MMSCFD. This is equivalent to 1,021 m^3/day of LNG applying a conversion factor of 46 m^3 of LNG/MMSCFD of gas (Budiyanto et al., 2020). The LNG requirement calculations for each power plant are the same as above and the results are presented in Table 5.

The shipping route for LNG transportation using small-scale LNG as shown in Figure 1 has a distance of 2107 Nautical miles (NM). The cycle time from the loading port at the LNG Badak plant to each unloading terminal and then back to the loading port is estimated at 9.6 days. For the shipping, the loading-unloading time was constant at 6 h. Uncertain shipping conditions are handled by giving each shipment an additional 3-h port-to-port buffer time.

With a total LNG consumption of 9,423 m^3 during the period of a cycle ship trip which is 10 days, the size of the LNG carrier along with the storage tank size is then calculated by considering the cycle time, ship average speed, and capacity. Table 6 shows the ship and tank sizes needed to ensure the security of the gas supply for each power plant.

Figure 3: Binomial lattice illustration modelling of an underlying asset (a) and option valuation (b)

Time	0	1	2	3	4	5
Stock	1.0.E+02	1.1.E+02	1.3.E+02	1.4.E+02	1.6.E+02	1.7.E+02
		8.9.E+01	1.0.E+02	1.1.E+02	1.3.E+02	1.4.E+02
			8.0.E+01	8.9.E+01	1.0.E+02	1.1.E+02
				7.2.E+01	8.0.E+01	8.9.E+01
					6.4.E+01	7.2.E+01
a						5.7.E+01

Time	0	1	2	3	4	5
Call	**1.3.E+01**	**2.0.E+01**	**2.9.E+01**	**4.2.E+01**	**5.7.E+01**	**7.5.E+01**
		5.8.E+00	**9.8.E+00**	**1.6.E+01**	**2.6.E+01**	**4.0.E+01**
			1.6.E+00	**3.1.E+00**	**6.1.E+00**	**1.2.E+01**
				0.0.E+00	**0.0.E+00**	**0.0.E+00**
					0.0.E+00	**0.0.E+00**
b						**0.0.E+00**

3.2. Economic Evaluation

3.2.1. Capital expenditure

To estimate the capital expenditure (CAPEX), calculate the cost of the requirements at the LNG receiving terminal at each destination power plant. The direct cost value can be obtained by multiplying the percentage factor (Tarlowski and Sheffield, 2012) with the regasification reference price from past findings (Armita et al., 2016). With these two pieces of information, the capital cost can be found in each power plant based on the generating capacity of the power plant. Table 7 shows that the total investment cost of this small-scale LNG is 118.2 million USD, which includes direct costs in the construction of the LNG receiving terminal, and indirect costs which includes contractor costs and contingency plan costs, as well as working capital costs.

The cost of storage tanks has the largest investment cost contribution with a percentage of 28.28%. This correlates with the important storage tanks for holding LNG as the main source of small-scale LNG. In addition, the cost of regasification is the second largest contributing factor to CAPEX, as the process required to use LNG in power plants by converting LNG to fuel gas.

3.2.2. Operational expenditure

Operational costs (OPEX) at the receiving terminal include maintenance costs, spare parts, manpower, insurance, taxes, and utility costs with a calculation based on generating capacity. The value of the operating costs of the terminal can be determined based on the early calculation of the maintenance and spare parts components, these two parameters are equal to 1.5% and 2.5% of total capital expenditure respectively. After obtaining these two values, the rest operational component can be calculated by the percentage of each component (Tarlowski and Sheffield, 2012). Based on Table 8, the total terminal operations and maintenance cost is 9.6 million USD, and the top three cost items that contribute the most are parts, manpower, and maintenance cost.

The cost of LNG includes the cost of LNG free on board (FOB) and the transportation cost is calculated based on the amount of LNG needed at each power plant. The gas supply comes from Bontang and is assumed to have a price of USD 7.00/MMBTU (Lemigas, 2018), making the LNG purchase cost to be 63.3 million USD. The distribution costs for the ship's distance from Bontang-Nusa Tenggara are USD 0.95/MMBTU (Lemigas, 2018), bringing the distribution costs to 8.6 million USD. Based on Table 9, the total cost of LNG annually is about 71.9 million USD.

Taking into account the total operating costs at the terminal, the cost of the LNG cargo raw materials, and its transportation, the annual operational cost is USD 81,604,881 or USD 9.02/MMBTU. The cost of free onboard LNG is dominant, accounting for about 78% of the total operational cost.

Table 4: Bontang LNG product specification (Lemigas, 2018)

Physical properties		Composition	
Phase	Liquid	C_1H_4	Min. 90.0%
Temperature	−158°C	C_2H_6	Max. 5.0%
Pressure	0.07 kg/cm²g	C_3	Max. 3.5%
Color	Colorless	C_4	Max. 1.5%
Odor	Hydrocarbon odor	C_5	Max. 0.02%
Density	Average 453 kg/m³	N_2	Max. 0.05%
Heat Content (HHV)	1132.5 Btu/SCF	Hg	0 ppb

3.2.3. Revenue calculation

The receiving terminal's revenue is derived from the volume of LNG, which can be converted to gas through the regasification process. The calculation of the minimum price of gas at the power plant is the sum of the FOB LNG price, transportation costs, and profit. This minimum profit value of 4.47/MMBTU is obtained from the goal seek method using macro excel, yielding an IRR value that is considered acceptable, and the minimum revenue is USD 12.42/MMBTU. The details of the goal seek results can be seen in Table 10 as follows.

After obtaining the minimum gas price at the generator, a regasification margin calculation is carried out. In this cluster, it is not yet known how much the right regasification margin is, and, therefore the project generates profits for investors and has relatively minimal risk. Several regasification margin trials were carried out in order to obtain a regasification margin that meets all investment feasibility parameters and minimal risk. From the data that has been processed in Table 11, it can be determined that the regasification margin for this cluster is USD 1.0/MMBTU resulting in revenue generation of USD 13.42/MMBTU or about USD 0.046/kWh.

3.2.4. Discounted cash flow analysis

The results of the economic evaluation are summarized in Table 12. The NPV value of the small-scale LNG project is 56.8 million USD, indicating that the small-scale LNG project will be profitable and feasible. The calculated IRR parameter value is 15.3%, greater than the WACC value of 9.99%, which supported the feasibility of establishing the small-scale LNG project designed. The payback period or PBP as seen in Figure 4 was achieved after 7.25 years when the cumulative cash flow is zero. In <8 years, it takes relatively little for an investment to pay off.

The calculated PI parameter value is 1.48. From the perspective of the PI parameter, the small LNG project is feasible because the obtained PI value is greater than 1, indicating that the small LNG project will be profitable. Based on these financial indicators of NPV, IRR, PBP, and PI, it can be concluded that small-scale LNG projects are feasible to establish with profitable results.

Table 5: Allocated gas demand for each of power plant

Gas power plant	Capacity MW	Average gas usage		
		MMBTU/D	MMSCFD	m³/day
Lombok peaker	124	7,770	6.86	315.60
PLTMG sumbawa	50	4,750	4.19	192.94
PLTMG bima	50	4,980	4.40	202.28
PLTMG MPP flores	23	1,120	0.99	45.49
PLTMG MAUMERE	40	2,360	2.08	95.86
PLTMG kupang peaker	40	1,670	1.19	54.83
PLTMG alor*	10	1,350	1.47	67.83
MPP waingapu*	10	1,140	1.01	46.30
Total	347	25,140	22.20	1021.14

Table 6*: The particular ship and tank sizes needed*

Ship size (Marine Traffic, 2008) (seapek unikum)	Average speed	Sea distance	Round trip duration	Total demand/trip	40 ft ISO tank quantity
11,327 m³	15 knots	2107 NM	9.6 days	9,423 m³	26

3.2.5. Sensitivity analysis

A sensitivity analysis is carried out to find selected variables that are strongly correlated with the economic aspects of a small-scale LNG project. The selected variables are the price of gas at the power plant, terminal operational costs, investment costs, and generator capacity requirements. The analysis is performed by variating changes in the four variables and by analyzing the sensitivity of financial indicators of NPV, IRR, PBP, and PI.

As shown in Figure 5, the value of the economic indicators is most affected by the gas price at a power plant. This means that the gas price at the power plant has a significant effect on the small-scale LNG project and therefore, should be considered in the risk calculation.

Table 7: Component of total capital expenditure

Category	Cost component	Percentage	Total cost
Direct	Unloading facilities	6.91	USD 8,170,123
Cost	Storage tank	28.28	USD 33,423,231
	Regasification	15.08	USD 17,825,723
	Utility equipment	10.06	USD 11,883,815
	Land and building cost	2.51	USD 2,970,954
Indirect	EPC contractor	9.43	USD 11,141,077
cost	Contingency plan	12.57	USD 14,854,769
Working capital		15.16	USD 17,917,823
Total		100	USD 118,187,515

Table 8: Total terminal cost operational and maintenance

Cost component	Percentage	Total Cost (USD/year)
Maintenance	18.36	USD 1,772,813
Spare parts	30.62	USD 2,954,688
Manpower	29.42	USD 2,840,749
Insurance	7.88	USD 760,880
Tax	1.14	USD 110,366
Utility (Water, Fuel)	12.58	USD 1,214,705
Total	100.00	USD 9,654,201

Table 9: LNG free on board and shipping cost

Cost component	Basis cost (USD/MMBTU)	LNG quantity (MMBTU)	Total cost (USD/year)
FOB LNG	7	9,050,400	63,352,800
Shipping	0.95	9,050,400	8,597,880
Total			71,950,680

Table 10: Minimum revenue and gas price calculation

Cost component	Cost value (USD/MMBTU)
FOB LNG	USD 7.00
Shipping	USD 0.95
Minimum revenue (goal seek)	USD 4.47
Minimum gas price	USD 12.42

3.2.6. Cost of electricity generation and total emission

The dedieselisation program has two overall impacts, reducing electricity generation costs and emission reduction (Upadana et al., 2018; Acciaro, 2014). The final price of gas at the power plant obtained in the previous calculation is compared with the price of diesel fuel based on an assumption value of USD 0.083/kWh. Based on the calculation, the conversion of diesel to gas in the Nusa Tenggara region has the potential to reduce fuel consumption by about 45%.

$$Fuel\ Savings = \frac{diesel\ price - gas\ price}{diesel\ price}$$

$$Fuel\ Savings = \frac{0.083 - 0.046}{0.083} = 45\%$$

The fuel emission factor to be used for general emissions reduction is based on carbon dioxide emissions that can be represented as greenhouse gas emissions (Chung et al., 2019; European Commission, 2020), where the emission factor for diesel and natural gas is 74.72 Metric Ton CO_2/Ton Joule (TJ) and 57.27 Metric Ton CO_2/TJ respectively. Based on Table 13, the conversion of diesel to gas in the Nusa Tenggara region has the potential to reduce consumption by about 23% CO_2 emission.

3.3. Risk Calculation

The real options analysis conducted is designed to examine the options for carrying out certain business initiatives from various scenario options. This technique helps the management deal with various uncertainties in making decisions. In this study, the options raised are open and abandoned options, and the level of risk faced is based on the assumptions used and expressed by a volatility value. In addition, a Monte Carlo simulation is carried out to obtain the volatility value with a normal distribution of 1000 iterations. The assumption used for the Monte Carlo simulation is that the risk comes from changes in gas prices at power plants with an average selling price of 13.42 USD/MMBTU and a standard deviation of 0.07. The standard deviation value is obtained from the track

Figure 4: Cumulative cash flow of small-scale LNG

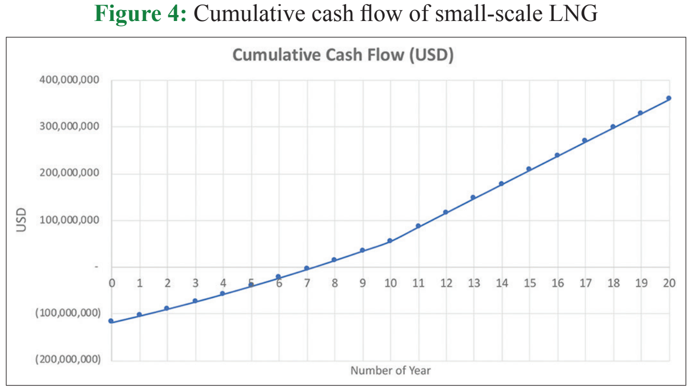


Table 11: Margin regasification calculation

Margin regasification (USD)	Fee (USD) price	NPV	IRR	PBP	PI
0.2	12.62	USD 10,622,304	11.00%	9.93	1.09
0.4	12.82	USD 22,185,896	12.08%	9.12	1.19
0.6	13.02	USD 33,749,489	13.16%	8.42	1.29
0.8	13.22	USD 45,313,081	14.23%	7.80	1.38
1	13.42	USD 56,876,674	15.30%	7.25	1.48

Figure 5: Economic sensitivity calculation based on internal rate of return (a), net present value (b), profitability index (c), and payback period (d)

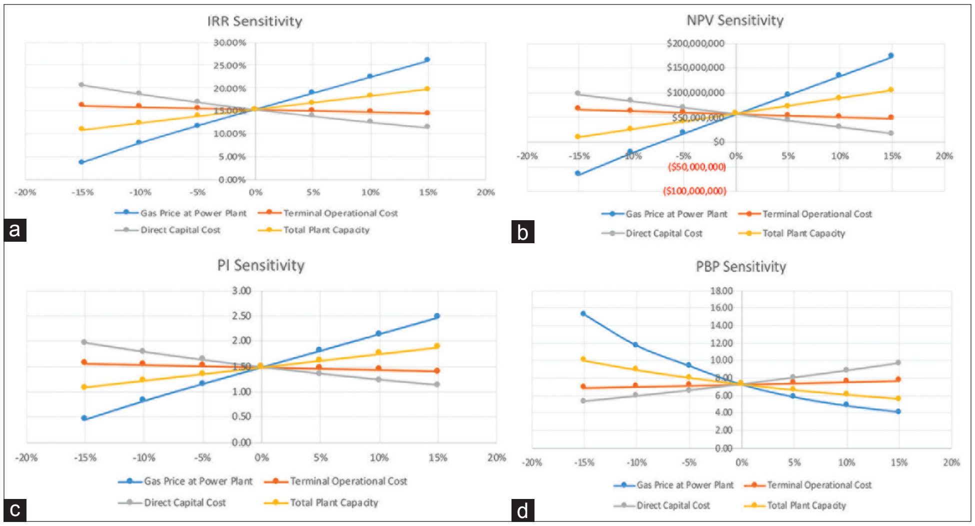
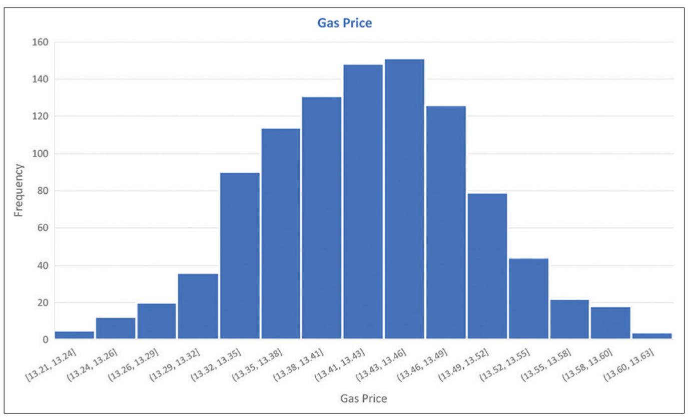


Figure 6: Monte Carlo simulation



record of changes in gas prices in Indonesia over the last 10 years. The results of the Monte Carlo simulation are shown in Figure 6.

The annual volatility value can be obtained by multiplying the average standard deviation value by the year of risk analysis used. The volatility value obtained is 21.6%, which describes the level of risk. Therefore, real options analysis is needed to minimize long-term risks in a way that companies and investors can avoid losses. The input parameters for real options analysis using the binomial lattice method include the basic input parameters, namely the present value of the underlying asset (S), the present value of the cost of the option (X), the value of risk or volatility (σ), maturity (T), and the risk-free rate (rf). Furthermore, two additional calculations are needed, namely the up factor (u) and down (d) as well as the calculation of risk-neutral probabilities (p). All input parameters to form a binomial tree are shown in Table 14. With the input parameters obtained, a binomial tree can be constructed for a 20-year analysis with a yearly interval and the active value for each computed node can be constructed as shown in Figure 7a. Starting from the leftmost node, which is year 0 by inputting the value of S, then the value of S is multiplied by the up factor (u) and down factor (d) values in year 1. This step is continued until the year 19 node.

The next step is to determine the option value for each node of the binomial tree using backward induction with Equation (4).

Table 12: Economic evaluation result

Component	Calculation result
Minimum price	USD 12.42/MMBTU
Margin regas	USD 1.00/MMBTU
Gas price at power plant	USD 13.42/MMBTU
CAPEX	USD 118,187,515
WACC	9.99%
NPV	$56,876,674
IRR	15.30%
Payback period	7.25 years
Profitability index	1.48

Table 13: Fuel emission comparison

Fuel type	Fuel quantity for power plant (TJ)	Emission factor (metric ton CO_2/TJ)	Total emission (metric ton CO_2/TJ)
Diesel	2.652×10^7	74.72	1.982×10^9
Natural gas		57.27	1.519×10^9
Emission reduction			23%

Table 14: Real option binomial lattice basic input

Parameter	Value	Description
S ($)	56,876,674	NPV value from discounted cash flow
X ($)	Open 0 Abandon 11,497,803	Abandon option if 20% of salvage value
T (year)	20	Year analysis
Risk volatility (%)	21.60%	Yearly risk based on Monte Carlo simulation
rf	6.45%	Based on market risk premia (2022)
dt (year)	1	step size
u	1.25	Based on Equation (1)
d	0.80	Based on Equation (2)
p	0.59	Based on Equation (3)

Each node represents the maximum value of various options, which can be determined whether the option to be taken is to open or abandon. The option valuation lattice can be seen in

Figure 7: Binomial lattice result consists of small-scale LNG underlying asset (a), and option valuation (b)

a

Time	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Stock	5.7.E+07	7.1.E+07	8.8.E+07	1.1.E+08	1.4.E+08	1.7.E+08	2.1.E+08	2.7.E+08	3.3.E+08	4.1.E+08	5.1.E+08	6.4.E+08	8.0.E+08	1.0.E+09	1.2.E+09	1.5.E+09	1.9.E+09	2.4.E+09	3.0.E+09	3.7.E+09	4.7.E+09
		4.6.E+07	5.7.E+07	7.1.E+07	8.8.E+07	1.1.E+08	1.4.E+08	1.7.E+08	2.1.E+08	2.7.E+08	3.3.E+08	4.1.E+08	5.1.E+08	6.4.E+08	8.0.E+08	1.0.E+09	1.2.E+09	1.5.E+09	1.9.E+09	2.4.E+09	3.0.E+09
			3.7.E+07	4.6.E+07	5.7.E+07	7.1.E+07	8.8.E+07	1.1.E+08	1.4.E+08	1.7.E+08	2.1.E+08	2.7.E+08	3.3.E+08	4.1.E+08	5.1.E+08	6.4.E+08	8.0.E+08	1.0.E+09	1.2.E+09	1.5.E+09	1.9.E+09
				2.9.E+07	3.7.E+07	4.6.E+07	5.7.E+07	7.1.E+07	8.8.E+07	1.1.E+08	1.4.E+08	1.7.E+08	2.1.E+08	2.7.E+08	3.3.E+08	4.1.E+08	5.1.E+08	6.4.E+08	8.0.E+08	1.0.E+09	1.2.E+09
					2.4.E+07	2.9.E+07	3.7.E+07	4.6.E+07	5.7.E+07	7.1.E+07	8.8.E+07	1.1.E+08	1.4.E+08	1.7.E+08	2.1.E+08	2.7.E+08	3.3.E+08	4.1.E+08	5.1.E+08	6.4.E+08	8.0.E+08
						1.9.E+07	2.4.E+07	2.9.E+07	3.7.E+07	4.6.E+07	5.7.E+07	7.1.E+07	8.8.E+07	1.1.E+08	1.4.E+08	1.7.E+08	2.1.E+08	2.7.E+08	3.3.E+08	4.1.E+08	5.1.E+08
							1.5.E+07	1.9.E+07	2.4.E+07	2.9.E+07	3.7.E+07	4.6.E+07	5.7.E+07	7.1.E+07	8.8.E+07	1.1.E+08	1.4.E+08	1.7.E+08	2.1.E+08	2.7.E+08	3.3.E+08
								1.2.E+07	1.5.E+07	1.9.E+07	2.4.E+07	2.9.E+07	3.7.E+07	4.6.E+07	5.7.E+07	7.1.E+07	8.8.E+07	1.1.E+08	1.4.E+08	1.7.E+08	2.1.E+08
									9.8.E+06	1.2.E+07	1.5.E+07	1.9.E+07	2.4.E+07	2.9.E+07	3.7.E+07	4.6.E+07	5.7.E+07	7.1.E+07	8.8.E+07	1.1.E+08	1.4.E+08
										7.8.E+06	9.8.E+06	1.2.E+07	1.5.E+07	1.9.E+07	2.4.E+07	2.9.E+07	3.7.E+07	4.6.E+07	5.7.E+07	7.1.E+07	8.8.E+07
											6.3.E+06	7.8.E+06	9.8.E+06	1.2.E+07	1.5.E+07	1.9.E+07	2.4.E+07	2.9.E+07	3.7.E+07	4.6.E+07	5.7.E+07
												5.0.E+06	6.3.E+06	7.8.E+06	9.8.E+06	1.2.E+07	1.5.E+07	1.9.E+07	2.4.E+07	2.9.E+07	3.7.E+07
													4.0.E+06	5.0.E+06	6.3.E+06	7.8.E+06	9.8.E+06	1.2.E+07	1.5.E+07	1.9.E+07	2.4.E+07
														3.2.E+06	4.0.E+06	5.0.E+06	6.3.E+06	7.8.E+06	9.8.E+06	1.2.E+07	1.5.E+07
															2.6.E+06	3.2.E+06	4.0.E+06	5.0.E+06	6.3.E+06	7.8.E+06	9.8.E+06
																2.1.E+06	2.6.E+06	3.2.E+06	4.0.E+06	5.0.E+06	6.3.E+06
																	1.7.E+06	2.1.E+06	2.6.E+06	3.2.E+06	4.0.E+06
																		1.3.E+06	1.7.E+06	2.1.E+06	2.6.E+06
																			1.1.E+06	1.3.E+06	1.7.E+06
																				8.7.E+05	1.1.E+06
																					7.0.E+05

b

Time	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Call	5.9.E+07	7.4.E+07	9.2.E+07	1.1.E+08	1.4.E+08	1.8.E+08	2.2.E+08	2.7.E+08	3.4.E+08	4.2.E+08	5.2.E+08	6.5.E+08	8.1.E+08	1.0.E+09	1.3.E+09	1.6.E+09	1.9.E+09	2.4.E+09	3.0.E+09	3.7.E+09	4.7.E+09
		4.7.E+07	5.9.E+07	7.3.E+07	9.1.E+07	1.1.E+08	1.4.E+08	1.8.E+08	2.2.E+08	2.7.E+08	3.4.E+08	4.2.E+08	5.2.E+08	6.5.E+08	8.1.E+08	1.0.E+09	1.3.E+09	1.6.E+09	1.9.E+09	2.4.E+09	3.0.E+09
			3.8.E+07	4.7.E+07	5.9.E+07	7.3.E+07	9.1.E+07	1.1.E+08	1.4.E+08	1.7.E+08	2.2.E+08	2.7.E+08	3.4.E+08	4.2.E+08	5.2.E+08	6.5.E+08	8.1.E+08	1.0.E+09	1.2.E+09	1.6.E+09	1.9.E+09
				3.0.E+07	3.8.E+07	4.7.E+07	5.8.E+07	7.3.E+07	9.0.E+07	1.1.E+08	1.4.E+08	1.7.E+08	2.2.E+08	2.7.E+08	3.4.E+08	4.2.E+08	5.2.E+08	6.5.E+08	8.0.E+08	1.0.E+09	1.2.E+09
					2.4.E+07	3.0.E+07	3.8.E+07	4.7.E+07	5.8.E+07	7.2.E+07	9.0.E+07	1.1.E+08	1.4.E+08	1.7.E+08	2.2.E+08	2.7.E+08	3.3.E+08	4.2.E+08	5.2.E+08	6.4.E+08	8.0.E+08
						2.0.E+07	2.4.E+07	3.0.E+07	3.8.E+07	4.7.E+07	5.8.E+07	7.2.E+07	9.0.E+07	1.1.E+08	1.4.E+08	1.7.E+08	2.1.E+08	2.7.E+08	3.3.E+08	4.1.E+08	5.1.E+08
							1.6.E+07	2.0.E+07	2.4.E+07	3.0.E+07	3.7.E+07	4.6.E+07	5.8.E+07	7.2.E+07	8.9.E+07	1.1.E+08	1.4.E+08	1.7.E+08	2.1.E+08	2.7.E+08	3.3.E+08
								1.3.E+07	1.6.E+07	1.9.E+07	2.4.E+07	3.0.E+07	3.7.E+07	4.6.E+07	5.8.E+07	7.2.E+07	8.9.E+07	1.1.E+08	1.4.E+08	1.7.E+08	2.1.E+08
									1.1.E+07	1.3.E+07	1.6.E+07	1.9.E+07	2.4.E+07	3.0.E+07	3.7.E+07	4.6.E+07	5.7.E+07	7.1.E+07	8.9.E+07	1.1.E+08	1.4.E+08
										9.0.E+06	1.1.E+07	1.3.E+07	1.6.E+07	1.9.E+07	2.4.E+07	3.0.E+07	3.7.E+07	4.6.E+07	5.7.E+07	7.1.E+07	8.8.E+07
											8.0.E+06	9.2.E+06	1.1.E+07	1.3.E+07	1.6.E+07	1.9.E+07	2.4.E+07	3.0.E+07	3.7.E+07	4.6.E+07	5.7.E+07
												7.4.E+06	8.3.E+06	9.4.E+06	1.1.E+07	1.3.E+07	1.6.E+07	1.9.E+07	2.4.E+07	2.9.E+07	3.7.E+07
													7.3.E+06	7.9.E+06	8.7.E+06	9.8.E+06	1.1.E+07	1.3.E+07	1.5.E+07	1.9.E+07	2.4.E+07
														7.5.E+06	8.0.E+06	8.6.E+06	9.3.E+06	1.0.E+07	1.1.E+07	1.3.E+07	1.5.E+07
															7.9.E+06	8.4.E+06	9.0.E+06	9.5.E+06	1.0.E+07	1.1.E+07	1.1.E+07
																8.4.E+06	9.0.E+06	9.5.E+06	1.0.E+07	1.1.E+07	1.1.E+07
																	9.0.E+06	9.5.E+06	1.0.E+07	1.1.E+07	1.1.E+07
																		9.5.E+06	1.0.E+07	1.1.E+07	1.1.E+07
																			1.0.E+07	1.1.E+07	1.1.E+07
																				1.1.E+07	1.1.E+07
																					1.1.E+07

Figure 8: Succession rate of option open and abandon

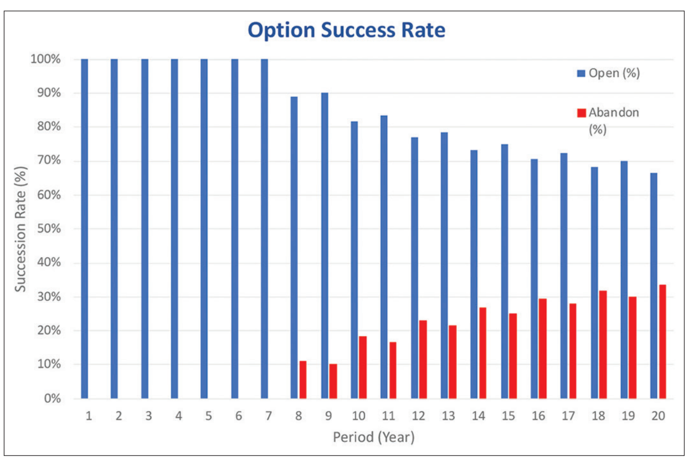


Figure 7b. Based on the calculation results of the option value in Figure 7b, a diagram is then formed that represents the degree of success of the open and abandoned options, as shown in Figure 8.

Based on the option valuation lattice in Figure 8, the blue nodes representing the value of the option fulfill the option to open, therefore the management can decide to open and run the project. The results of the calculation of the option value on the blue nodes illustrate that management can start running the project at the beginning of the year without delay with a 100% success rate.

In Figure 8, there is a red bar that spans from the end of year 8 to the end of year 20. This bar represents the option value that takes into account both the option to abandon and the option to open, meaning the option value indicates that management can begin to make decisions to either stop the acceptance terminal operations and sell it, or keep the terminal running without selling or renting it out. The option value at the red bar is still positive, and therefore if the management decides to keep the terminal operations running, investors will not incur losses. The management should consider abandoning the terminal at the end of year 20, based on the option value and the higher level of success for the abandoned option at the end of year 20, which increases the probability for the company to achieve higher profits.

4. CONCLUSION

Based on the calculation analysis, several important points can be drawn. First, to support the dedieselisation program for eight power plants with a capacity of 347 MW in the region, gas demand is estimated to be 9,151 BBTU annually. Second, using the small-scale LNG model, the LNG distribution process in the Nusa Tenggara regions has met the profitability parameters.

Third, risk analysis by the real options method suggests that the investment risk is less if the project starts in the 1st year and ends in the 20th year of operation. Finally, the dedieselisation program in the Nusa Tenggara region leads to a reduction in the unit cost of electricity generation and the number of emissions.

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