Economic analysis on the LNG Distribution to power plants in Bali and Lombok by utilizing mini-LNG carriers

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Abstract. In recent years, small-scale LNG has contributed significantly in supplying the demand from industry users of natural gas as clean fuel. Small-scale LNG has the advantages of providing the greater operational flexibility and lower initial investment cost than conventional LNG or pipeline supply. Focusing on the case in Indonesia, many designed gas-fuel power plants are located in remote area or in the limited depth of water level especially in eastern part of Indonesia, such as Lombok and Bali. Therefore, small-scale LNG is purposed to overcome the natural gas demand in such conditions. Two scenarios were developed in this study in utilizing the conventional LNG carriers to deliver the natural gas from origin located in LNG terminal Benoa, Bali, to several power plants in Bali and Lombok. Both scenarios are new ship LNG building and the conversion of Landing Craft Tank (LCT) into non-conventional LNG carrier. Economic analysis on the LNG Distribution to power plants in Bali and Lombok utilizing mini LNG carriers is the main objective of this study. Capital Expenditure (CAPEX) including mini-LNG carrier, investment in jetty, storage facility, regasification unit and the system distribution to the power plant were considered. While the Operational Expenditure (OPEX) consist of operational and maintenance cost in receiving terminal and LCT. The result of this papers can be concluded that based on the economic perspective, utilizing the mini LNG carriers are feasible and requires relatively small cost to supply the LNG demand in Lombok and Bali.

1. Introduction

Liquid Natural Gas (LNG) has become increased global demand for electricity generation since natural gas is the efficient and the cleanest energy source compared to fossil fuel [1]. The growth of investment in gas infrastructure is an critical issue and become increases in order to meet the gas demand, particularly in countries with potential reserves and those currently with a high dependence on coal [1]. Gas reserves in Asia Pacific, which account for 9% of the global total, are more distributed across countries, including China, Indonesia, Malaysia and Australia [1]. According to BP Statistical Review of World Energy, by the end of 2018, the total proven gas reserve in Indonesia has approximately 2.3 trillion cubic meters [2]. The government of Indonesia committed to increase the consumption of domestic energy sources, including natural gas. Through Government Regulation Number 79 of 2014 concerning National Energy Policy, domestic consumption of natural gas is
targeted to increase from the current 19% to 24% in 2050. On the contrary, the use of fossil fuel is reduced from the current 42% to 20% in 2050 [3]. This research supports energy management particularly in Indonesia that is directed towards equitable energy by increasing equal access to energy at affordable prices and a more efficient management of energy supply.

Design of the LNG supply chain is the most critical system to support the natural demand. The LNG supply chain consists of exploration, extraction, liquefaction, transportation, storage and regasification an then delivered to gas costumers as end users [4]. However, as the archipelago country, the locations of gas costumers particularly power plants in Indonesia are scattered at several point. It brings the great challenge to distribute the LNG in such location of users. Small-scale LNG has been much applied to design the LNG supply power plants which are located in remote area or in the limited depth of water level due to its operational flexibility and lower initial investment cost [5], [6]. Small scale LNG generally refers to LNG associated facilities (receiving terminals, storage units, vessel, etc.) with similar characteristics but of a lower magnitude than conventional LNG infrastructure [6]. The vessel used in small scale LNG has smaller dimensions to meet the water depth requirement so that the operational will be easier, more flexible and reduce the investment cost.

This study aims to provide the economic analysis on the LNG distribution to power plants utilizing mini-LNG carriers to support equitable energy, affordable prices and a more efficient management of energy supply. Not only utilizing the conventional LNG carriers only, this study also performs the economic analysis regarding the conversion of LCT vessel into non-conventional LNG carrier. LNG are stored in the ISO tank then transported to the power plant using LCT. Finally, this work provides an overview of the implementation of small scall LNG distribution to small scale power plant in Lombok and Bali island, Indonesia.

2. Design of LNG distribution in Bali and Lombok, Indonesia
Small scale LNG supply chain is adopted in this study to design the LNG distribution. In general, the concept of small-scale LNG is not much different from the medium-large LNG supply chain. In a small-scale LNG, LNG-related facilities have a lower magnitude than conventional LNG infrastructure [6], [7]. LNG can be shipped to smaller satellite terminals using mini LNG carriers with smaller capacities.

Small-scale LNG (SSLNG) carriers is the most common vessel used in shipping the LNG for sea based transports [5], [7]. However, the characteristic of waterway near the location of power plant in Indonesia has limited depth of water level or shallow waterway. Based on the current condition, this study purposes to utilize the converted Landing Craft Tank (LCT) as the non-conventional LNG carriers and also compare the economic aspect between the converted LCT and new building of ships. The conversion of LCT vessel into non-conventional LNG carriers has been proved that it could be implemented in remote area and give better efficiency both in technical and economic aspects [8]. The advantage of the LCT vessel is that it does not require a special port in the loading process because LCT vessel has a ramp door that can be used in loading and unloading the passengers, heavy equipment, cargo, construction materials and transportation equipment. LCT vessel also have a relatively low draft that allows them to operate in shallow waterway [8]. LCT vessel is converted and modified in order to meet requirement particularly ship’s construction, lashing system, seating system and stability. ISO Tank is used to store the LNG then to be shipped by using LCT to the user. ISO tank is a tank constructed based on International Organization for Standardization (ISO) standards so that it can be transported using various modes of transportation. This tank has a protective and insulating construction on the surface of the tank.

As shown in Figure 1, LNG is filled to the ISO tank in LNG Terminal (origin) then LNG ISO tank is stored in the LCT vessel. LCT vessel carrying ISO LNG tanks sailing to the MPP plant destination. At the receiving terminal, the ISO LNG tank is unloaded from the ship and then transported by truck to stacking yard. Before entering the regasification unit, LNG is pumped from the ISO LNG tank to the buffer tank. This buffer tank serves to prevent interruption of the LNG supply to the regasification unit due to ISO LNG replacement activities.
The design route of mini LNC supply chain actually has been conducted by authors in previous research. This study is a continuation and part of LNG supply chain research of the author’s road map. Based on the statement of Directorate General of Oil and Gas of Indonesia at the Green-Eco Energy conference in Bali, distribution in Bali is used as an example of LNG distribution which adapts the conditions in Indonesia which are spread over several islands and separated by waterway. The utilization of Mini Scale LNG carrier is one of the factors that causes LNG distribution in Bali to be carried out in more efficient cost. Therefore, supporting the Bali Green Eco Energy, power plants in Bali and island near to Bali, Lombok island, will be defined as the end users of natural gas in small-scale LNG supply chain. Floating storage and regasification unit (FSRU) in Benoa Terminal, Bali, was selected as a potential LNG supply terminal. Lombok Peaker, MPP Lombok, Gilimanuk and Pemaron power plants located in Bali and Lombok Island are used here as the demand in this case study.

Figure 1. Distribution process diagram with ISO LNG Tank

Figure 2. Design of LNG distribution route in Bali and Lombok Island, Indonesia
Mathematical model has been performed previously to solve capacity-based transportation cases. The location of users, Lombok Peaker, MPP Lombok, Gilimanuk and Pemaron power plants in Bali and Lombok Island are denoted by $X_1$, $X_2$, $X_3$ and $X_4$ as shown in Figure 2. Figure 2 also illustrates the distribution of LNG in four power plant. Table 1 shows the capacity of power plant and LNG demand. Those 4 powerplant will be supplied by LCT non-conventional as mini LNG carrier with specification as in Table 1.

Table 1. Specification of LCT non-conventional as mini LNG carrier

| Symbol | Location           | Capacity (MW) | MMSCFD | LNG Demands (m$^3$/day) | ISO Tank Demand (unit/day) |
|--------|--------------------|---------------|--------|-------------------------|--------------------------|
| BHP    |                    | 1760 kW       |        |                         |                          |
| SFOC   |                    | 190 g/kWh     |        |                         |                          |
| Vs     |                    | 10 knots      |        |                         |                          |
| Gross Tonnage |                | 1200 GT       |        |                         |                          |
| LOA    |                    | 50.50 m       |        |                         |                          |

Table 2. Capacity of power plants in Bali and Lombok Island, Indonesia

| Symbol | Location           | Capacity (MW) | MMSCFD | LNG Demands (m$^3$/day) | ISO Tank Demand (unit/day) |
|--------|--------------------|---------------|--------|-------------------------|--------------------------|
| X0     | LNG Terminal Benoa |               |        |                         |                          |
| X1     | PLTMG Lombok Peaker| 136           | 9.07   | 417.07                  | 21                       |
| X2     | MPP Lombok         | 50            | 10.00  | 460.00                  | 24                       |
| X3     | Gilimanuk          | 130           | 8.70   | 398.70                  | 20                       |
| X4     | Pemaron            | 80            | 5.30   | 245.30                  | 13                       |

Considering the capacity of power plants, roundtrip and sailing frequency, the number of mini LNG used to meet the gas demand can be summarized in Table 3.

Table 3. Summary of Number of mini LNG carrier and total trip per year

| Route | Route     | Number of Mini LNG Carrier | Total Trip/Year | Information |
|-------|-----------|----------------------------|-----------------|-------------|
| A     | X0-X1-X0  | 1                          | 180             | Continuous  |
|       |           | 1                          | 180             | Intermittent|
| B     | X0-X2-X0  | 1                          | 120             | Continuous  |
|       |           | 1                          | 120             | Intermittent|
| C     | X0-X3-X0  | 2                          | 53              | Continuous  |
| D     | X0-X4-X0  | 1                          | 80              | Continuous  |

3. Economic Analysis
Economic analysis needs to be performed to evaluate whether the cost occurred by distribution activities of the LNG ships is feasible. The revenue derived from the gas selling with varied price margin is included in the economic analysis. Two parameters, capital expenditure (CAPEX) and operational expenditure (OPEX), are considered in the economic analysis. CAPEX is defined as the total capital for the initial investment. CAPEX consists of two major which are the investment or capital costs for transportation and investment costs for terminal construction. OPEX is all costs occurred to support the operational distribution of LNG, including the operational costs of the
receiving terminal and the transportation costs for transporting LNG from the refinery to the receiving terminal, as well as maintenance costs. Related work about economic analysis in small scale LNG distribution concluded that cost of LNG transportation depends on the amount of cargo demand and shipping distance. Several parameter or criteria to analyze the feasibility in the economic aspects are used, Payback Period (PDB), Net present Value (NPV) and Return of Investment (ROI).

The payback period (PDB) is a capital budgeting procedure used to determine the profitability of a project. A discounted payback period gives the number of years it takes to break even from undertaking the initial expenditure, by discounting future cash flows and recognizing the time value of money. Formula for calculating PDB is described as follows:

$$PDB = \frac{Total\ Cost\ of\ Investment}{Project\ Cash\ Flow}$$

(1)

The Net Present Value (NPV) is the difference between the present value of cash inflows and the present value of cash outflows. NPV is used in capital budgeting to analyze the profitability of a projected investment or project. Formula for calculating NPV is described as follows:

$$NPV = \sum_{t=0}^{n} \frac{(C)_{t}}{(1+i)^{t}} - \sum_{t=0}^{n} \frac{(Co)_{t}}{(1+i)^{t}}$$

(2)

Where:

NPV = Net Present Value

(C)$_{t}$ = Cash Inflow on year $t$

(Co)$_{t}$ = Cash Outflow on year $t$

n = Project Duration

i = Discount Rate

t = Number time of Periods

The relationship between NPV and discount rate can be presented as the Internal Rate of Return (IRR). IRR is used to find out at the interest rate (discount rate) at what rate an investment can provide benefits. The IRR also shows how much the discount rate is when the net present value (NPV) is zero. If the interest rate is more than the IRR, it is better not to continue investing. The greater the IRR value than the Weighted Average Cost of Capital (WACC) value, it means that the investment in the project is more feasible.

The Return on investment (ROI) is a performance measure used to evaluate the efficiency of an investment or to compare the efficiency of a number of different investments. ROI measures the amount of return on an investment relative to the investment’s cost. To calculate ROI, the benefit (or return) of an investment is divided by the cost of the investment, and the result is expressed as a percentage or a ratio. Formula for calculating ROI is described as follows:

$$ROI = \left( \frac{\sum_{t=0}^{n} CashFlow}{n} \right) \times \frac{1}{Investment}$$

(3)

4. Results and discussion

4.1. Capital Expenditure (CAPEX)

CAPEX is calculated for all initial cost of investment from the transportation using mini LNG carrier to gas consumed by power plant, including jetty construction, regasification unit and transportation in receiving terminal. In this study, two scenarios are developed for the mini LNG construction, which is new building ships of mini LNG and conversion from LCT vessel to non-conventional LNG carrier.
Two results will provide different insights which one is feasible and more efficient. In the receiving terminal, the process of loading and unloading LNG ISO tank from mini LNG Carrier to the stockpile is utilized the container crane and stacker as presented in Figure 3. The process applies for all power plants. The scenario of loading and unloading LNG ISO tank is important to be designed because the equipment involved in the process should be considered in the component of CAPEX.

![Figure 3. Loading-unloading LNG ISO Tank](image)

The detail component considered in the CAPEX calculation is shown in Table 4. Pricing on the detail calculation for CAPEX supported by qualified vendor which has long experience in related business.

| SYSTEM                        | Equipment                                                                 |
|-------------------------------|---------------------------------------------------------------------------|
| Mini LNG Carrier (New Building or Conversion) | Jetty<br>Crane<br>Jetty Equipment (bollard, wire, etc)<br>Procurement and Civil Works (hardening, cut & fill) |
| Jetty and Terminal            | Truck & Trailer (40”)<br>Jetty Equipment (bollard, wire, etc)<br>Procurement and Civil Works (hardening, cut & fill) |
| LNG Storage and Stockpile Yard | Land Rent<br>Stacker<br>LNG Metering Unit <br>LNG buffer Tank<br>LNG Vaporizer (Ambient Air Type)<br>Compressor<br>Gas Heater<br>Gas Pipeline (Carbon Steel)<br>Piping System (Pigging, valve, etc)<br>Gas Metering Unit<br>LNG pipeline (stainless steel)<br>Crane and Stacker |
| Regasification Unit           | Building (control room, monitor room, office)<br>Hydrant and Portable Fire Fighting Equipment<br>Alarm and Security Systems |
| Gas Distribution to Power Plant| PCS, SCADA (hardware dan software)<br>Building (control room, monitor room, office)<br>Storage Tank |
| Building                      | Pump<br>Piping System<br>Fire Fighting Equipment<br>Fire Fighting Equipment |
| Safety Stock (Diesel Oil)     | Monitoring and Control System<br>Decommissioning<br>Project cost |
Engineering and cost estimate study to calculate the price of building the new mini LNG carrier or conversion from LCT vessel is the most important part because the cost of investment for mini LNG carrier contribute a huge percentage in the components of CAPEX. An approach model of price estimation and construction scheduling of LCT Non-Conventional LNG ISO Tank carriers by making a cost breakdown are as follows:

1. Engineering & Design  
   a. Engineering Design  
   b. Class Approval Fee (Design & Construction)
2. Procurement Materials & Materials
3. Ship Construction & Installation
4. ISO Tank & Installation of supporting equipment

Detailed cost estimates are made which include each activity in the Work Breakdown Structures (WBS) structure and the Cost Breakdown Structures (CBS) structure are calculated by estimating the cost of each activity or the material price at that time. According to the calculation of the estimated cost of building a ship, the cost of the LCT vessel for new building and conversion schemes, including materials, construction services and procurement of 20 ft LNG ISO Tank, is US$ 4,199,543 and US$ 2,705,188. The prices are included 10% VAT.

In addition, since the generator in power plant can be operated both natural gas and oil fuel mode, diesel fuel is used as the safety stock in the power plant to mitigate if there is a delay in LNG distribution to the power plant. The storage for diesel fuel and the piping system has been considered in the calculation of CAPEX.

Table 5. Summary of CAPEX for both scenario

| CAPEX                      | Unit | Price Scenario 1 | Price Scenario 2 |
|----------------------------|------|------------------|------------------|
| LNG Distribution to Lombok Peak | set  | $ 18,290.869    | $ 18,744.569    |
| LNG Distribution to MPP Lombok | set  | $ 18,888.542    | $ 18,378.292    |
| LNG Distribution to Pemaron | set  | $ 12,575.145    | $ 12,098.825    |
| LNG Distribution to Gilimanuk | set  | $ 18,412.798    | $ 17,902.548    |
| **TOTAL**                  |      | **$ 68,167.354**| **$ 76,969.689**|

Table 5 presents the summary of CAPEX of LNG distribution to four power plants for both scenario, first scenario which is utilizing new building of LNG ships and the second scenario, the conversion of mini LNG carrier from LCT vessel. Based on Table 5, it can be concluded that there is no significantly difference price between two scenarios because cost of construction services and procurement of 20 ft LNG ISO Tank has major contribution in total cost. However difference of CAPEX value will be further analyze how much CAPEX affect to the NPV and IRR in economic analysis.

4.2. Operational Expenditure (OPEX)

OPEX consist of two major components, operational and maintenance cost of LNG receiving terminal and Mini LNG Carrier. The detail prices for all component in the operational distribution LNG are presented in Table 6 and Table 7 respectively. The operational costs of the receiving terminal consist of maintenance cost, operational cost and labor cost. The components of operational cost are included logistic cost, lant rent and power requirement at all receiving terminal. All the prices are determined based on the literature study. Operational and maintenance cost of mini-LNG carrier are the summed cost for all required number of mini LNG carrier in a year.
Table 6. Operational and Maintenance Cost of LNG Receiving Terminal

| O&M Cost of Receiving LNG Terminal | Maintenance Cost (US$/Year) | Operational Cost (US$/Year) | Labour Cost (US$/Year) | TOTAL (US$/Year) |
|------------------------------------|-----------------------------|------------------------------|------------------------|------------------|
| PLTMG Lombok Peaker                | 300,000.00                  | 3,501.103                    | 514.759                | 4,315.862        |
| MPP Lombok                         | 300,000.00                  | 1,552.759                    | 514.759                | 2,367.517        |
| Pemaron                            | 300,000.00                  | 2,182.414                    | 514.759                | 2,997.172        |
| Gilimanuk                          | 300,000.00                  | 3,365.172                    | 514.759                | 4,179.931        |
| Total                              | 1,386,0483                  |                              |                        |                  |

The operational and maintenance costs of this mini LNG carriers are all costs occurred during the operation of the LCT ship per year, including ship maintenance costs. The operational costs in LNG distribution consist of several things as listed in Table 7 and the total cost are included for all 7 mini LNG carriers.

Table 7. Operational and Maintenance Cost of Mini LNG Carrier

| O&M Cost of Mini LNG Carrier | Unit   | Value     |
|------------------------------|--------|-----------|
| Fuel Oil                     | US$/year | 5,804.848 |
| Lubricating Oil              | US$/year | 115.019   |
| Fresh Water                  | US$/year | 16.605    |
| Consumable cost              | US$/year | 204.828   |
| Port Service Fee             | US$/year | 65.604    |
| Maintenance Cost             | US$/year | 207.586   |
| Annual crew cost             | US$/year | 660.414   |
| Insurance and Administration Costs | US$/year | 338.738   |
| Total                        | US$/year | 7,413.641 |
| Total + margin 30%           | US$/year | 5,804.848 |

Based on the sum of operational and maintenance cost of LNG terminal and mini-LNG carrier, Table 8 shows a summary of the OPEX costs for each distribution route. There is no difference value of OPEX for both scenario because the operational and maintenance cost for either new built LCT and LCT conversion is same.

Table 8. The summary of OPEX

| OPEX                              | US$/year |
|-----------------------------------|----------|
| Benoa-Lombok Peaker-Benoa         | $ 6,609.552 |
| Benoa-MPP Lombok-Benoa            | $ 4,391.043 |
| Benoa-Pemaron-Benoa               | $ 4,700.767 |
| Benoa-Gilimanuk-Benoa             | $ 7,796.854 |
| Total                             | $ 32,450.782 |
4.3. PDB, NPV and IRR Calculation

In order to carry out economic feasibility studies of LNG distribution in this study, the economic models are conducted by given varies margins/expected profits earned from the sale of LNG to end customer. The scenario of economic calculation is performed by doing a variation of the expected sale price margin namely US$ 2 - US$ 4 with an increase of 0.5 USD.

Table 9. Revenue and Variation of margin rate.

| Revenue (USD/mmbtu) | Margin $ | Total |
|---------------------|----------|-------|
| $ 2,00              | 24,138,667 |
| $ 2,50              | 30,173,333 |
| $ 3,00              | 36,208,000 |
| $ 3,50              | 42,242,667 |
| $ 4,00              | 48,277,333 |

Finally, the NPV and IRR are calculated to ensure whether the LNG investment from the financial aspect is feasible. Figure 4 and Figure 5 display the payback period on the LNG investment estimate for both scenario with differing revenue margins. The graph of payback period shows that the larger LNG sale margin, the faster the payback period can be achieved. The payback period graph in Figure 4 shows that with a project duration of 10 years, investment capital can be fulfilled in 4 years at the earliest if the margin is USD 4. However, payback period calculation with margin USD 2 and USD 2.5 per MMBtu cannot be achieved in 10 years of project duration. For the scenario 2 as shown in Figure 5 presents that the payback period has sooner payback period to recover the cost of an investment. Both scenarios show that the margin USD 2 are not feasible because of longer paybacks but margin USD 2.5 still can provide benefits for the second scenario.

Table 10. IRR for both scenarios with different margin

| Margin | IRR (Scenario 1) | IRR (Scenario 2) |
|--------|------------------|------------------|
| $ 2,00 | -13,7%           | -13,3%           |
| $ 2,50 | -1,3%            | 3,0%             |
| $ 3,00 | 8,5%             | 14,0%            |
| $ 3,50 | 16,6%            | 23,4%            |
| $ 4,00 | 21,6%            | 29,5%            |

To get the profit, the NPV value must be positive in the 10th year, where the IRR value must be greater than the discount rate value. The project will be worth investing if the IRR is above 10% according the government's discount rate. Table 10 represents the summary of IRR for both scenarios for different margin variation. It shows that both scenarios will give benefits if the margin rate is set above USD 3.

According to some references, the margin rate of LNG distribution using small scale LNG is higher than large-scale LNG vessels due to the transportation cost. In the SSLNG vessels, the LNG price dropped into the range of USD 4 [5]. Therefore, focus on minimizing the cost for LNG vessels and design ISO tank can be alternative to reduce the transportation cost in SSLNG distributions to make the projects become feasible.
IRR can be used as a basis for determining the discount rate at which the present value of all future cash flows is equal to the initial investment. The higher an investment's IRR, the more desirable it is to carry on with the investment. Based on the result of NPV and discount rate, IRR for both scenarios with different margin are presented in Table 10. It shows that the scenario 2 has better profitability of investments due to lower investment of cost with the same margin.

Based on the IRR calculation, if the government set the discount rate is 10%, both the scenario 1 and 2 are still feasible if the margin rate is above 3 USD MMBTU.
Figure 6. Discount rate and net present value for economic analysis of scenario 1

Figure 7. Discount rate and net present value for economic analysis of scenario 2

5. Conclusion
This study presents the implementation of small-scale LNG supply chain by using conventional LCT to supply gas-fuel power plants which are located in remote area or in the limited depth of water level especially in east part of Indonesia, particularly in Lombok and Bali. The utilization of ISO tank to store the LNG then transport them using conventional LCT proves that it provides easier operational. The economic analysis was performed to convince whether the LNG distribution for power plants in Bali and Lombok will be worth investing. Finally, the result of the study can be concluded by utilizing small scale LNG with ISO tank, both scenarios is feasible for investment if the margin rate is above 3 USD/ MMBTU.
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