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Investment Analysis in Natural Gas Infrastructure Development for Nias Gas Engine Power Plant

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Abstract:*The Indonesian government has set policies of green energy in power generation to support global decarbonization issue towards net zero emissions. One of the policies was fuel-switching program of diesel fuel into natural gas (de-dieselization). Nias Island became one of the government's concerns for equitable access to electricity and accelerating the de-dieselization program through government's decree to provide natural gas infrastructure for the Nias Gas Engine Power Plant (PLTMG). This research performed the analysis of natural gas distribution logistics scheme by sea lane in the form of LNG and CNG from the Arun LNG Hub to look for the lowest transportation cost. The LNG distribution scheme included of LNG Carrier-onshore terminal, Mini FSRU and LNG ISO Tank, while the CNG distribution scheme was comprised of CNG Tube-Skid and Marine CNG. The result of calculation showed that the lowest transportation cost was $5.18/MMBtu by using LNG Carrier-onshore receiving terminal distribution scheme. The result of sensitivity analysis indicated that the crude oil price and the volume of natural gas transported are important factors which determine natural gas competitiveness compared to diesel fuel.*

Key Words*:De-dieselization, Small Scale LNG, Compressed Natural Gas, Investment Analysis, PLTMG Nias*

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I. Introduction

Government of Indonesia pays great attention inthe growth of electricityconsumption and equitable access of electricity to remote areas [1]. This commitment has been manifested in the strategic plan of increasing power plant capacity with consideration of decarbonization policies to comply with clean energy campaign.One of the policieswasfuel-switching programin order toreduce fuel oil and coal consumption and increase fuel gas utilization [2, Sec. 2.7].

Among the remote areas that were considered to be strategic wasNias Island. Nias Island became one of top priority area in the Bright Indonesia Program of enhancing electrification ratio [3].In 2019,the National Electricity Company(PLN) has completed the construction of a 5x5 MW gas engine power plant (PLTMG) [4], following by another gas-fired power plantsconstruction plan in the next few years to replace fuel oil-powered generators and to fulfill electricity demand growth in Nias Island [2, Sec. A.2].Therefore, it requires natural gas supply as main fuel.

Based on that condition, this study discusses the selection of natural gas distribution conceptsto the PLTMG Niaswhich are potential to be implemented. The key parameter set by the government was the cost of good sold of natural gas has to be lower than diesel fuel [5].The best scheme was selected based on the lowest transportation cost,so as resulting in better price than diesel fuel.

The aim of this study was to obtain the best logistic concept of natural gas supply to PLTMG Niasthat offers the lowest cost and economically feasible. In addition, this study was also aimed to get correlation of changes in the price of natural gas and the volume of natural gastransported against the end user price (plant gate), in order to identify the attractiveness of this projectwithin those changes.

II. Literature Review

Principally there are several concepts of natural gas transportation that can be used, such as gas pipelines, Liquefied Natural Gas (LNG), Compressed Natural Gas (CNG), and in the form of liquid derivative products such as methanol and DME [6, Sec. 5, pp-85]. LNG is natural gas which is liquefied by lowering the temperature of the gas to -162^{o}C at atmospheric pressure, resulting in volume reduction of around 1:600 [7, Sec. 1]. CNG is natural gas compressed to a pressure of 3600 psi. CNG volume reduction is around 1:200-300 [8]. CNG is an alternative to the high cost of making and transporting LNG, in the situations where there is a need to transport large volume of gas over relatively short distances (<1000 km) and out of gas pipelines coverage[6, Sec. 5, pp-96].

Based on that information, transporting natural gas to Nias Island can be done through several routes. The first is to build ±240 km land based and ±130 km offshore transmission pipelines from North Sumatra. However, this option requires expensive construction costs [7, Sec. 1]which caused this option uncompetitive. The second alternative use the concept of small-scale LNG (SSLNG). Since this concept is suitable for archipelagic area and scattered demand, the government of Indonesia is eager to implement this concept by establishing a program to accelerate the supply of LNG, in which PLTMG Niasis included [5].Several previous studies [9-14] have suggested thatthe SSLNG concept can produce competitive and economically viable tariff.The third option is CNG Marine concept, asthis concept has been implemented in several regions of Indonesia. According to Hadiwarsito [15], CNG Marine couldoffer competitive rate but require large amount of CAPEX.

Natural Gas Demand

The government of Indonesia through the Ministry of Energy and Mineral Resources (MEMR) Decree No. 13K/13/MEM/2020 [5] has set the PLTMG Nias as one of the strategic plansto accelerate de-dieselization program. The indicative volume of natural gas is 5.17 BBTUD.

Small Scale LNG

Smallscale LNG (SSLNG) generally refers to conventional LNG facilities with similar characteristics but in smaller size [14, Sec. 1]. The SSLNG value chain involves Small Scale LNG Carriers (SSLNGCs) as a means of transporting LNG to the destination point. SSLNGCsareconsidered as small scale because their capacity <30,000 m^3 and haveshallow-draft capability between 5-8 m [16, Sec. 3]. SSLNGC logistics were calculated using following equation:

$$t_{roun\,dtrip} = \left(\frac{L}{v} \times 2\right) + t_{loading} + t_{unloading} \tag{1}$$

$$min.V_{carrier} = \frac{Q_D}{0{,}9} \times t_{roundtrip} \tag{2}$$

$$t_{spare} = \frac{V_{carrier} - (Q_D \times t_{roundtrip})}{Q_D} \tag{3}$$

$$V_{storage} > V_{carrier} \times 1{,}2 \tag{4}$$

Where, Q_D is gas throughput (m^3/day), L is distanceof Aceh-Nias(NM), v is speed of ship (knots), $t_{roundtrip}$ is duration of the ship's cycle (days), $t_{loading}$/$t_{unloading}$ is loading/unloading time of ship at wharf (days), t_{spare} is inventory stock/gas reserve (days), $V_{carrier}$ is ship capacity (m^3), factor 0.9 is correctionfor carrier's capacity occupied by LNG, and $V_{storage}$ is onshore storage capacity (m^3).

Design concept of Mini Floating Storage and Regasification Unit (FSRU) is basically developedfrom a non-propelled barge with modifications on the deck for regasification facilities [17], so that the mini FSRU can carry out almost the same function as a land-based receiving terminal but in smaller capacity [10]. FSRU capacity is calculated through equationis as follows:

$$min.V_{storage\_FSRU} = (t_{spare} + t_{roundtrip}) \times Q_D \tag{5}$$

Where, Q_D is gas throughput (m^3/day), t_{spare} is inventory stock/gas reserve (days), $t_{roundtrip}$ is duration of the SSLNGC cycle (days).

According to Rachmadi [18], the LNG ISO Tank concept is practically used for land-based gas transportation in conditions of limited coverage of gas pipeline network, or uneconomical to develop gas pipeline because of scatteredlocation between the sources and end-users. The LNG ISO Tank is an IMO type C cryogenic pressure vessel mounted into an ISO standard frame, with varietyof length of 20, 30 or 40 ft[18]. Boil-Off Gas (BOG) that occurs in containers and holding time can be predicted using following approach: [18]

$$\%BOG = \frac{Q}{\rho_{LNG} \times V_{tank} \times H_{fg}} \tag{6}$$

$$Q = U_{insulation} \times A_{tank} \times (T_{ambient} - T_{LNG}) \tag{7}$$

Where, A_{tank} is the total heat transfer surface area of inner tank (m^2), $U_{insulation}$ is thermal conductance of the storage tank (W/m^2.K), $T_{ambient}$ is ambient temperature (^{o}C), T_{LNG} is LNG temperature (^{o}C), BOG is Boil-Off Gas (%), ρ_{LNG} is specific gravity of LNG (kg/m^3), V_{tank} is capacity of LNG tank (m^3), H_{fg} is heat of evaporation (kJ/kg), and Q is heat transfer rate to the tank (kJ/s). Then the %-BOG obtained becomes the input for the next formulation is as follows:

$$T = T^0 + \left[H - \frac{(M_l h_l \times T^0) + (M_g h_g \times T^0)}{(M_l Cp_l + M_g Cp_g)}\right] \tag{8}$$

Where, T is LNG saturation temperature at certain pressure (^oC), T_0 is LNG saturation temperature at initial pressure (^oC), M_l is liquid mass (kg), M_g is gas mass (kg), H_l is liquid enthalpy (kJ/kg), H_g is gas enthalpy (kJ/kg), C_{pl} is liquid heat capacity (kJ/kg.^oC), and C_{pg} is liquid heat capacity (kJ/kg.^oC).

Compressed Natural Gas (CNG)

The basic principle of CNG is storageof natural gas in tubes or vessels at high pressure and ambient temperature. In general, CNG vessel pressure is designed for 250 bar at ambient temperature. CNG can be distributed by land and sea. Distribution on land routes (CNG Terrestrial) use truckmounted CNG or CNG trailers. Meanwhile, sea lanes (CNG Marine) use ships with special designs. CNG logistics are calculated using following equation:

$$t_{roundtrip} = \left(\frac{L}{v} \times 2\right) + t_{loading} + t_{unloading} \quad (9)$$

$$t_{loading} = \frac{V_{skid}}{Q_{compression}} \quad (10)$$

$$t_{spare} = \frac{(N_{skid} \times V_{skid}) - (Q_D \times t_{roundtrip})}{Q_D} \quad (11)$$

$$N_{skid} = \frac{Q_D}{V_{skid}} \times \left(t_{roundtrip} + t_{spare}\right) \quad (12)$$

Where, Q_D is gas throughput (mscf/day), L is distance of Aceh-Nias (NM), v is speed of ship (knots), $t_{roundtrip}$ is duration of the ship's cycle (days), $t_{loading}/t_{unloading}$ is $_{loading}/_{unloading}$ time of the ship at wharf (days), t_{spare} is the inventory stock/gas reserve (days), V_{skid} is container capacity (mscf), and N_{skid} is number of tube-skid (units), and $Q_{compression}$ is gas required during compression (mscf/day).

The CNG compression power requirement is calculated using following approach:[19]

$$ICFM = SCFM \frac{P_{std}}{P_s} \frac{T_s}{T_{std}} \quad (13)$$

$$R = {P_d}/{P_s} \quad (14)$$

Single-stage: $$VE\% = 93 - R - 8\left(R^{1/n} - 1\right) \quad (15)$$

Two-stage: $$VE\% = 89 - R - 7{,}8\left(R^{1/2n} - 1\right) \quad (16)$$

$$PD = {ICFM}/{VE} \quad (17)$$

Single-stage: $$BHP = 0{,}00528\left({n}/{n-1}\right)(P_s)PD\left(R^{(n-1)/n} - 1\right) \quad (18)$$

Two-stage: $$BHP = 0{,}00528\left({2n}/{n-1}\right)(P_s)PD\left(R^{(n-1)/2n} - 1\right) \quad (19)$$

Where, ICFM is inlet volume in cubic feet per minute, SCFM is inlet volume in standard cubic feet per minute, P_{std} is standard pressure (14.7 psia), P_s is suction pressure (psia), P_d is discharge pressure (psia), T_{std} is standard temperature (520 ^oR), T_s is suction temperature (^oR), R is compression ratio, n is gas specific heat ratio, PD is piston displacement (CFM), VE is volumetric efficiency, and BHP is brake horsepower.

CNG refrigeration power requirements are calculated through the following approach:

$$M_g = \frac{Q_g \times SG_g \times 0{,}0763}{24} \quad (20)$$

$$T_d = T_s R^{(n-1)/n} \quad (21)$$

$$Q_R = M_g \times Cp \times \Delta T \quad (22)$$

$$Q_{ch} = {Q_R}/{12000} \quad (23)$$

Where, M_g is mass gas flowrate (lbm/hr), Q_g is volumetric gas flowrate (MMscfd), SG_g is gas specific gravity, factor 0.0763 is air density at standard condition (lbm/ft^3), T_d is discharge temperature (^oR), T_s is suction temperature (^oR), R is compression ratio, n is gas specific heat ratio, Q_R is heat duty (BTU/hr), Cp is average gas specific heat (BTU/lbm.^oF), ΔT is temperature difference (^oF), Q_{CH} is heat duty in ton refrigeration (1 ton = 12000 BTU/hr), and Q_g is heat duty (BTU/hr).

Economic Assessment

The economic feasibility assessment used microeconomic analysis indicators, namely Net Present Value (NPV), Internal Rate of Return (IRR), and Payback Period (PBP). In addition, comparison was also made to the price of fuel oil to determine the competitiveness of natural gas. The price of fuel oil was estimated through the following approach: [18]

$$Pp_{intl} = \frac{P_{CO} \times F_{PT}}{159} \quad (24)$$

Where, Pp_{intl} is international fuel price (USD/liter), P_{CO} is Indonesian price of crude oil (ICP) (USD/bbl), and F_{PT} is processing and transportation factor (1.427 for diesel).

III. Research Methods

Literature Study

The literature study was carried out to find out the natural gas distribution model that can be applied in the archipelago area, especially Nias Island. Materials were obtained from textbooks, scientific papers, academic journals, study reports, and previous research. The main focus of the study was on supply chain schemes using small scale LNG and CNG by sea lane.Distributionpattern for this case was using point to pointscheme. The scheme started from the same point, namely Lhokseumawe City, Aceh, where the Arun LNG Hub located.The destination was PLTMG Nias which is located on the east coast of Nias Island, GunungSitoli City, North Sumatera. The travel distance between Lhokseumawe City and Nias Island is estimated to be around 905 km or equivalent to 488.7 nautical miles (NM).

Based on this information, 5 distribution logistics scenarios wereproposed to be simulated, namely: 1) Small scale LNG Carrier – onshore receiving terminal, 2) Small scale LNG Carrier – mini FSRU, 3) LNG ISO Tanks,4) CNG Tube Skids, 5) Marine CNG. The illustration for each scenario can be seen in Figure 1.

Data Collection and Assumptions

This stepconsisted of data collection activities. The data was obtained from published report, scientific papers, academic journals, previous research, government regulations, articles and websites on the internet, as well as defining the necessary assumptions.

Design of Natural Gas Transportation Facility

At this step, technical and costcalculations were carried out for each of scenarios. Technical calculations consisted of transport capacity, roundtrip, number of trips, number of ship operationdays, storage and regasification capacity, BOG in ISO Tanks, CNG compression and refrigeration duty, and other supporting facility. The storage capacity was designed with consideration of inventory stock to ensure the continuity of plant operations and anticipate delays in the delivery of natural gas. According to Michael [10], recommended inventory stock is minimum of 10 days of normal operation. SSLNGC technical data is shown in Table 1[20].

The cost calculations were conducted using levelized cost method,involvingthe components of shipping cost, construction of facility cost (CAPEX) and operational cost (OPEX). The component of shipping cost was consisted of charter cost of SSLNGC, ship fuel, rental cost of ISO Tank or CNG Skid, charter cost of cargo ships, and rental cost of mobile cranes & trailer trucks. The terminal cost wascomprised of rental cost of the Arun LNG Hub facility, charter cost of FSRU, capital cost of LNG Filling Stationconstruction, capital cost of CNG Plantconstruction, and capital cost of Nias receiving terminalconstruction. Operational cost was composed of port charges, operation andmaintenance costof facility, and company overhead. CAPEX wascalculated through the following equation [6, Sec. 6] with exponential factor of 0.6.

$$Cost\ B = Cost\ A \times \left(\frac{Cap\ B}{Cap\ A}\right)^{0,6} \quad (24)$$

Economic Analysis

Economic feasibility was determined by using indicator of NPV, IRR, and PBP obtained from cash flow calculations involving CAPEX, OPEX, insurance cost, tax and depreciation. The calculations were conducted to obtain tollingprice of gas transportation services within expected value of IRR. This tolling price was then considered to be the gas transportation cost.The gas transportation costwas then added up with the purchase price of natural gas to estimate end-user price (plant gate). The best scenario was chosen based on the lowest plant gate price.

Database used for calculations were: project duration (operational) was 20 years, project construction was 24 months with capital cash-out divided into25% of first year and the rest in second year, number of operating days was 360 days/year, currency exchange rate was Rp 14,350/$[21], equity funding was 60% by corporate financing, IRR was targetedof 12%, slope of LNG price (FOB) was 12% ICP, ICP price was $ 63/bbl[21], natural gas price (well head) was $5.5/MMBTU[22], calorific value of LNG & natural gas was 252,000 kcal/mscf[2, Sec. 5.5], HSD calorific value 9,100 kcal/liter [2, Sec. 5.5], OPEX was 2.5 % of CAPEX, OPEX escalation was ±2% per year according to inflation rate, income tax was 25%, insurance was 1%, and depreciationusedstraight-line-depreciation method.

Sensitivity Analysis

This simulationwas carried out to review changes onthe most influential variablesto enduser price, and also to find out the boundariesthat madethis business still economically attractive. Those variables were price of natural gas and volume of gas transported. The natural gas price was a formulation of crude oil price (ICP),while the volume of gas transportedwould affect transportation cost.

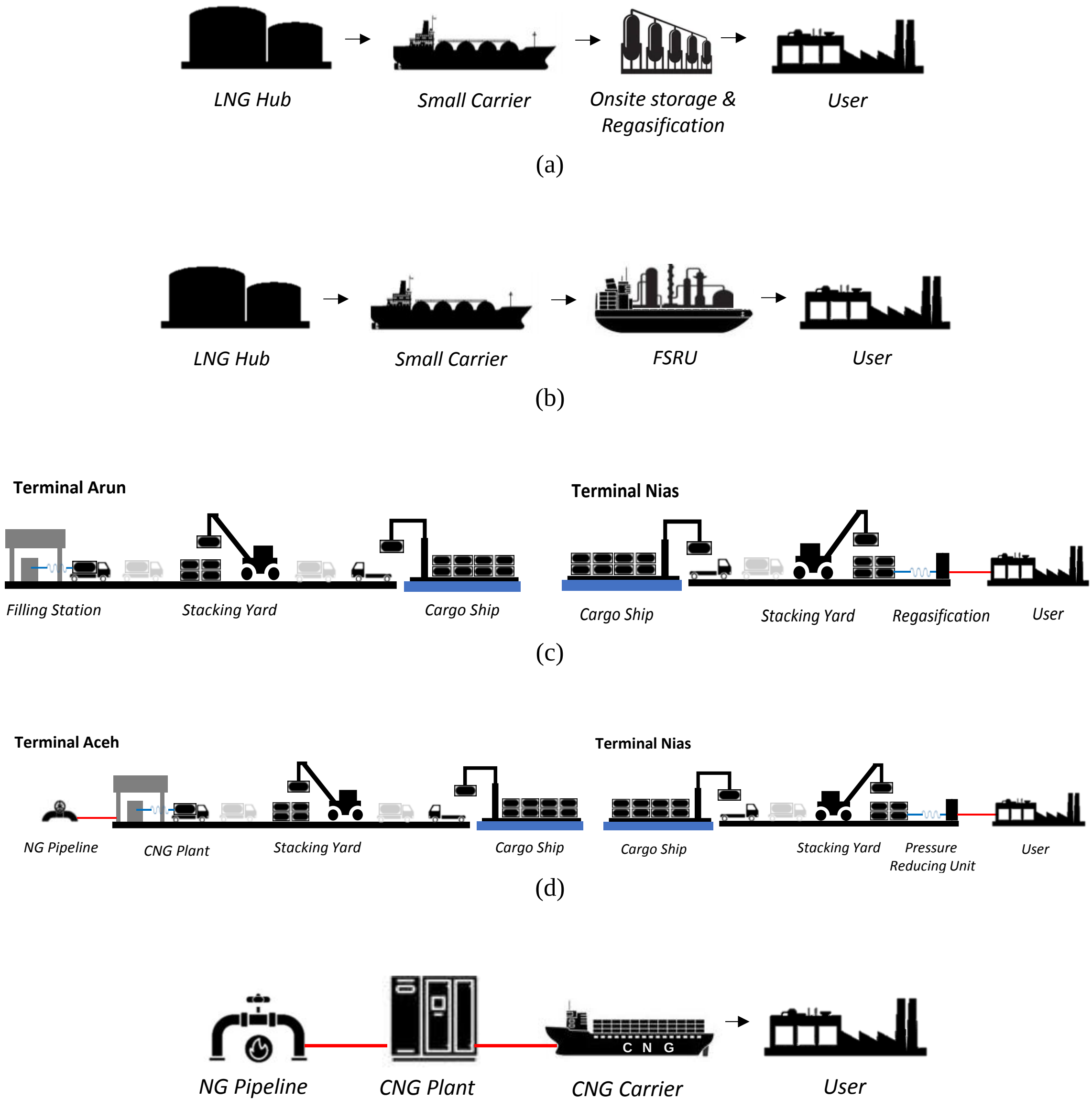

Figure1: DistributionScenarios of (a) Small scale LNG Carrier – onshore receiving terminal, (b) Small scale LNG Carrier – mini FSRU,(c) LNG ISO Tanks, (d) CNG Tube Skids,(e) CNG Marine

Tabel 1: Specificationof SSLNGC

Detail	Unit	*LNG Carrier*			
		Kakurei Maru	**Akebono Maru**	**Coral Anthelia**	**Coral Methane**
Capacity	m^3	2.536	3.556	6.500	7500
Length Overall (LOA)	m	86,3	99,4	115,0	117,8
Breadth	m	15,1	17,2	16,8	18,6
Draught	m	4,3	4,8	6,8	6,7
Avg. Speed	knot	11,4	11,7	9,5	9,5
LNG *transferrate*	m^3/jam	2x370	2x370	3x270	2x450

IV. Resultand Discussion

Logistics and Infrastructure Evaluation

The result of technical calculations in logistics and infrastructure can beseen in Table 2, while the result oflevelized costs calculation can be seen in Table 3.

In the first scenario, namelySSLNGC–onshore receiving terminal, the main factor that determines logistics efficiency was ship capacity. According to Budiyanto[23], design capacity of SSLNGC that should be considered wasbetween 2,500 – 10,000 m^3 because it has relatively small draft (4-7 m) so thatmaking it suitable for shallow waters. Therefore, this study considered capacity of 2500 m^3, 3500 m^3, 6500 m^3 and 7500 $m^3$to be simulated.

The result of simulation shows that the greater the capacity of ship,would reduce the number operation days of the ship, which had positive impact on reducing the rental cost of ship in timecharter scheme. In the other side, this also made positive impact in providingsecurity of gas supply to power plantdue to high inventory stock. The consequences of larger vessel capacity were higher charter rate and alsohigher CAPEX. Based on levelized cost calculation, the most optimal cost was obtained by using ship capacity of 7500 m^3.

In the SSLNGC–mini FSRU scenario, the capacity of mini FSRU needs to be determined in advanceusing simple stock calculation as follow: (10 days required inventory stock + 5 days travel time) x gas throughput of 225 m^3/day = 3,375 m^3.Based on market availability, FSRU capacity of 5,000 m^3 was chosen [24]. Furthermore, simulation of SSLNGC with capacity of 3500 m^3 and 6500 m^3 then carried on. The result was the most optimal cost obtained by using ship of 6500 m^3 capacity but with LNG load only 4500 m^3 due to limitationof mini FSRU storagecapacity.

From levelized cost calculation, it can be shown that mini FSRU concept does not require large amount of CAPEX compared to previous scenario. However, OPEX would increase due to the addition of FSRU rental expenseswhich caused higher overall transportation cost compared to previous scenario.

In the LNG ISO Tank scenario, 2 types of ISO Tank size, namely 20-ft and 40-ft,were simulated. The result of simulation shown that the most optimal cost was obtained using 40-ft ISO Tank, resultingtotal required containments were83 cargoes per cycle. The usage of larger cargo size would result in higher efficiency in LNG filling process and load/unload cargoes, and less area of stacking yard. The large amount of cargoeshas raised consequence of tight scheduling of ISO Tank filling so that the filling operation of all the tanks should be completed before the arrival of next cargo ship. Thus, sufficient LNG filling dispenser, trailers, and mobile craneswere needed.From BOG calculation, the ISO Tank holding time was higher than durationof ISO Tank consumption, which is around 17 days, so that BOG venting was not expected to occur.

The CNG Tube Skid scenario is similar with the LNG ISO Tank scenario. Learning from previous result that larger natural gas containment will make the transportation cost more efficient, then in this scenario large capacity of tube-skid will be used, namely 40-ft in size containing 12 tubes.Of the calculation made, the required containments of CNG were284 skids per cycle.This amount was three times greater than LNG cargo due to differences in basic characteristics of LNG and CNG, where LNG can produce a volume reduction of 1:600 while CNG is 1:200-300. This large number of cargoes causedhighershipping cost, and generate expensive transportation cost. In other words, CNG Tube Skid scheme is uneconomical scheme for inter-island gas transportation due to huge logistical burden.

In the CNG Marine scenario, the ship capacity was designed according to the needs of gas to be transported with the addition of desired stock inventory.The calculated capacity was 120,000 mscf or equivalent to 3.2 MNm^3. Through this scheme, the logistical burden of CNG containment can be reduced, resulting in lower transportation cost than the CNG Tube Skid scheme.

Another factor that needs to be addressed in CNG scenario is availability of natural gas supply during compression. From this study, a minimum of 17 MMscfd gas supply from natural gas pipelines is mandatory requirement during the compression so that ship scheduling runs smoothly. Moreover, it also has the potential to disrupt the stability of pipelines network due to unbalance supply during compression. Thus, mitigation plans to accommodate smooth gas compression were needed.

Economic Evaluation

The cash flow calculation was carried on with expected value of 12% IRR. The cash flow calculation result can be seen in Table 4, while the result of price calculation at the plant gate is presented in Table 5.According to Table 4, all the transportation scenarios could generate positive value of NPV, and PBP would be obtained before the end of project. At this point, all the scenarios are considered to be economically feasible at the price of gas transportation services in accordance with the transportation cost listed in Table 5.

Furthermore, price comparison with HSD can also be done.HSD price calculation at ICP of $63/bbl yielded a value of $15.66/MMBTU. From Table 5, there was a considerable price gap between LNG and CNG. Even though it was supported by lower gas prices, the cost of CNG's logistics were still too high for inter-island gas transportation, which caused the plant gate price higher than HSD. On the other hand, the plant gate price with LNG scenarios were lower than HSD because of better volume reduction characteristics.

Tabel 2: Resultof Logistic and Facility Design Calculation

Item	Unit	LNG			CNG	
		SSLNGC-ORT	**SSLNGC-FSRU**	**ISO Tank**	**CNG Skid**	**Marine**
Logistic Simulation						
Capacitydesign/effective	m^3 (LNG) ormscf (CNG)	7,500 / 6,750	6,500 / 4,500	52.2 / 47.0	293.3	120,000
Number of containments	Unit			83	284	
Number of ships	Unit	1	1	1	3	2
Travel time	Days	4.29	4.29	5.09	4.07	4.07
Loading time	Days	0.52	0.44	0.74	0.83	6.70
Unloading time	Days	0.52	0.44	0.74	0.83	21.64
Roundtrip	Days	5.33	5.17	6.58	5.72	32.40
Number of trips	Trip/year	12	18	21	23	9
Service period	Days/year	64	93	139	132	292
Inventory stock	Days	24.7	14.8	10.7	10.4	10.7
LNG Facility						
Onshore Storage	m^3	8 x 1,000				
Onshore Vaporizer	SCFH	8 x 32,000		8 x 32,000		
BOG	%			1.15		
Holding time	Days			23		
Filling Dispenser	Unit			5		
Duration of Filling	Days			5.8		
CNG Facility						
Required Inlet Volume of Compressor	MMscfd				17.0	17.0
Duration of Compression	Days				4.9	6.5
Compressor Duty	BHP				2 x 1,461	2 x 995
Refrigeration Duty	Ton Refrigeration					987

Tabel 3: Result of Levelized Cost Calculation

Item	Unit	LNG			CNG	
		SSLNGC-ORT	**SSLNGC-FSRU**	**ISO Tank**	**CNG Skid**	**Marine**
Shipping Cost	USD/year	2,226,025	3,023,005	6,458,467	39,956,378	18,651,888
Terminal Cost	USD/year	5,387,776	9,011,663	3,553,393	3,160,366	3,793,990
Operational Cost	USD/year	964,705	781,408	1,048,308	2,546,190	1,078,177
Total Cost	USD/year	8,578,506	12,816,076	11,060,168	45,662,935	23,524,056
Total Cost per unit	**USD/MMBTU**	**4.609**	**6.886**	**5.942**	**24.534**	**12.639**

Table4: Result ofCash Flow Calculation

Item	Unit	*LNG*			*CNG*	
		SSLNGC-ORT	**SSLNGC-FSRU**	**ISO Tank**	**CNG Skid**	**Marine**
CAPEX	USD	23,294,293	9,025,943	21,960,034	23,606,179	28,338,997
Cash Flow						
Revenue	USD/year	9,636,394	12,278,562	12,074,276	46,931,125	24,800,270
Avg. OPEX	USD/year	5,653,277	11,764,332	8,330,327	43,012,971	19,946,194
Avg. Insurance	USD/year	122,295	47,386	115,290	123,932	148,780
Depreciation	USD/year	1,164,715	451,297	1,098,002	1,180,309	1,416,950
Earning before Tax	USD/year	2,696,108	1,015,546	2,530,658	2,613,912	3,288,347
Economic Indicator @IRR 12%						
NPV	USD	3,994,225	1,528,884	3,751,892	3,935,033	4,873,648
PBP	Years	13.73	13.52	13.71	13.46	13.74

Table5: Result ofEnd User Price (Plant Gate)Calculation

Item	Unit	LNG			CNG	
		SSLNGC-ORT	**SSLNGC-FSRU**	**ISO Tank**	**CNG Skid**	**Marine**
Purchase price	USD/MMBTU	7.56	7.56	7.56	5.70	5.70
Transportation Cost	USD/MMBTU	5.18	7.13	6.49	25.22	13.32
Plant Gate Price	USD/MMBTU	12.74	14.69	14.05	30.92	19.02

Sensitivity Analysis

Figure 2 shows the result of simulation on changes in ICP price against the natural gas and HSD price at the plant gate. As ICP price increased, the gap between natural gas and HSD prices would also getting bigger. This means that high ICP price could be a driving factor to increase the proper use of natural gas in savingfuel expenses. Breakeven point converged at ICP price of around $39.60/bbl. Below this point, natural gas price at the plant gate would potentially higher than HSD. Thus, mitigation plans to reduce purchase price of natural gas have to be considered for the purpose of maintainingnatural gas competitiveness and sustainability of de-dieselization program.

Sensitivity on changes in gas volume transported against plant gate price can be seen in Figure 3.Higher volume could reduce distribution cost, which in turn would lower the price at plant gate. Breakeven point was at volume around 3.2 MMscfd. Below this point HSD was considered muchbetter than natural gas. This means that it is necessary to simulate another scenario to generate lower transportation cost.

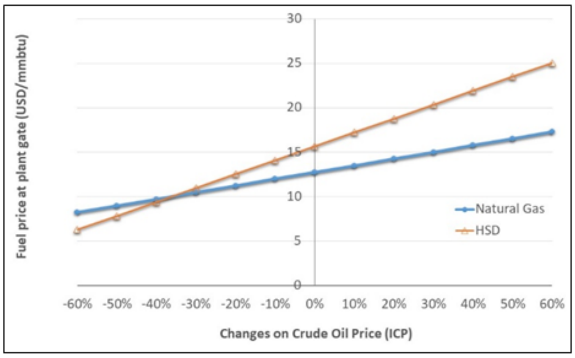

Figure 2 Correlation of Changes on Crude Oil Price/ICP Against Plant Gate Price

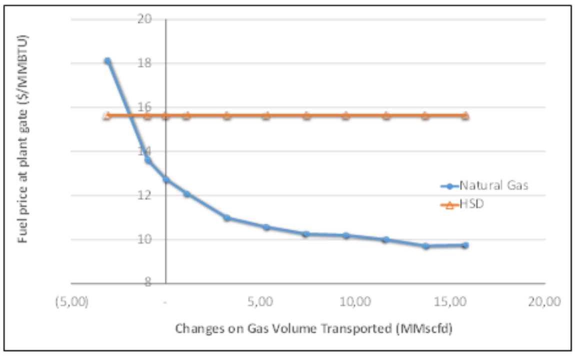

Figure 3 Correlation of Changes on Gas Volume Transported Against Plant Gate Price

V. Conclusion

Based on the technical and economic analysis, it can be concluded that the supply of natural gas to the Niaspower plant can be achieved using LNG or CNG in 5 distribution logistics schemes. The scheme that offers the lowest transportation costs was SSLNG Carrier and onshore receiving terminal facility at cost of $5.18/MMBTU, with economic feasibility of 12% IRR, 13.73 years PBP and $3,944,225 NPV at the end of project.

The sensitivity analysis shows that the price of natural gas was highly dependent on the price of crude oil (ICP), while the volume of natural gas transported was the most influential factor in determining transportation cost. Every 10% increase in the ICP would result in 6% increase ofthe end userprice (plant gate), and vice versa. Meanwhile, an increase in the volume of natural gas transported would result in exponential decrease of the plant gate price, towards $10/MMBTU at transported gas volumes ≥12.5 MMscfd.These two parameters determine the competitiveness level of natural gas against diesel fuel.

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