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Determination of LNG Supply Chain and Estimation of LNG Economical Price for Locomotives in Java Island

Mirza Mahendra[a], Fiqi Giffari[b], ParamitaWidiastuti[b], &D.A. Ismukurnianto[a]

[a]Directorate General of Oil & Gas, Indonesia
[b]PPPTMGB "Lemigas", Indonesia

*mirza_mahendra@yahoo.com&fiqigiffari.11@gmail.com

Abstract: Natural gas is one of fuel utilization alternatives besides diesel. As a country that has a huge amount of natural gas reserves, Indonesia should utilize its fuel optimally. In addition, gas fuel for trains (locomotives) is more environmentally friendly compared to locomotive diesel fuel. The goal of this study is to conduct supply chain analysis of fuel in Java Island – Indonesia, through cash flow modeling system. This system will be applied for locomotive fuel usage that is efficient, effective and economical. The methodology of this study is conducting survey to calculate demand data and existing facilities, estimating the investment cost which is needed to apply LNG technology in the rail sector (locomotives), and conducting simulation of economical calculation to get the fee for each supply chain. Based on calculation, diesel consumption for train sector in Java Island is 162,961 KL per year or equivalent to 8.80 MMSCFD of natural gas consumption. The pattern of LNG distribution on the supply chain for locomotive sector that is suitable to be applied in Java Island consists of two types, LNG distribution pattern using LNG resource from outside or inside Java Island (by constructing mini LNG plant). By doing economical calculation, the result of LNG price for the train (locomotive) sector ranges from 19.51 to 26.51 US$/MMBtu, depending on distribution pattern type and conversion percentage.

Keywords: LNG, locomotive, supply chain

1. Background

Trains have more energy efficiency compared with other modes of land transport due to its ability to transport passengers in large numbers. The following table shows the comparison of fuel consumption per person of several modes of transportation

Table 1: Energy Consumption in Various of Transportation Modes

No	Transportation Mode	Capacity (man)	Energy Consumption (1/km)
1	Train	1500	3 liter
2	Bus	40	0,5 liter
3	Flight	500	40 liter
4	Ship	1500	10 liter

Source: Directorate General of Railways Ministry of Transportation 2012

PT Kereta Api Indonesia (KAI) is the only company that operates trains in Indonesia. In 2012, PT KAI fuel consumption reached 170,000 kiloliters and increased 9 % in 2013 as a result of operational improvement. As the quality of service of PT KAI increased, operational related consumption and fuel consumption also rose.

This need has to be anticipated by finding and developing new alternative fuel usage for freight trains. Liquid Natural Gas (LNG) is an alternative fuel which is worth to be considered because the level of its production in the country is quite high. This study was conducted to determine the pattern of LNG supply chain for railwaysthat iseligible to be applied in Indonesia, especially in Java Island by using the approach of economical calculation for infrastructure development.

2. Methodology

Methodology which is conducted in this study consists of six phases:

1. Data collection.

   Data was collected from stakeholders that areassociated with the operation of trains and ~~the~~ utilization of LNG in Indonesia. These stakeholders consist of:

   - Ministry of Energy and Mineral Resources
   - Ministry of Transportation
   - PT Kereta Api Indonesia (KAI)
   - PT Pertamina
   - PT PGN
2. Technology Review (Literature Study)

Based on literature study, utilization technology of LNG for locomotives isproven and implemented in other countries. Generally, the utilization technology of LNG for train uses tender cars as LNG storage. LNG in the storage will be transported using cryogenic pump to the vaporizer. In the vaporizer, LNG in liquid phase will transform into natural gas in vapor phase. The transformation process will significantly increase the pressure (nearly 200 bars). Before natural gas enters the combustion chamber, the pressure will be reduced byusing a valve. The process in the combustion chamber is nearly same with natural gas combustion process. The process is illustrated in the following Figure 1.

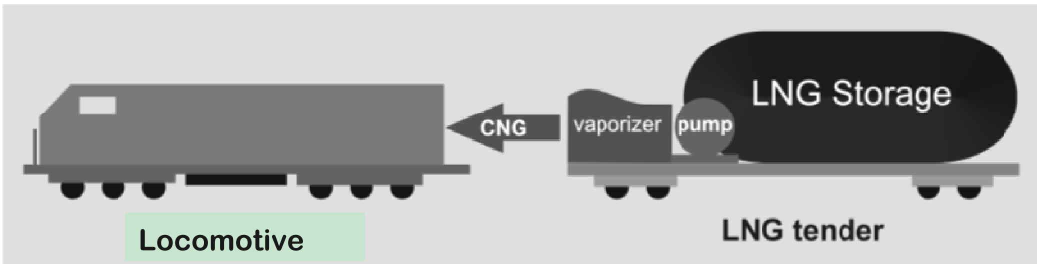

Figure 1. LNG Tender for Trains (locomotives)

The effect of tender car installation in trains causes the weight of trains to increase significantly. The increase of weight means that not allrailways areeligible for this technology.

1. Estimation of Potential LNG Demand

   Due to the weight problem of LNG tender cars, tracks that are eligible for implementation of LNG fueled locomotives include:

   - The north track of Jakarta – Surabaya
   - The south track of Yogyakarta – Surabaya
2. Demand of LNG will be separated based on working operation of PT KAI in which the availability of eligible tracks is considered as a constraint. As a result, the region of LNG demand comprises:
   - Region of Jakarta
   - Region of Cirebon
   - Region of Semarang
   - Region of Yogyakarta
   - Region of Madiun
   - Region of Surabaya

Demand of LNG is estimated based on locomotive consumption of High Speed Diesel (HSD) using the following basic assumptions:

- Heating value of LNG is 1.000 btu/scf
- Calorific value of equality : 1 kiloliter of HSD = 0.0364 mmscf natural gas
- There are two scenarios to implement LNG technology:
  - Converting all locomotives using dedicated gas engines
  - Using converter kits for all ~~of~~ locomotives which decreases demand to 80% compared to full dedicated demand
- Equation to estimate demand of LNG/Gas

$$LNG\ Demand = HSD\ consumption\ \times Caloric\ value\ of\ equality$$

1. Determine the pattern of LNG supply chain for locomotives and infrastructure development capacity.
   The pattern of LNG supply chain for locomotives is determined based on the LNG source in which the availability of locomotives and gas facilities is considered as a constraint. The infrastructure facilities which are being considered as constraints to determine the pattern of LNG supply chain consist of:
   - Domestic Train station
   - Domestic Train Depot
   - Domestic LNG plant
   - Domestic LNG Receiving Terminal

   Afterward, the infrastructure development capacity is calculated by considering technical aspects and estimating previous LNG demand.

2. Economic calculation for infrastructure development.
   Phases for conducting economic calculation include:
   - Estimating the capital expenditure (capex) and operational expenditure (opex)
   - Simulating cash flow calculation to estimate economical product price
3. Determine LNG economical price structure for locomotives

3. Result and discussion

Potential demand of LNG/gas which is calculated during the study is8.80 mmscf for full dedicated scenario and 7.04 mmscf for retrofit scenario (80% converted). The following table shows potential demand of LNG/gas for each region:

Table 2: Potential LNG Demand

REGION	FULL DEDICATED (MMSCFD)	RETROFIT (80:20) (MMSCFD)
JAKARTA	3.54	2.84
CIREBON	0.55	0.44
SEMARANG	0.49	0.39
YOGYAKARTA	1.14	0.91
MADIUN	0.31	0.25
SURABAYA	2.77	2.22
TOTAL	**8.80**	**7.04**

There are 2 patterns of LNG supply chain for locomotives that are feasible to be applied in Indonesia:

- Sources from outside Java island

In this pattern LNG will be provided from outside Java Island. The potential sources of LNG include existing domestic LNG plants and imported LNG from spot markets. LNG from these sources will be

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transported using LNG Tankers to LNG Depots or LNG Receiving Terminals. LNG Depots will distribute LNG by using trailers to LNG Locomotive Stationswhich are installed near the train depot. This pattern needs additional infrastructure to be applied such as:

- LNG Depots, infrastructure serves as a repository of LNG sourced from outside the island of Java.
- LNG Locomotive Station, infrastructure serves as LNG filling station for train tender cars.

The advantage of this pattern is the ease of implementation, because Indonesia already has a domestic LNG plant with sufficient production. The disadvantage of this pattern is the security of supply, because generally domestic LNG plants havegas sales contracted, so that the possibility of acquisition of LNG supply from domestic plants is relatively small. The other source to obtain LNG in this pattern is importing LNG from LNG plants abroad, but being heavily dependent on imports will result in a decrease of security of energy supply. If there are gas sales contracts of domestic LNG plants that will expire in the near future then the government must create policies to drive the next gas sales contract of domestic LNG plants forthe railsector. The following figure illustrates the LNG supply chain using sources outside of Java Island.

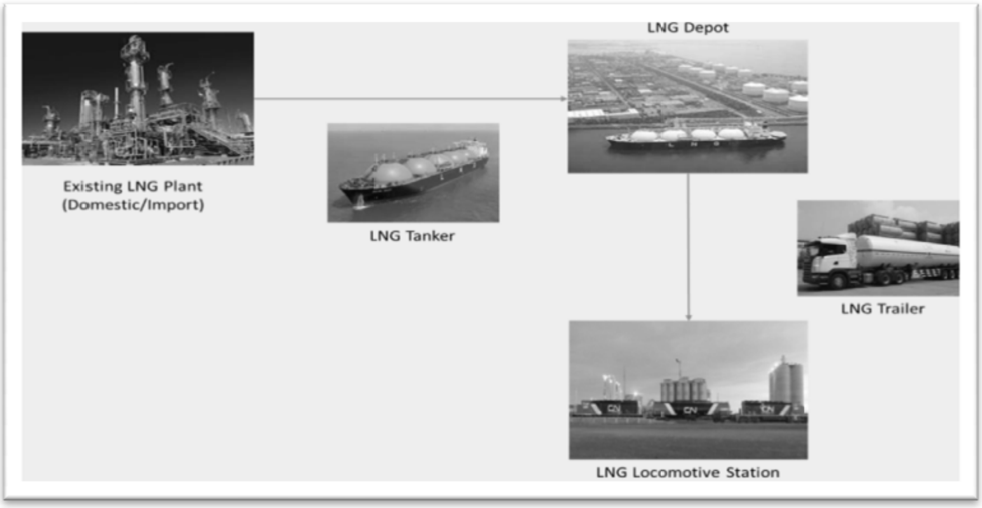

Figure 2. LNG Supply Chain using Sources Outside of Java Island

- Source from inside Java Island

In this pattern LNG will be provided from sources inside Java Island. The sources includenew mini LNG plants thatwill be developed in Java Island. LNG from new mini LNG plants will be distributed directly to LNG locomotive stations using LNG trailers. This pattern needs additional infrastructure to be applied such as:

- LNG mini plants
- LNG locomotive stations

The advantage of this pattern is higher security of energy supply and the simplicity of the supply chain structure compared to other options. The disadvantage of this pattern is the difficulty of implementation compared to other options, because building new mini LNG plants needs more time than building LNG depots. The following figure illustrates the LNG supply chain pattern usingsources inside Java Island.

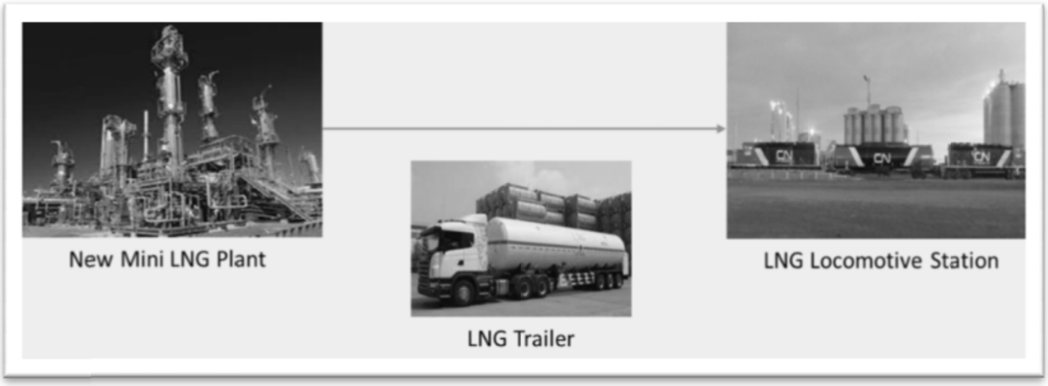

Figure 3. LNG Supply Chain using Sources Inside Java Island

The capacity of LNG distribution infrastructure is estimated by considering demand and existing gas distribution facilities. The following table informs the capacity of LNG infrastructure.

Table 3: Capacity of LNG Infrastructure

LNG Supply Chain Pattern	Capacity (mmscfd)			
	LNG Plant	LNG Depot	LNG Filling Station	
			I	II
Outside Island	0	40	5	5
Inside Island	8	0	5	5

The next phase is the economiccalculation for infrastructure development. The capital expenditure (capex) and operational expenditure (opex) estimation is made for each infrastructure. Furthermore, cash flow calculation to estimate economical product price is simulated. These economic calculations are based on the LNG supply chain patterns that have been determined in the previous phase.

First, economic calculation is done for the outside Java pattern. The pattern which LNG will be provided from sources outside of Java Island needs LNG Depots and LNG Locomotive Stations as additional infrastructure. Hence, economic calculation is conducted for each infrastructure. The estimated capex of anLNG Depot is $ 117.67 Million and estimated opex is $ 1.47 M (Table 4).Using the estimated investment, thus cash flow calculation of LNG Depot infrastructure is conducted. The result of this calculation is described in Table 5. Compared to an LNG Depot, the estimation of capex and opex for an LNG Locomotive station are lower. The estimation of capex is $ 9.38 M and opex is $ 0.26 M (Table 6). Afterward, the cash flow of Locomotive Station infrastructure is calculated (Table 7).

Second, the economics of the other pattern is also calculated. The other pattern is inside Java pattern which LNG will be provided from sources inside Java Island thus needing additional infrastructure that includes LNG plants and LNG Locomotive Stations. The result of capex estimation for an LNG plant is$ 55.05 M and opex is $ 2.19 M (Table 8). The estimated capex of LNG plants is lower than LNG Depots. Meanwhile, the estimated opex of LNG plants is higher than LNG Depots. Economic Indicator of LNG Plant is showed in Table 9.

Table 4: Economic calculations for LNG Depot / Receiving Terminal

CAPEX and OPEX ESTIMATION for LNG Receiving Station		
CAPEX Estimation		
Description		Cost (million US$)
LNG Receiving Terminal Construction Cost		115.34
Pre-operation Cost		0.37
Initial Working Capital		1.69
Land Acquisition Cost		0.26
	TOTAL	117.67
OPEX Estimation		
No		Cost (US$/MMBTU)
Utility Costs (at Full Operation)		0.17
Manpower Costs (at Full Operation)		0.10
Overhead & Management Costs (at Full Operation)		0.10
Marketing Costs (at Full Operation)		0.61
Maintenance Costs (at Full Operation)		0.24
Insurance Costs (at Full Operation)		0.24
	TOTAL	1.47

Table 5: Economic Indicator of LNG Depot for Full dedicated and Retrofit Scenario

Economic Indicator	Full Dedicated		Retrofit	
	Jakarta	Surabaya	Jakarta	Surabaya
POT (PBP)	7.3 years	7.3 years	7.2 years	7.2 years
IRR	15.04%	15.04%	15.05%	15.05%
NPV	86,690	92,737	96,625	100,228
PI (BCR)	1.00	1.00	1.00	1.00
Product Price, US$/MMBtu	16.76	17.09	16.90	17.27
Depot Fee, US$/MMBtu	5.76	6.09	5.90	6.27

Table 6: Economic Calculation for LNG Locomotive Station

CAPEX Estimation		
No	Description	Cost (US$)
I	LNG Fill. Unit & Construction	9,214,528
II	Site Location (Land Acquisition and Preparation)	166,667
	TOTAL PROJECT COST	**9,381,195**
OPEX Estimation		
No	Description	Cost (US$/MMBTU)
		0.51
I	Utilities and Labour	0.18
II	Operation and Maintenance	0.08
III	General & Administration	0.26

Table 7: Economic Indicator of LNG Locomotive Station for Full dedicated and Retrofit Scenario

Economic Indicator	Full Dedicated		Retrofit	
	Jakarta	Surabaya	Jakarta	Surabaya
POT (PBP)	7.2 years	7.2 years	7.2 years	7.2 years
IRR	15.05%	15.05%	15.05%	15.05%
NPV	10,086	10,298	8,676	9,050
PI (BCR)	1.00	1.00	1.00	1.00
LNG Sale Price, US$/MMBtu	21.85	17.14	22.54	18.31
Filling Fee, US$/MMBtu	3.18	3.45	3.50	3.80

Table 8: Economic calculations for LNG Plant

CAPEX Estimation	
Description	Cost (million US$)
LNG Complete Package System	22,323,903
Installation	2,191,303
Instrument & Control	3,149,999
Piping	5,341,302
Electric Equipment	3,149,999
Civil Works	1,780,434
Yarn Improvement	1,095,652
Service Facilities	1,095,652
Land	4,519,563
Indirect Expense	10,408,691
TOTAL	55,056,497

OPEX Estimation	
Description	Cost (US$/year)
Fuel for Power Generation	1,232,608
O & M + Labor	958,695
TOTAL	2,191,303

Table 9: Economic Indicator of LNG Plant for Full dedicated and Retrofit Scenario

Economic Indicator	Full dedicated	Retrofit
POT (PBP)	7.2 years	7.2 years
IRR	15.06%	15.06%
NPV	72,322	59,886
PI (BCR)	1.00	1.00
Product Price, US$/MMBtu	13.51	14.30
Processing Fee, US$/MMBtu	8.51	9.30

The final phase is the determination of LNG economical price structure for locomotives. It is conducted for patterns both from outside and inside Java Island with two scenarios for each pattern (Figure 4,5,6,7).

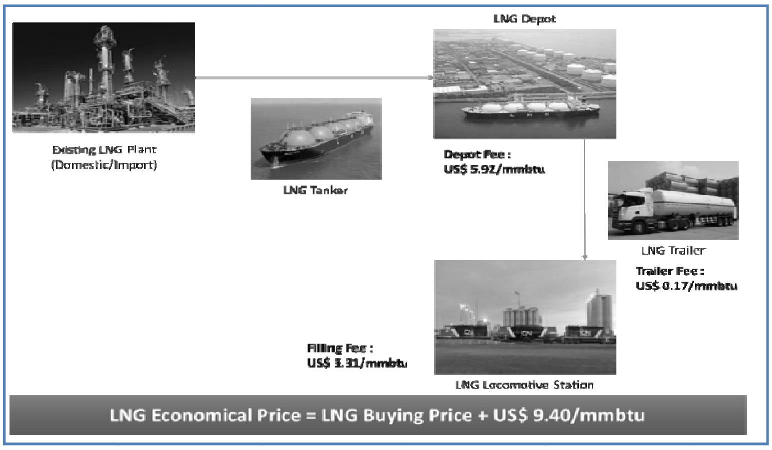

Figure 4. Outside Java Island pattern with full dedicated scenario

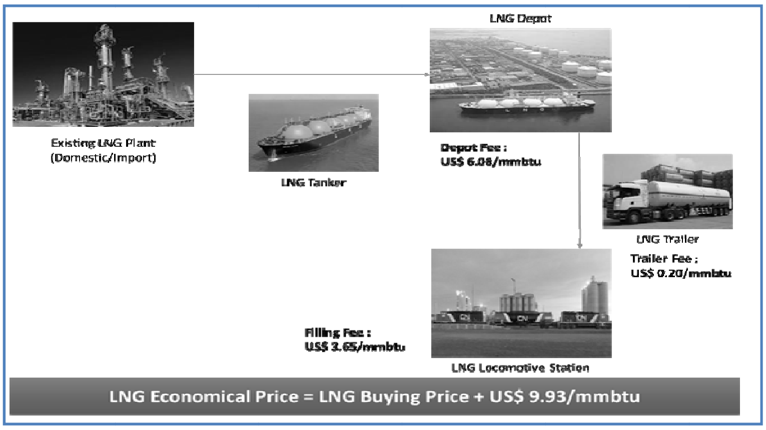

Figure 5. Outside Java Island pattern with retrofit scenario

Figure 6. Inside Java Island pattern with full dedicated scenario

Figure 7. Inside Java Island pattern with retrofit scenario

4. Conclusion

- The LNG supply chain patterns for locomotives that arefeasible to be implemented in Indonesia consist of two types based on origin of source: outside Java Island and inside Java Island.
- Based on economical calculation, the economical price of LNG for locomotives is within range of US$ 19.51/MMBtu– US$ 26.51/MMBtu.

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