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Formulating Policy Options for Promoting Natural Gas Utilization in the East Asia Summit Region

Volume II: Supply Side Analysis

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Unless otherwise specified, the sources of figures and tables in this report are from the results of the study.

Foreword

There is an increasing interest in natural gas demand potential and its implications in the East Asia region. This study, proposed by Japan at the 10th East Asia Summit Energy Ministers Meeting in 2016, focuses on markets in the Association of Southeast Asian Nations (ASEAN) and India to understand the future natural gas demand, estimates the size of market on the demand side, and correspondingly derives the necessary investment in infrastructure on the supply side. The challenges and policy options are drawn from both the demand and supply sides.

On the demand side, expanded gas demand will lead to some increases in fuel costs in the power generation sector, as it mostly substitutes cheap coal. But this could be partly offset by the reduction of construction costs since natural gas-fired power plants have lower capital costs. Other sectors will see significant benefits in fuel costs since natural gas could be much cheaper than oil products. Reduction in carbon emission is also expected in all sectors. Various policies are needed for maximizing demand potential. They include clear policy indications for promoting natural gas use, enhancing economic competitiveness of natural gas, supporting the development of supply infrastructure, and institutional and capacity building. Volume I of this report is dedicated to the demand side analysis.

On the supply side, the study identified the most suitable and feasible supply chain solutions based on the size of demand, the main users of natural gas, the technical constraints, geographical constraints, as well as available existing transport infrastructures such as road, rail, and ports. Even with the existing and planned primary liquid natural gas (LNG) terminals, more primary LNG terminals are still needed by 2030.

The study also found that primary LNG terminals in ASEAN can cover other countries' area. It is therefore recommended that natural gas infrastructure be shared for cost saving. The estimated investment for additional LNG supply chain by 2030 is US$81 billion. Volume II of this report is dedicated to the supply side analysis.

Yanfei Li

Leader of the Study

October 2017

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List of Abbreviations/Acronyms

ASEAN	Association of Southeast Asian Nations
FSRU	floating storage and regasification units
GIS	geographic information system
IGU	International Gas Union
ISO	International Organization for Standardization
JGA	Japan Gas Association
LNG	liquefied natural gas
MTPA	million tonnes per annum
SSLNG	small-scale liquefied natural gas

Chapter 1

Introduction

This Part II of the report discusses two main topics: how much liquefied natural gas (LNG) supply infrastructures are needed in the Association of Southeast Asian Nations (ASEAN) + India by 2030 to satisfy the LNG demand projection results presented in Part I; and how much investments are required by 2030 to implement the identified LNG supply infrastructure in ASEAN and India.

To explore these topics, the following discussions and findings from Part I were considered: additional demands of LNG at provincial levels due to new natural gas thermal power plants; converted thermal power plants from diesel fuel to natural gas; additional industrial, household, and transport uses of compressed natural gas; and LNG bunkering for shipping. The projected LNG demands were presented in three scenarios in Part I. Part II is based on the middle projection scenario in Part I. These projected demands were assumed to be added to the current natural gas demand. Therefore, the estimated additional investment for additional LNG supply chain infrastructure development includes the existing LNG supply chain infrastructure.

Chapter 2 will discuss the methodology and the results. Chapter 3 will identify the LNG supply chain configuration based on Japanese experience. Chapter 4 will discuss the distribution of LNG demands at provincial levels in each country in 2030. Chapter 5 will discuss the closest ports for demand location, hierarchy of ports to import LNG, and LNG supply infrastructure between demand location and LNG importing ports. Chapter 6 will discuss the estimated LNG supply infrastructure development costs and Chapter 7 will discuss the legal framework for LNG supply chain infrastructure development. The policy implications from this study will then be presented. Finally, the concluding remarks will present the summary and issues for further study.

Chapter 2

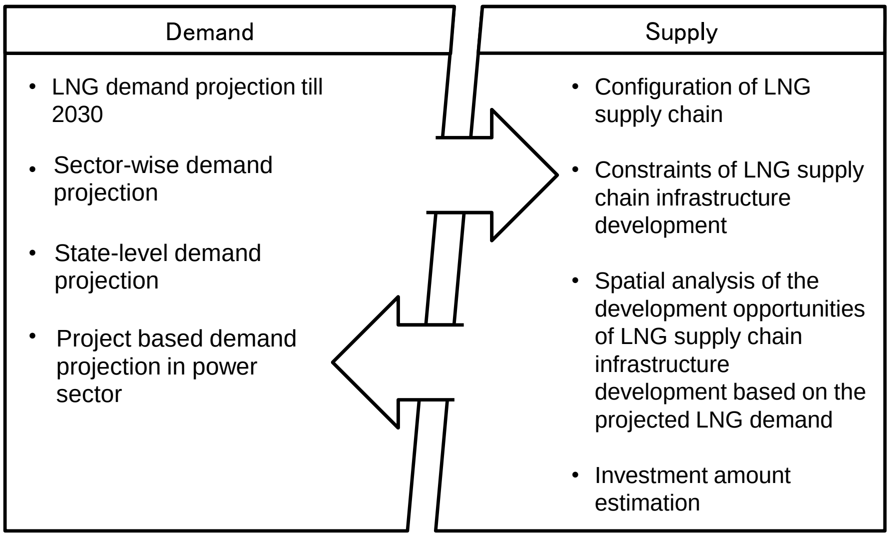
Methodology of Part II

2.1 Framework of Part II

Part II presents the results of the supply side study as well as the results of the legal framework study.

The supply side study consists of four sub-items, namely: configuration of the LNG supply chain, constraints of the LNG supply chain infrastructure development, spatial analysis of the development opportunity of LNG supply chain infrastructure, and investment amount estimation as shown in Figure 1.

Figure 1. Study Framework and Study Items



LNG = liquefied natural gas.

Source: Authors.

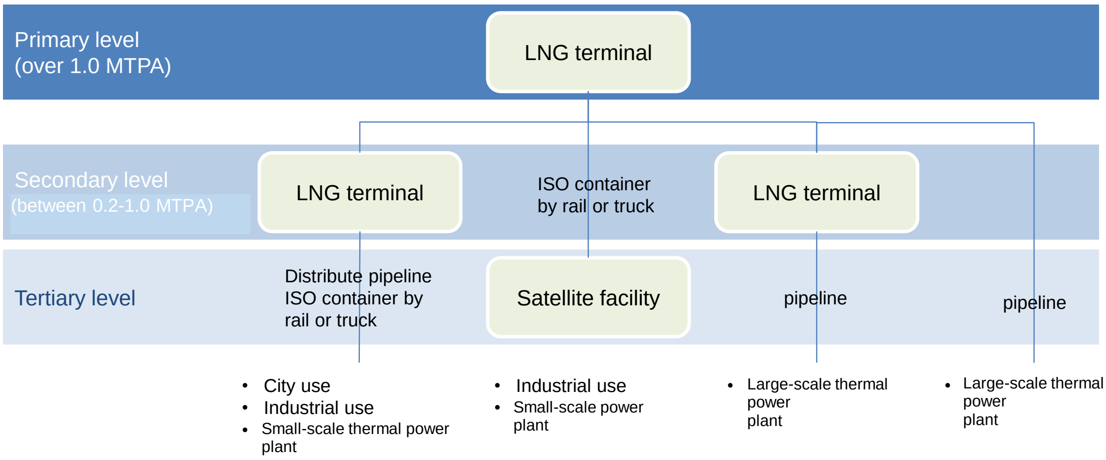
2.2 Scope of LNG supply chain infrastructure analysis

This study assumes a three-level hierarchy system of LNG supply chain infrastructure. The primary level has more than 1.0 million tonnes per annum (MTPA) facility capacity, the secondary level has 0.2–1.0 MTPA facility capacity, and the tertiary level has less than 0.2 MTPA facility capacity. These are based on the Japanese case study results. The evidence of this classification will be presented in Chapter 3.

The transport modes between the different levels in the hierarchy to the final consumption points are assumed to be small-scale LNG (SSLNG) vessels, pipelines, lorries, and International Organization for Standardization (ISO) containers by either lorry or rail. The geographical conditions between neighbour

LNG terminals and the demand size of final consumption points will determine the transport mode. There are few chances to reflect economic analysis in the selection of the best transport mode because, in most cases, physical constraints were faced such as lack of railway connectivity, bigger amount of LNG demand against transportable amount of LNG by lorries, and so on. In Chapter 5, the constraints analysis on the transportation mode of LNG will be conducted and the results will be presented for each LNG transport mode.

Figure 2. Three-Level Hierarchy System of LNG Supply Chain Infrastructure



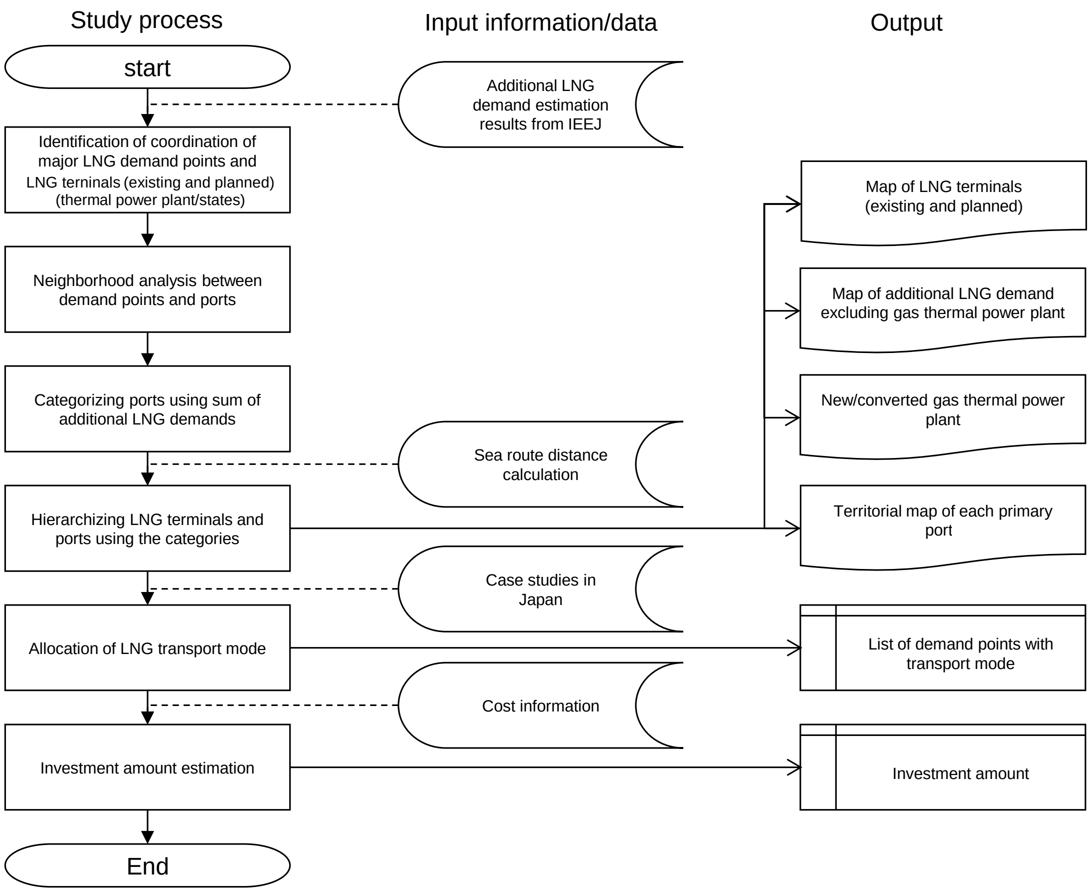
ISO = International Organization for Standardization, LNG = liquefied natural gas, MPTA = million tonnes per annum.
Source: Authors.

2.3 Flow of LNG supply chain infrastructure development investment estimation

Figure 3 shows the flow of LNG supply chain infrastructure development investment estimation. The demand data were presented in Part I, and the necessary unit cost of investment data and information on transport mode selection conditions from case studies in Japan were used. The unit cost of investment on LNG supply chain infrastructure development in Japan might be higher than the actual unit investment level in ASEAN and India, but a higher number will suggest less risk of investment cost escalation for the future due to inflation and other reasons. Of course, to improve the accuracy of the investment amount, more detailed cost studies are required, but this is for future research tasks.

Major outputs of the study include map of LNG terminals (existing and planned); map of additional LNG demand, excluding gas thermal power plant; new/converted gas thermal power plant; map of coverage by each primary port; list of demand points with transport mode; and the required amount of investment.

Figure 3. Flow of LNG Supply Chain Infrastructure Development Investment Estimation



IEEJ = The Institute of Energy Economics, Japan, LNG = liquefied natural gas.

Source: Authors.

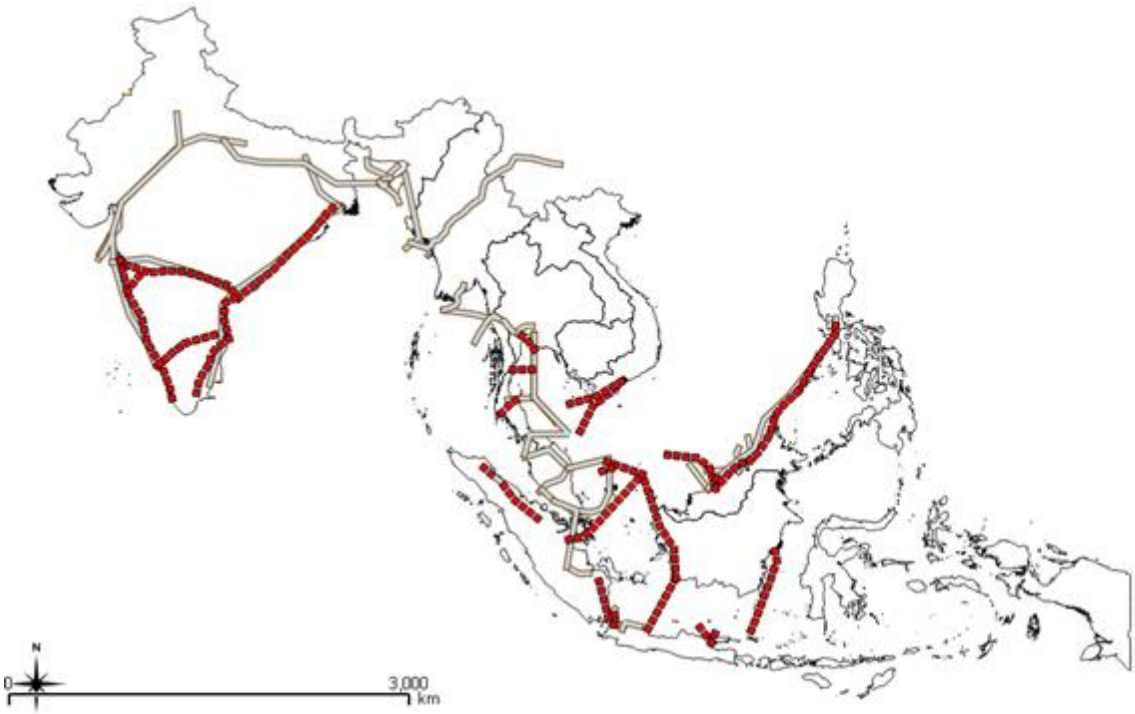
2.4 Constraints and conditions

2.4.1 Constraints

When this study was conducted, not all necessary information was collected. Therefore, this study has some data availability constraints.

First, it is difficult to collect reliable natural gas pipeline information. Figure 4 shows a Geographical Information System (GIS) map of existing natural gas pipelines in ASEAN and India but the data is old and not necessarily accurate from a spatial analysis perspective. Using inaccurate and old information will mislead the analysis. Thus, during the study, the research team and the Economic Research Institute for ASEAN and East Asia (ERIA) requested ASEAN members and India to provide their latest GIS information on natural gas pipelines. However, no responses were received during the study. Therefore, this study does not reflect the latest natural gas pipeline information in these countries. The study results can be updated in the future once the latest pipeline GIS information with location, capacity, and pressure have been provided.

Figure 4. Map of Natural Gas Pipelines in ASEAN and India



NG = natural gas.
Source: Authors. Available at: http://worldmap.harvard.edu/geoserver/wfs?outputFormat=SHAPE-ZIP&service=WFS&request=GetFeature&format_options=charset%3AUTF-8&typename=geonode%3Agas_proposed_nsp&version=1.0.0

Second, some domestic regulations on road structure do not allow the use of ISO containers because of its width, length, and axial weights, but these regulations were not taken into consideration because of the lack of information on road category. This study also did not consider the capacity and standard of railway lines which will be used for freight service of LNG transport. Accordingly, the estimated investment does not also include road and railway infrastructure improvement costs.

Third, some LNG terminal ports are not registered in the marine transport distance table. In these cases, the nearest neighbour port was used as a proxy because this difference will not influence the results critically.

Fourth, the location of industrial and household consumption of natural gas was assumed to occur in the centre of the province. This means that this study did not consider the population distribution within the province. Moreover, the industrial and household demands cannot be identified geographically. Small- and medium-sized island demands were also not identified. Therefore, ISO-container transport by truck was assumed as the average transport. This ISO-container transport can become the typical transport mode for small- and medium-sized islands because ISO containers can be transported by normal barges and ferries in those islands.

2.4.2 Conditions

This study has three major conditions.

First, when the nearest neighbour points between LNG terminals and LNG terminal and demand points, road networks, and railway networks were analysed, it was difficult to identify the exact location of the LNG supply chain infrastructure because, in some cases, the spatial resolution of the railway network was not enough and the port aspect information like the connectivity of railway supplied by World Port Index did not reflect the actual situation. Therefore, the distance between the additional LNG demand points and ports were calculated as direct distance using coordinates information. On the other hand, the distance between ports (primary and secondary LNG terminals on the ports) is calculated using aquaplot service (https://www.aquaplot.com/). This service calculates the distance between ports following shipping routes. If not, the direct distance between ports calculated by coordination information will give misleading estimation of the distance of of ports.

Second, only the 40-feet ISO container for LNG transport was assumed to be used for simplification instead of the usual 20-, 30-, and 40-feet containers. This is because the 30-feet ISO container is the special size for Japanese railway transport and it is difficult to be found in ASEAN and Indian markets. The 20-feet containers can be found in the market, but this needs more frequent distribution service than the 40-feet ones. When considering the operation of LNG supply, operational costs will increase if the 20-feet containers will be used. Of course, if the demand points are in rural areas, the demand size is small enough, and the transport infrastructure constraints are strong, the 20-feet containers will be used. It is, however, difficult to identify those situations one by one. Therefore, the 40-feet container was used as a model case to estimate the investment amount in this study.

Third, the investment amount on LNG supply infrastructure to satisfy the additional LNG demand is estimated as the accumulated value of investment until 2030. This is because the estimated additional demand only provided discrete data points about the future and there is no information when the estimated additional demand will be realized. None of the countries in ASEAN or India provided detailed plans to implement LNG supply chain and further discussions are needed to develop a detailed roadmap of LNG supply chain infrastructure implementation.

2.5 Methodology to decide transport modes

In this study, various modes of transport for LNG/natural gas transportation are assumed. They include: small LNG tankers for secondary transport, pipelines, and 40-feet ISO containers for truck/rail transport. If the 40-feet ISO container will be used, satellite LNG tanks and evaporators are assumed to be installed. The outline of transport mode application rules are shown in Table 1.

Small LNG tankers were not included in the investment estimation but they are necessary tools to transport LNG to islands and middle-sized demand areas near primary LNG terminals. The water draft of small LNG tankers is normally 4–5 metres (m) and it will not become a critical constraint for the small LNG tankers to enter the port with secondary LNG terminal.

Pipeline is assumed to be used for natural gas transport between primary LNG terminals and gas thermal power plants. This is because gas thermal power plants consume huge amounts of natural gas and it is difficult to transport such a huge amount of natural gas through other means. Japan has the longest natural gas transport from the primary LNG terminal to the inland thermal power plant at 32.5 kilometres (km). Therefore, this 32.5 km is regarded as the threshold to check the possibility of transmission pipeline usage for gas transport for natural gas thermal power plants.

For rail transport, the threshold distance for LNG transport must be shorter than 15 km between either port or demand point. This is because the distance from the acknowledged ports and demand points – like thermal power plants to the railway service – is less than 15 km when the authors checked them manually. Even though there is no railway connectivity or poor railway connectivity, new connectivity construction or improvement of rail tracks is not significantly costly for such a short distance. Therefore, those cases will not influence the final results. In addition, when railway transport is considered as the transport mode, the availability of railway connectivity on both the port side and the demand point side is essential. If one side does not satisfy the condition on railway connectivity, railway transport mode will not be assigned. Furthermore, when discussing the possibility of railway transport, the volume of natural gas consumption is also considered. This is because unloading LNG also needs some time and frequency of freight train service is also consequently limited. For example, in Japan, the maximum load capacity for transport by electric locomotive is 1,300 tonnes, which is the maximum capacity in the railway freight service. This time, there is no information on such constraints for freight railway transport. Thus, the Japanese capacity limitation was applied for the railway transport mode.

In terms of the ISO container transport by trucks, the maximum distance that road transport can economically reach ASEAN and India is 700 km. Considering the loading and unloading times, the frequency of the truck transport faces some limitations. This time, the maximum frequency of truck transport to one demand point is set at 24 times/day. If the LNG demand goes beyond this upper cap, the other transport mode will be assigned.

Other cases that do not satisfy the above-mentioned conditions are discussed case by case, but in some demand points near mega cities in countries with natural gas distribution pipelines like Jakarta and Delhi, the pipeline transport is assumed without any additional pipeline infrastructure expansion.

Table 1 summarizes how to decide on which transport mode to use.

Table 1. Transport Mode Assignment Rules

Transport Mode from Neighbour Ports		Transport Mode Assignment Rules
Transmission pipeline		Based on Japan's experience (Tokyo Electric Corporation), distance from Futtsu LNG terminal to Chiba gas thermal power plant is 32.5 km. So, the transmission pipeline is assumed as the transport mode, with 32.5 km from the port to the thermal power plant.
Rail	At port	Based on existing port-rail connectivity, a 15 km distance between railway and port is judged as connectivity.
	At demand points (e.g. thermal power plant)	Based on existing thermal power plant-rail connectivity, a 15 km distance between railway and thermal power plant is judged as connectivity.
Trucks	Distance	Normally, ports have road connectivity. So, if the demand points are within 700 km from ports, they are judged as transportable.
	Frequency	Upper limit is set at 24 times/day of 40 ft ISO containers (equivalent to 13.5 tonnes).

ft = feet, km = kilometre, ISO = International Organization for Standardization, LNG = liquefied natural gas.
Source: Authors.

2.6 Other methodologies

This study also used other methods like literature review. In addition, it consists of several sub-study items, and methods to collect and analyse necessary information are introduced in the beginning of each chapter to help readers understand them.

Chapter 3

LNG supply chain infrastructure configuration

3.1 Introduction

This chapter clarifies the basic configuration of LNG infrastructure to supply gas to power plants and other end users based on the experience of Japan and other countries.

It is important to show the basic structure of the LNG infrastructure, including recent SSLNG structures, before discussing potential LNG supply chain infrastructures in ASEAN and India.

3.2 Methodology

3.2.1 Scope of the study

The study covers the LNG infrastructures from LNG-receiving terminals to end users, elaborating on the one mile modes of delivery, including pipeline, rail, and lorry/truck.

3.2.2 Literature review

The Japanese experience implied that the choice of transportation mode for LNG/natural gas is based on three factors: regional gas demand, distance of delivery, and quantity to be delivered.

The Agency for Natural Resources and Energy of Japan (2004) summarized the typical choice of transportation modes departing from a primary LNG-receiving terminal. This document was intensively reviewed for the study.

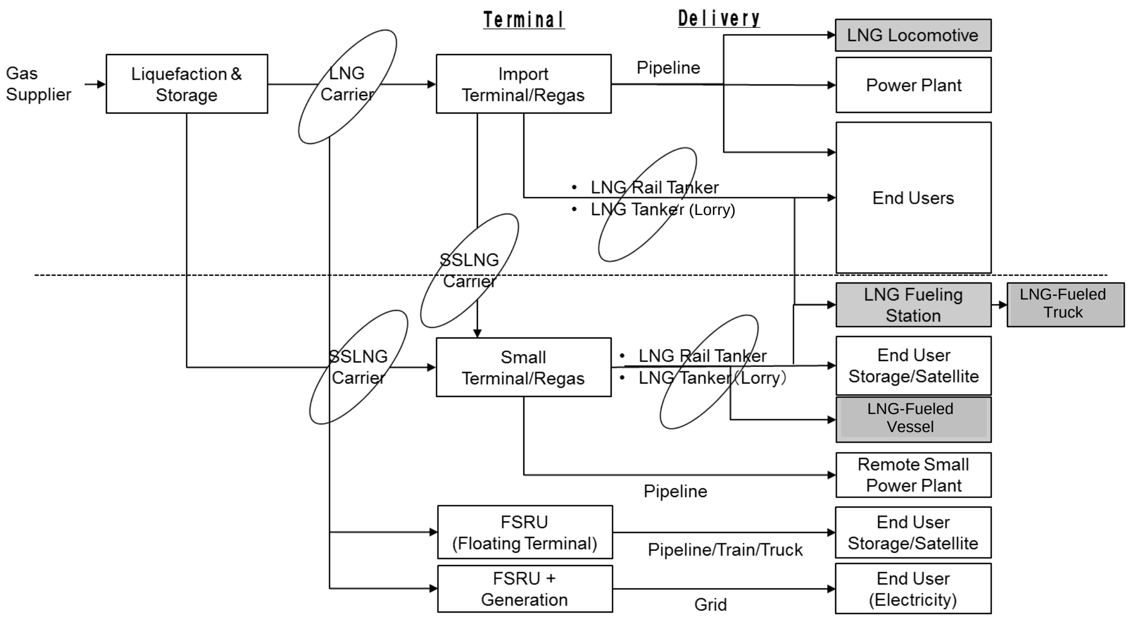
3.2.3. Interviews

Interviews were conducted with a plant engineering company, a pipeline manufacturing company, a city gas company, and a trading company.

3.3 Results

Figure 5 shows the overall configuration of the LNG value chain. The left-hand side shows the upper stream of the value chain and the right-hand side illustrates the downstream, extended to the consumption points.

Figure 5. Configuration of the LNG Value Chain



FSRU = floating storage and regasification units, LNG = liquefied petroleum gas, SSLNG = small-scale liquefied petroleum gas.
Source: Adapted from International Gas Union (2015).

The coupling of LNG satellites and gas engine generators is an attractive application from a manufacturer's perspective. PTT, a petroleum company in Thailand, did a pre-feasibility study to transport LNG to mountainous areas and islands. Loading facilities to lorries is estimated to cost several hundred million yen, and lorries and unloading facilities at the receiving site is estimated to cost another several hundred million yen.

Combining small-sized gas cogeneration systems and waste heat boilers is also possible in Southeast Asian countries. Indonesia and the Philippines are large markets for such an application. This is also suitable for industrial parks in Myanmar. For industrial parks, the installation of 100–200-megawatt (MW) capacity systems with a couple of combined heat and power systems is possible. A package deal of receiving terminal, satellite, and cogeneration system is doable.

Gas-fired generation in a remote island was studied in Japan and it was found that such project was not economical if small tankers are used. However, the use of scheduled ferry services to carry LNG through lorries to such islands may be an option. This option may work in Viet Nam and the Philippines. In the case of remote islands, generators are likely to be gas-engine based. Some regulatory standards may be needed for such an application.

The minimum regional demand for justifying city gas conversion is 1 MTPA. In Southeast Asia, regional demand for gas could double or triple in a decade, and the ultimate demand considered is 3 MTPA. In this case, a primary terminal of 3–5 MTPA is planned and pipelines are connected. For security, multiple tanks or circulation among tanks may be considered.

In the case of primary terminals with 5 MTPA, secondary terminals of up to 1 MTPA are located in each demand area. Coastal tankers of 0.15–0.20 MTPA serve between the primary and secondary terminals. There is a regulation on the number of crews in Japan[1] and smaller tankers are usually used.

When regional LNG demand is within 50,000–100,000 tonnes per annum, the lorry is the most suited mode of transport, while train containers are more suitable when the demand is between 50,000–500,000 tonnes per annum. In the latter case, railroad infrastructure is needed near the loading points such as LNG-receiving terminals and off-loading points such as power plants. Coastal vessels could be utilized to transfer LNG cargoes from a primary LNG-receiving terminal to secondary terminals.

The LNG supply network of developed countries usually consists of primary and secondary LNG terminals. Gas suppliers allot a primary or secondary LNG-receiving terminal for those with 1.0 MTPA regional demand. Typically, more than half of the regional demand is from gas-fired thermal power plants with 0.5–1 million kilowatt generation capacity and the rest are from regional industrial and commercial users plus residential users (a couple of hundred thousand tonnes per annum).

A primary LNG terminal larger than 3 MTPA is desirable for natural gas to be cost competitive with petroleum. Such a large LNG terminal usually transfers some LNG to secondary terminals in other regions, usually by coastal tankers, in addition to supplying the regional demand.

LNG/NG is transported from a primary terminal with 3–5 MTPA capacity to several regions with a demand of approximately 1.0 MTPA each. The mode of transportation could be tankers or pipelines. One of the Japanese companies interviewed suggested that a 20 km pipeline could be deployed between the terminal and a power plant. For example, Map Ta Phut terminal in Rayong has a 5 MTPA capacity and an expansion to 10 MTPA is planned. Gas is served to neighbouring industrial parks via trunk pipelines. Satellites will be placed in Chiang Mai and Nakhon Ratchasima. There is a 0.2–0.3 MTPA demand in Krabi, and other areas in the Gulf of Thailand, and LNG could be transferred to a secondary terminal there. LNG could also be transferred to Samui, as conversion to gas from other fuels is easier in remote islands where energy cost is high.

[1] Ministry of Health, Labour and Welfare. 'Standard Notification on Improvement of Working Hours of Automobile Drivers'.

Table 2. Typical Modes of LNG and Natural Gas Transport: Japanese Experience

	Pipeline	Lorry	Train Container	Coastal Vessel
Minimum lot of regional LNG demand	—	50 thousand tonnes per annum	50 thousand tonnes per annum	30 thousand tonnes per annum (20-year guarantee)
Maximum lot of LNG demand	No limit	0.1 MTPA	0.4-0.5 MTPA	0.2 MTPA
Transport distance	Up to 300 km, with high pressure pipelines, compressors beyond 300 km	50～200 km	180～400 km （1,000 km maximum）	More than 50 km
Transport volume	Variable, dependent on demand	0.01–0.1 MTPA (9.8–12.4 tonnes per truck × 260–280 days per year)	400 tonnes per haul Operating days determined by train schedule	0.03–0.14 MTPA (1,000–3,000 tonnes per haul)
Legal restriction		Two drivers are required if one-way haul is more than 200 km		

km= kilometre, LNG = liquefied natural gas, MTPA = million tonnes per annum, NG = natural gas.
Source: Agency for Natural Resources and Energy (2004).

Japanese engineering companies can deploy high-pressure pipelines underneath urbanized areas and they have experience providing protection against earthquakes. There was an instance where an inexperienced gas company of another country had serious trouble constructing a terminal in another country in Asia.

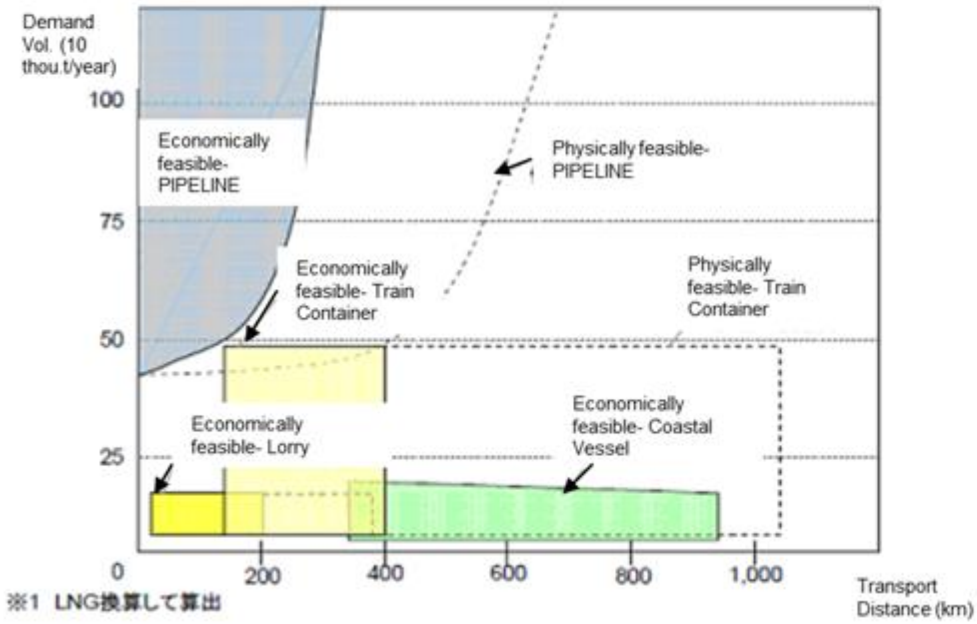
In terms of pipeline network, most Southeast Asian countries do not have a city gas network that is comparable to the size of the Japanese cities, except for Singapore and Kuala Lumpur where certain city gas networks exist. Usually, in other cities, propane gas cylinders are delivered instead. Tokyo Gas Engineering Solutions supplies city gas as part of a district energy supply in Malaysia.

Trunk gas pipeline networks in Southeast Asia are not developed by foreign contractors, including Japan. As state-owned enterprises are often involved in natural gas, local companies in each country are reportedly engaged in the network construction.

Thailand has trunk gas pipelines and a couple of south-to-north lines constructed in Bangkok. Top-notch local contractors have reportedly developed it. Gas network serving residences have yet to be developed.

Therefore, middle-to-low pressure pipe networks are limited. High-pressure pipelines for industrial customers serve factories of the Japanese manufacturers. For example, a Japanese engineering company finances, installs, operates, and maintains natural gas combined heat and power systems at customers' sites, and supplies power and heat on site. It has several customers including automobile, motorbike, chemical manufacturing, and the like.

Figure 6. Illustration of Modal Choice in Japanese Cases



Vol = volume, t = tonnes, thou = thousand.
Source: Ship and Ocean Association (2010).

Choice is done based on the quantity and distance of LNG/NG delivery. The rule of thumb is as follows. In case the delivery at the destination is large enough, pipeline is selected. If the delivery is small and LNG must be delivered to a remote area, lorry is used. Pipeline transport is appropriate for the delivery of 200 thousand tonnes per annum. The maximum transport by lorry is approximately 162 thousand tonnes per annum where 30 vehicles of 18 tonnes a day are used 300 days per year. However, typical lorry transport employs 10 vehicles a day.

The maximum distance of lorry transport is said to be 300 km in Japan. This is based on Japanese laws and regulations. The law specifies the maximum distance a commercial vehicle can travel in one haul on express and normal roads. When the haul is more than the legal limit, two drivers must be on board the vehicle, increasing the cost greatly. This is when the use of train transport is considered. Considering that regulations are different in each country, localization of transport networks is necessary. For example, small lorries are preferred in Japan since loading is not allowed at night. The network design also follows the pattern and characteristics of the distribution of end user demand. Thus, the choice of delivery mode, whether pipeline, lorry or tanker, is up to the demand distribution.

Most countries import LNG from abroad via maritime transportation. In Table 3, the International Gas Union (IGU) (2015) pointed out that the typical distance that a conventional ocean tanker can transport LNG is 37,000 km while smaller coastal tankers typically transport within 2,700–4,600 km. Traditionally, the Japanese LNG value chain consisted of primary and secondary LNG terminals. The former receives imported LNG from large ocean tankers, and then a part of the LNG is transferred by coastal vessels to secondary terminals. Primary terminals are located in metropolitan areas of the largest cities, while secondary terminals are in smaller cities.

Recently, most SSLNG networks are constructed using smaller vessels of 500 cubic metres (m^3) and over, compared to the ones used in conventional networks. Transport distance could be very short SSLNG networks. In archipelagos like the ASEAN region, many islands do not have adequate water depth nor piers or berths capable of handling large LNG tankers. Thus, smaller vessels may be used.

Table 3. Typical Radius of Offshore LNG Transport

		Parcel Size	Action Radius		
			International	Coastal	Onshore
Shipping Transport	Conventional	Q-max (266,000 m^3+)	Typical: 37,000 km		-
		7,500 m^3	Max: 2,700–4,600 km		-
	SSLNG	SSLNG (500–30,000 m^3)	556–23,150 km	0–3,241 km	-

Note: Q-max is a type of vessel specifically used for LNG. This vessel is the largest type of LNG carrier in the world. Q stands for Qatar while max stands for maximum.

Km= kilometre, LNG = liquefied natural gas, m^3 = cubic metres, SSLNG = small-scale liquefied natural gas.

Source: Adapted from International Gas Union (2015).

LNG transported by maritime transport is received by a primary LNG terminal. Currently, there are two types of LNG terminals: onshore and floating storage and regasification units (FSRU). An onshore LNG terminal is traditional and requires site acquisition for the construction of a permanent structure. An FSRU is a recent invention and is getting increasingly popular as it does not require land site and requires a shorter lead time before the start of commercial operation. Used LNG tankers could be converted to FSRUs, though newly built FSRUs are also used. One of the advantages of an FSRU is that it could be moved to other ports when it is not required in the original port. However, as an FSRU is not intended for permanent use, its duration is considered shorter than that of an onshore LNG terminal and, consequently, its lifetime cost per annum could be higher.

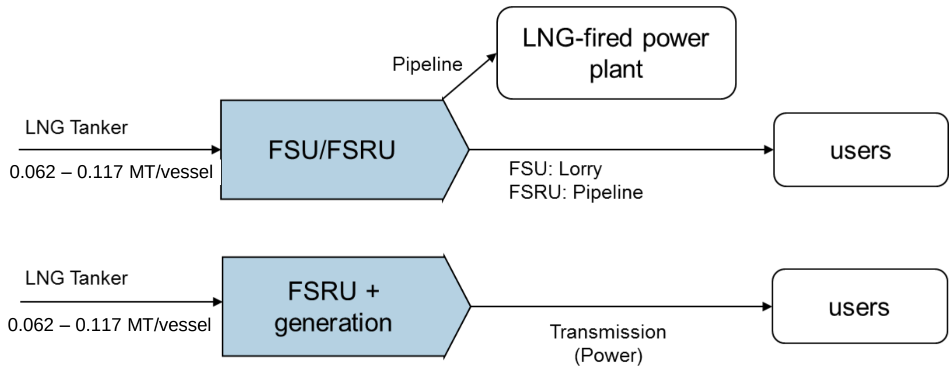
In the ASEAN region, LNG-receiving terminals have been completed and are operational in Singapore and Indonesia. Thailand also has a large-scale terminal and new ones are expected in the Philippines and Viet Nam. The new LNG-receiving terminals in Asia are often the consequences of the depletion of the domestic gas fields. Hence, export terminals will be converted into import terminals as pipelines become available between the depleting gas fields to the main cities.

The most principal application of LNG is usually for a gas-fired power plant, and Japanese manufacturers such as IHI and Mitsubishi Heavy Industries are developing a new type of FSRU that is equipped with gas-fired generators on it.

Gas-fired power plants are expected to be the main power sources in Thailand, the Philippines, and Malaysia where gas is delivered from the terminals to the power plants via pipelines.

As in Figure 7, LNG loaded from tankers to FSRUs could be regasified and delivered to power plants and/or end users as city gas. Also, LNG could be loaded from FSRUs to lorries. FSRUs equipped with generators could supply power to the transmission line when it is on the market. In terms of the prospect of FSRUs combined with generators, Japanese manufacturing companies, including IHI and Mitsubishi Heavy Industries, are studying the installation of gas-fired generators on FSRUs and are planning to receive, store, regasify, and use LNG for power generation on the vessel. Classification societies have approved certain FSRUs combined with generators. One manufacturer suggested that FSRUs with generators are suited for countries like Viet Nam and the Philippines as it takes less time and cost to be constructed.

Figure 7. FSRU and Delivery of LNG

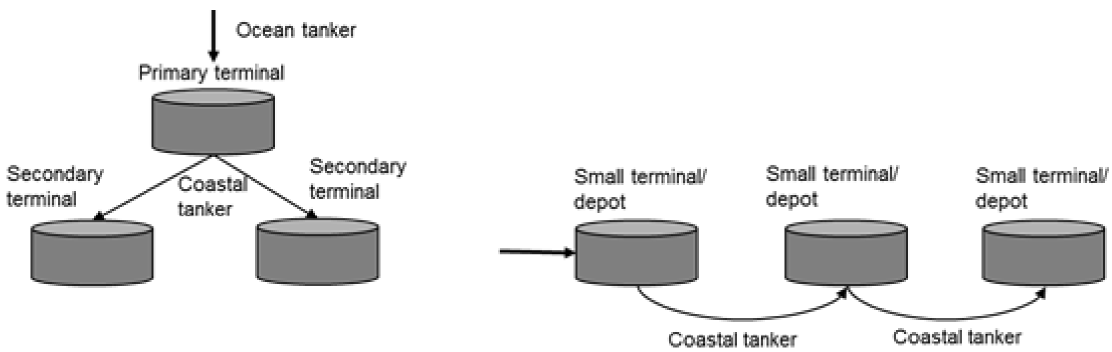


FSRU = floating storage and regasification unit, FSU = floating supply unit, MT = megatonne.

FSRU projects started approximately a decade ago and it is becoming the mainstream of receiving terminals. It is very popular to the customer without large funds, as they do not need to acquire land for terminal construction and they can just lease an FSRU ship without a huge upfront investment. Customers who need a terminal facility but do not want to spend JPY100 billion on onshore terminal prefer FSRUs. Originally, used tankers were transformed to FSRUs. However, as the need for used ship increased, the price of used ships surged and newly built FSRUs started to be built.

The Japanese LNG value chain is structured as a hierarchy of primary and secondary LNG terminals. Often, LNG is delivered to the secondary terminals by coastal tankers. However, physically, the difference between the two is the size only. In addition, the terminals of SSLNG networks, which are close to the size of Japanese secondary terminals, are used and/or are planned to be used as receiving terminals. Milk-run delivery by coastal vessels is a typical example of a horizontal network as shown in Figure 8.

Figure 8. Hierarchical and Horizontal Networks of LNG Terminals



There have been talks regarding small-scale receiving terminals and satellite projects in Asia. Such projects were completed only in Japan and China. However, such receiving terminal projects are expected to be realized in a couple of years in ASEAN in the wave of the construction of LNG supply chains.

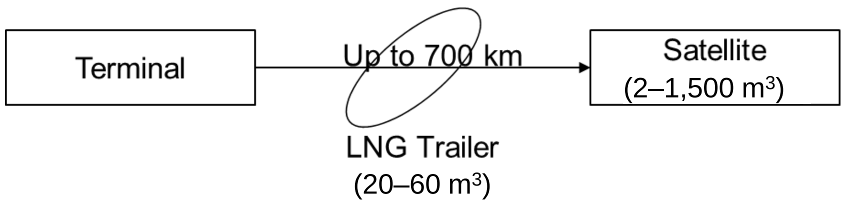
Small-scale receiving terminals need minimal size to be economically competitive. LNG is usually used in place of coal or petroleum, and for LNG to be economically competitive, the receiving terminal must be between 1–3 MTPA. For example, Minato terminal in Sendai City gas has 0.2 MTPA because it was the first LNG terminal to substitute the gas source to natural gas in that area in 1997 and it only considered its own demand size. This small size capacity needs a smaller LNG carrier from Malaysia. It is said that this brings higher LNG than other areas. If demand is not concentrated, pipelines must be built to connect a terminal to the sites of demand . Lorries are used when area demand is 10–50 thousand tonnes per annum and the site is far from the terminal.

Land delivery consists of lorries, trains, and pipelines. Technologies to manufacture lorries, ISO-containers, and pipelines have been established and there are well-known manufacturers in each technology such as Air Water Inc., Chart Industries, and Nippon Steel & Sumikin Engineering Co., Ltd. However, China has a different concept of an LNG network. China imports gas via pipeline, liquefies it at many small liquefaction stations, and delivers LNG to customer's sites by lorries.

LNG can be transported by road to customers who are not served on a gas grid. Also, LNG is often transported by road to the tanks/storages that are connected to the city gas grid. In this case, the distribution chain starts with a truck filling bay at the (import) terminal.

- The time for filling a normal-sized truck of 50 m^3 is approximately 1 hour.
- A competitive distance is typically up to 700 km[2] and it has been recently demonstrated under special circumstances to range up to 2,500 km.
- The maximum distance for transport depends primarily on the end user's capability to pay the additional transportation cost.
- Satellite storage typically ranges in capacity from 2–1,500 m^3 (68.4 tonnes), and several tanks may be used together.

Figure 9. LNG Distribution by Road (Truck)



LNG = liquefied natural gas, m^3 = cubic metres.

Source: Adapted from IGS 'LNG as Fuel' June 2015.

On the ground, the International Gas Union states that trucks deliver LNG by up to 2,000 km. This is much longer than the 50–200 km figure indicated by the Japanese Agency for Natural Resources and Energy. Other literatures typically indicate that 700 km is the maximum transport distance for trucks/lorries. As shown in Table 4, the Japanese Government requires transport companies to assign two drivers for a one-way haul of more than 200 km. Thus, Japanese companies limit the one-way haul to 200 km to avoid assigning one more driver.

[2] This number was pointed out during the interview of a Japanese engineering company which has experience in developing LNG facilities in ASEAN countries.

Table 4. Typical Radius of Onshore LNG Transport

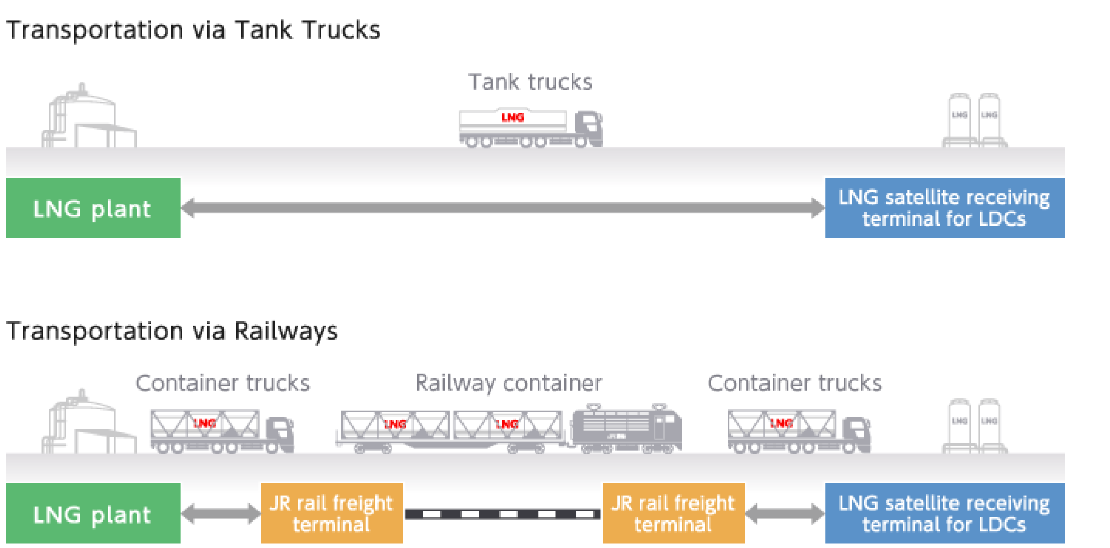
	Parcel Size	Action Radius		
		International	Coastal	Onshore
Truck Transport	30 m^3 (13 t) average (20–60 m^3)	-	-	0–2,000 km

km = kilometres, LNG = liquefied natural gas, m^3 = cubic tonnes, t = tonnes.
Source: Adapted from IGS 'LNG as Fuel', June 2015.

LNG has been transported by rail since the 1970s using flat railcars carrying ISO containers or specially designed LNG tank railcars. Loading of LNG is carried out at the terminal storage tank by connecting adjustable loading arms or flexible hoses to the tank on railcar or to the ISO container.

Japan Petroleum Exploration Co. Ltd. (Japex) has devised a low-cost way to deliver LNG to remote markets by using existing railways. A 30-feet 10-tonne capacity LNG container — developed by Japex, Air Water Inc., and Japan Oil Transportation Co. Ltd. — is hoisted from a flatbed truck to be placed on a railcar (see Figure 10).

Figure 10. LNG Distribution by Rail (Japex)



LNG = Liquefied natural gas.
Source: Japan Petroleum Exploration Co. Ltd homepage. Available at:
http://www.japex.co.jp/english/business/japan/lng.html

In a milk-run pattern, the vessel unloads partial cargoes to more than one destination. Indonesia is an example where SSLNG is distributed via this concept. In this pattern, a vessel serves several LNG terminals with a capacity of less than 1 MTPA.

The advantages of a milk-run scheme are:

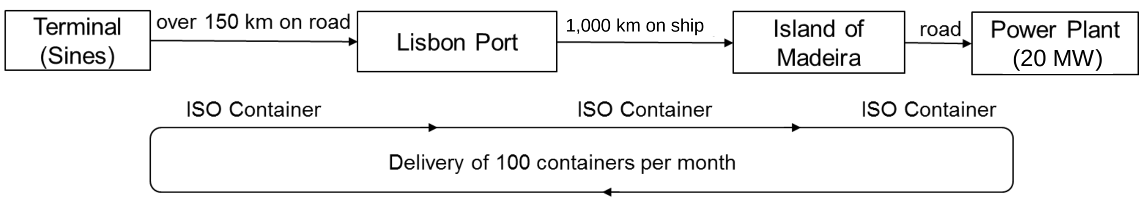
- makes use of existing LNG fleet;
- shares shipping cost between more locations; and
- takes advantage of economies of scale related to conventional LNG carriers (big volume).

The challenges are:

- Marine access for big ships will potentially trigger significant investment (dredging and port services such as tugs and big berths for small facilities);
- Arbitrage of distinguishing shipping costs among the customers; and
- Distance between customers can be limited to make it economically viable.

The virtual Sines-Madeira pipelines (road-ship-road) is a typical example where an LNG virtual pipeline using 40 ISO containers in circulation with delivery of 100 containers per month has been in operation since the spring of 2014 between the LNG marine terminal at Sines, Portugal and a remote 20-MW power plant on the island of Madeira (see Figure 11).

Figure 11. Virtual Pipelines Sines-Madeira (road-ship-road)



ISO = International Standard Organization, km = kilometres, MW = megawatt.
Source: Adapted from IGS 'LNG as Fuel', June 2015.

In terms of the development of LNG networks in ASEAN and India, a lot of costs and manpower are needed to transport LNG/NG in the region from a certain LNG hub. The basic structure of network starts from a large receiving terminal to gas-fired power plants connected by pipelines. If funds are available, satellite terminals served by lorries and pipelines connecting satellite terminals with industrial users could be developed, but such pipeline hardly pays off.

Four LNG-receiving terminals were developed in India 15 years ago. However, the development of satellite terminals connected to primary terminals has been difficult. Plans and feasibility studies have found the network of satellite terminals more difficult than expected. It is difficult to develop an electric grid between islands in archipelagos in Indonesia, and an LNG satellite terminal network is often discussed instead. However, such satellite networks do not usually pay off.

Small tankers must serve a small terminal, and three to four of such tankers are needed for a small secondary terminal. Economy of scale is hardly attainable with such a small system. Hence, the basic configuration of an economically feasible LNG network is a primary terminal plus a gas-fired power plant connected by pipeline.

LNG/NG projects merge about every 3 years, but finance is often not secured like in Indonesia. According to a manufacturer, same projects have been missed four times as finance was not available. The use of institutional banking makes it easier to proceed with LNG/NG projects.

Tables 5, 6, 7 summarises the discussions above.

Table 5. LNG Delivery Network with Primary and Secondary LNG-Receiving Terminals

LNG-Receiving Terminal		Aggregated LNG Demand		Mode of Transport	Requirements and Challenges
		Demand segments	Typical demand		
Onshore	LNG-receiving terminal (primary) Optimally, 3.0–5.0 MTPA Often, approximately 1.0 MTPA	Gas-fired power plant (IPP: PPA with state-owned power company)	0.5–1.0 MTPA/plant	• Pipeline (terminal to power plant)	• There must be a port with adequate depth of water for ocean vessels. • The port must be equipped with jetty. • There must be a large site for LNG tanks.
		Industrial park(s) and the like	0.5 MTPA (Area Demand)	• Pipeline (terminal to park) • Lorry + satellite (terminal to park)	
		Industrial customers Commercial customers		• Pipeline (terminal to customer sites) • Lorry + satellite (terminal to customer sites)	
		Residential customers		• Pipeline (city gas)	
		Transfer to secondary LNG-receiving terminals	0.2 MTPA/second terminal	• Coastal vessel	
Onshore/ Large Islands	LNG-receiving terminal (secondary) Typically 0.2–1.0 MTPA	Industrial park(s) and the like	0.2 MTPA	• Pipeline (terminal to park) • Lorry + satellite (terminal to park)	• Usually a centre of regional economy; without adequate depth of water; and not equipped with jetty. • Deployment of pipeline from the primary LNG terminal is a challenge.
		Industrial customers Commercial customers		• Pipeline (terminal to customer sites) • Lorry + satellite (terminal to customer sites)	
		Residential customer		• Pipeline (city gas)	

IPP = independent power producer, LNG = liquefied natural gas, MPTA = million tonnes per annum, PPA = power purchase agreement.

Table 6. LNG Delivery Network with FSRU

LNG-Receiving Terminal		Aggregated LNG Demand		Mode of Transport	Requirements
		Demand segments	Typical demand		
Onshore/Large Islands	FSRU Usually, 2.0–3.0 MTPA	Gas-fired power plant （IPP: PPA with state-owned power co.)	0.5-1.0 MTPA/plant	• Pipeline (terminal to power plant)	Usually a land site without a large room for LNG tanks.
		Industrial park(s) and the like	0.5 MTPA (Area Demand)	• Pipeline (terminal to park) • Lorry + satellite (terminal to park)	
		Industrial customers Commercial customers		• Pipeline (terminal to customer sites) • Lorry + satellite (terminal to customer sites)	
		Residential customers		• Pipeline (city gas)	

FSRU = floating storage and regasification units, IPP = independent power producer, LNG = liquefied natural gas, MPTA = million tonnes per annum, PPA = power purchase agreement.

Table 7. Virtual Pipeline Linking Several Small LNG-Receiving Terminals/Satellites

LNG-Receiving Terminal		Aggregated LNG Demand		Mode of Transport	Challenge
		Demand segments	Typical demand		
Archipelagos	Small LNG-receiving terminals/satellites	Gas-fired power plant to replace diesel power plant in each island	0.2 MTPA/plant	• Coastal vessel	• No port with adequate depth of water, nor equipped with jetty.
	Terminal/satellite in each island	Industrial park(s) and the like	Probably small demand	• Lorry + satellite (terminal to park)	
		Industrial customers Commercial customers		• Pipeline (terminal to customer sites) • Lorry + satellite (terminal to customer sites)	

LNG = liquefied natural gas, MPTA = million tonnes per annum.

Chapter 4

Additional LNG demand distribution in ASEAN and India in 2030

4.1 Introduction

The distribution by type of demand is illustrated on the map to visualize and capture the projected additional future LNG demand in Part I.

4.2 Methodology

For Part II, the Institute of Energy Economics, Japan (IEEJ) allotted additional LNG demand at the provincial level using population and the gross domestic product. In terms of new thermal power plants and converted thermal power plants, only the name of the plants and the volume of demand were assigned for the projected demand by IEEJ. So, the Nomura Research Institute manually checked the locations and coordinates from the map. Those power plant projects do not necessarily reflect national plans. Note, for example, that the Lao PDR will not have any LNG demand based on the assumption by the IEEJ. This is because the energy consumption level in the Lao PDR is still very low and other energy sources like hydropower are rich enough to satisfy its domestic energy demand.

The QGIS[3], an open source desktop geographic information system (GIS) application, was used to visualize the distribution of additional LNG demands. The country boundary data was downloaded from the DIVA-GIS website[4]. The demand points' data was fed as a comma-separated values (CSV) file. The map is shown in Figure 12.

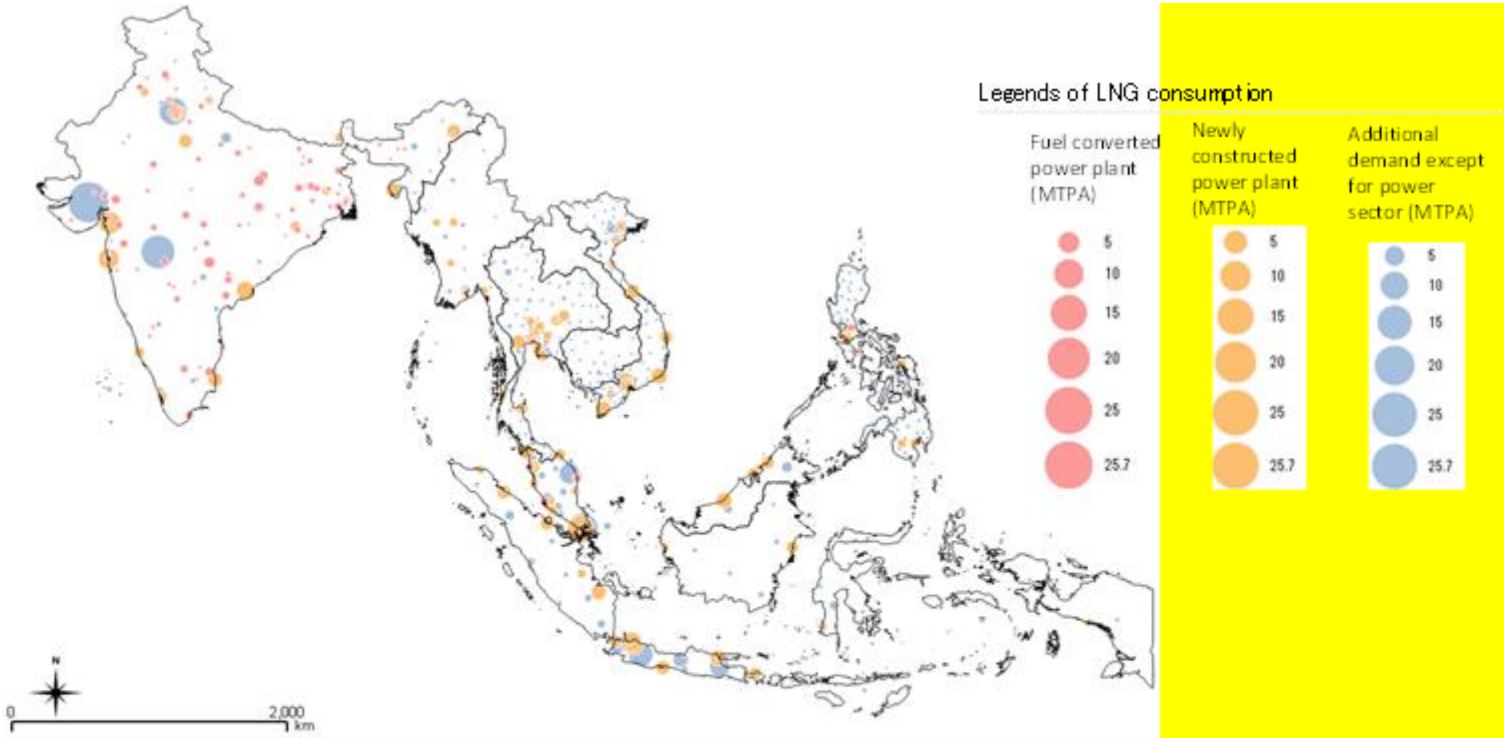
4.3 Results

India and Indonesia are the two countries in ASEAN and India with the biggest LNG demand. In these countries, the demand for thermal power plants as well as the demand for industrial and household uses are huge. On the other hand, Thailand, Cambodia, and the Philippines have many small demand centres represented by the circles because the area size of the province is smaller than other countries and the number of provinces is huge.

[2] http://qgis.org/en/site/

[3] http://www.diva-gis.org/Data

Figure 12. Distribution of LNG Consumption at Provincial Level in ASEAN and India



LNG = liquefied natural gas, MTPA = million tonnes per annum.
Source: LNG demand projection data was provided by the IEEJ.

Chapter 5

LNG supply chain infrastructure analysis

5.1 Introduction

This chapter analyses the spatial relationship between demand points and LNG supply chain infrastructures like LNG terminals and transport modes. The analysis used the results in Chapter 3.

The main outputs are the set of primary and secondary LNG terminals, assigned transport modes, and final demand points listed in the following tables.

5.2 Methodology

5.2.1 Procedure for LNG supply chain infrastructure development analysis

The LNG supply chain infrastructure development was analysed using the following procedure:

First, major LNG demand points and terminals (existing and planned, and thermal power plants/states) were identified. The thermal power plant location was identified using Enipedia. The area coordinates (latitude and longitude) were collected from the Enipedia site. The demand in a certain province, the centroid coordinate, is regarded as the demand point. The centroid is calculated from the polygons in shapefile format using QGIS.

Second, the nearest neighbour points between demand points and ports were identified. The direct distance can be calculated from the geographic coordinates of demand points and ports. The nearest ports based on this direct distance were then identified. At this point, the transport mode was still not being considered.

Third, LNG demand volume was summarized for each port using the previous procedure. According to the demand volume, the port is classified as either primary, secondary, or tertiary. Published national LNG terminal development plans were reviewed and, when some LNG terminals were planned as primary receivable terminals, they were classified as primary terminals even if the summarized estimated additional demand was not over the 1.0 MTPA threshold.

Through this process, all demand points were tied to ports. This is because ASEAN countries are surrounded by sea and secondary level LNG transport from primary terminals normally use sea transport. So, for hierarchizing ports, the nearest neighbour points based on sea route distance calculation should be used. Aquaplot, which provides sea route distance calculation service, was used in this study. The secondary and tertiary level ports were then tied to primary ports or larger secondary ports. After classifying and hierarchizing, the assigned LNG demands were recalculated and reclassified. Then, the final classification of the LNG terminal was decided.

The land transport modes were determined based on case studies in Japan. The criteria are introduced in the following subsections. Most of the transport modes for demand points were automatically determined by considering those criteria. When some cases remained undetermined even by applying the criteria, the transport modes for those cases were determined case by case.

The outputs of this procedure are: map of LNG terminals (existing and planned), territorial map of each primary port, and lists of demand points with transport mode.

5.2.2 Dataset

The sources of data are shown in Table 8.

Table 8. Dataset and Source of Information for LNG Supply Chain Infrastructure Analysis

Datasets	Source
Ports	Aquaplot (https://www.aquaplot.com/)
Thermal power plant	Enipedia (http://enipedia.tudelft.nl/wiki/Portal:Power_Plants)
Province	DIVA-GIS (http://www.diva-gis.org/Data)

LNG = liquefied natural gas.

5.2.3 Criteria for LNG transport mode assignment

The criteria for LNG transport mode assignment are shown in Table 9.

Table 9. Criteria for LNG Transport Mode Assignment

Transport mode	Criteria	Threshold
Pipeline	Distance to nearest port (km)	32.5 km
Railway	Distance to rail (km) of demand point side	15 km
	Distance to rail (km) of port side	15 km
	Number of train (1,300 tonnes/day equivalent)	24 times/day
Truck	Distance of road transport (km)	700 km
	Lorry operability (times/day)	24 times/day

km = kilometre, LNG = liquefied natural gas.

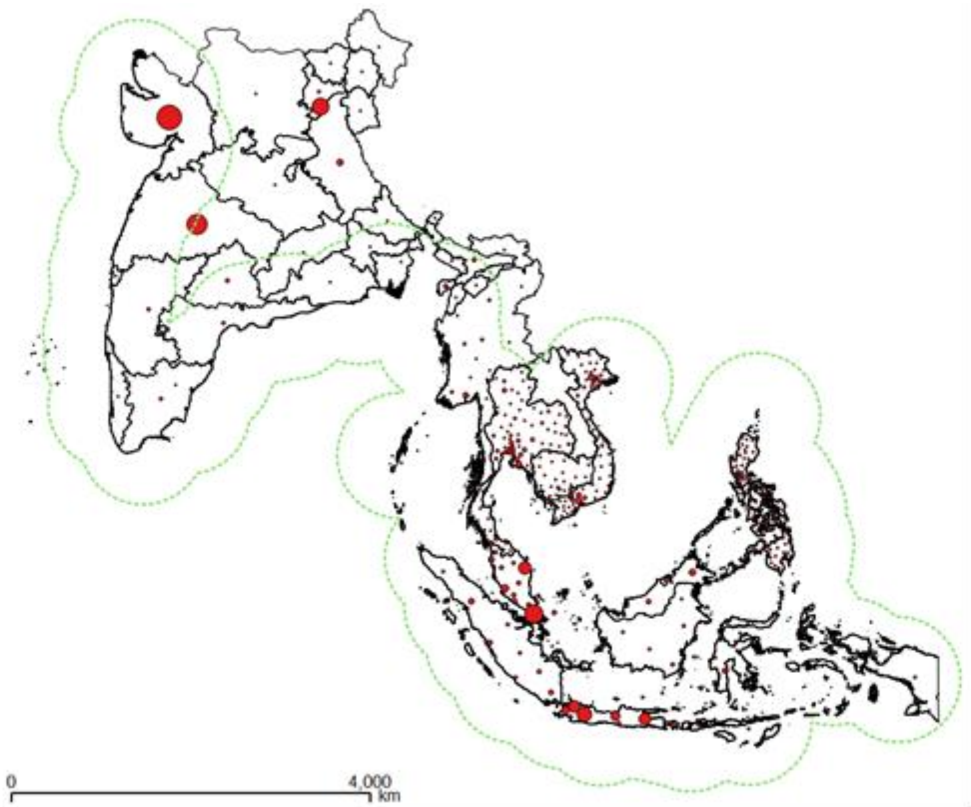
The most important criterion is the 700 km maximum distance for road transport. This is because ASEAN countries are surrounded by sea and from port to inland demand points, the distances are typically less than 700 km.

India is the only exception as shown in Figure 13. In the figure, the surrounding area within the green dotted line satisfies the condition of 700-km distance from the ports. The northern part of India (there is pipeline near Delhi) and the northern part of Myanmar are out of range. Those areas need tertiary transport networks[5] from the satellite facilities near the gas thermal power plants. Otherwise, railway connectivity or pipeline connectivity should be developed. Of course,

[4] Tertiary transport network means that the LNG was transported through primary and secondary terminals and then it reaches the major end consumption point like an LNG thermal power plant. In addition, from the storage facility at the end point, the next land transport to the further consumption point may be developed. In this case, the final land transport is defined as the tertiary transport network. Usually, the lorry transport is assumed.

the biggest demand point out of the green brake line is Delhi and it has a pipeline connection to primary LNG terminals located on the west coast of India. Therefore, only few cases need special care to transport LNG.

Figure 13. Cover Area of Each Primary LNG Terminal in 2030



LNG = liquefied natural gas.

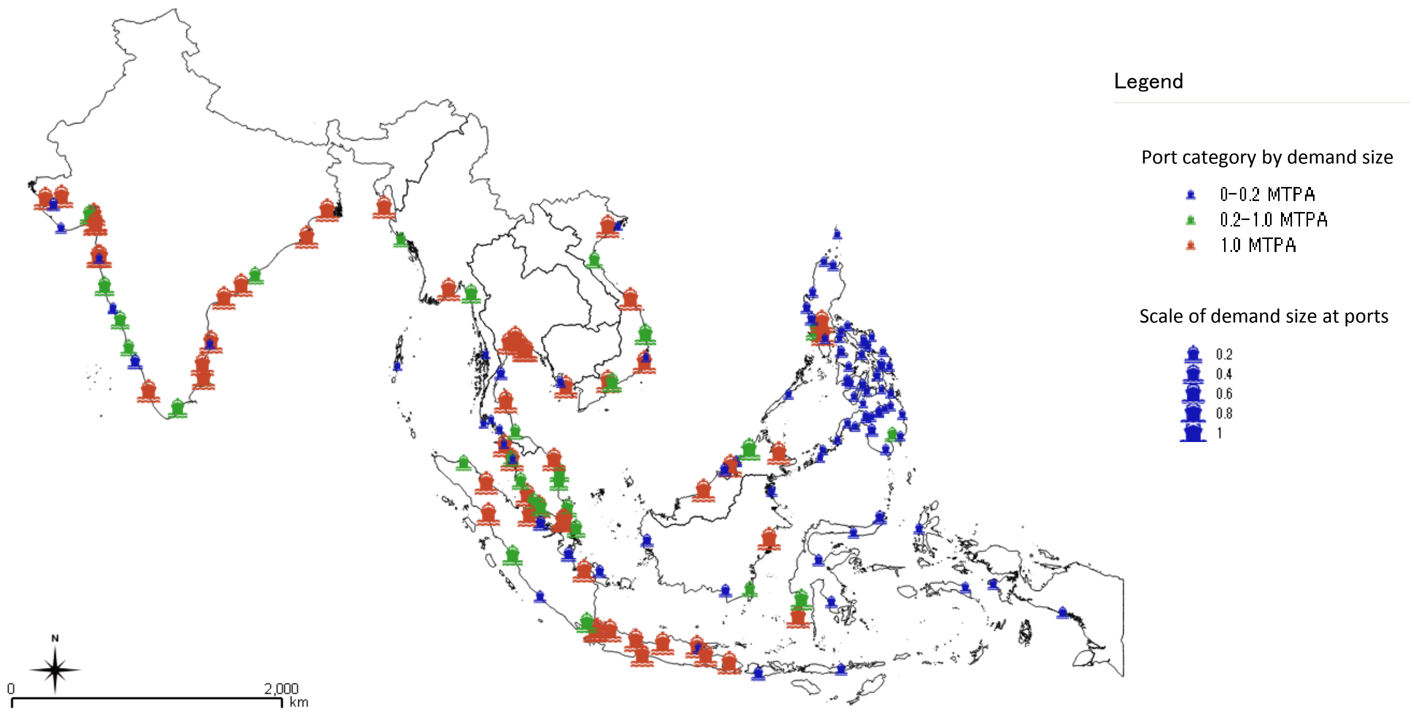
5.3 Results

5.3.1 Categorizing and hierarchizing LNG ports

The ship symbol in Figure 14 shows the location of the ports with LNG terminals. The colour shows the class of the LNG terminal. As can be seen, India and Indonesia have many primary LNG terminals, but the Philippines and Myanmar only have one LNG primary terminal.

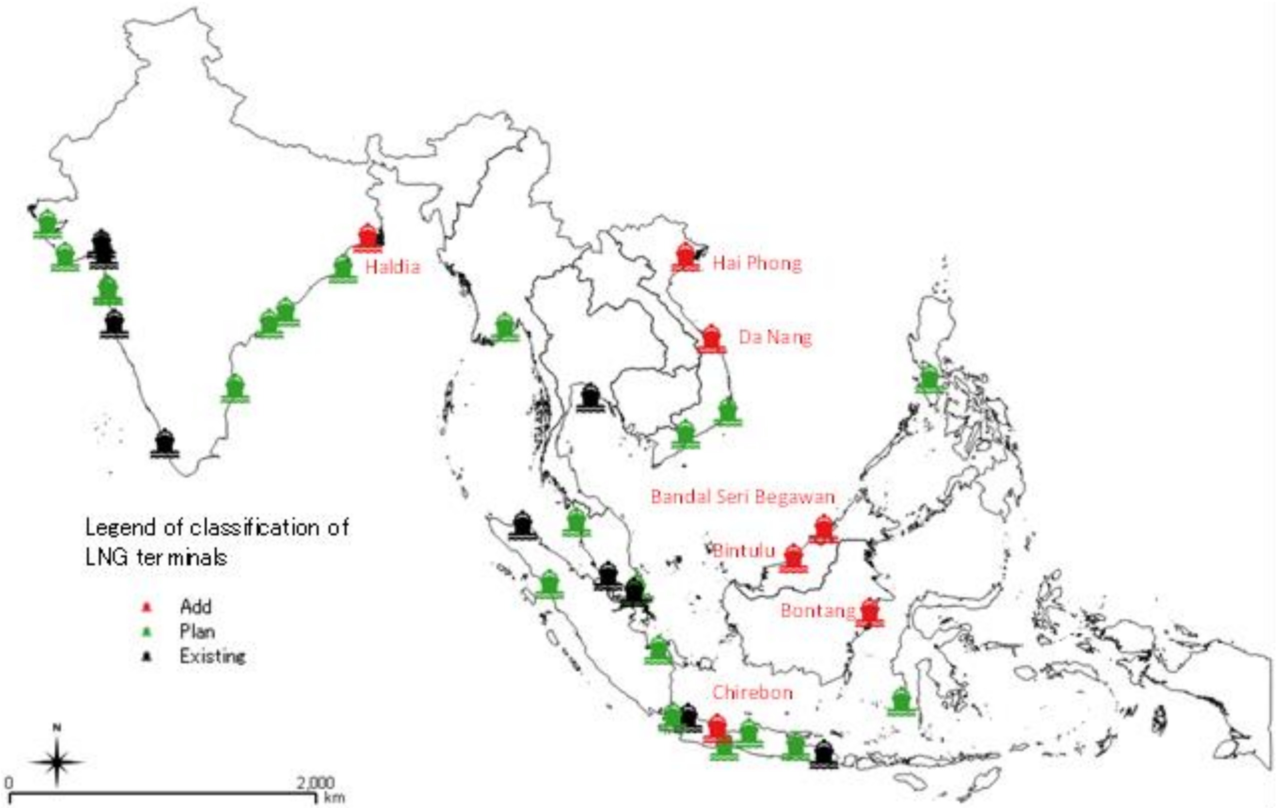
Most of the primary LNG terminals have already been planned by national governments. Only seven primary LNG terminals, namely: Haldia, Hai Phong, Da Nang, Bandal Seri Begawan, Bintulu, Bontang, and Chirebon, are recommended by this study to be added.

Figure 14. LNG Terminal Location (hierarchized)



LNG = liquefied natural gas, MPTA = million tonnes per annum

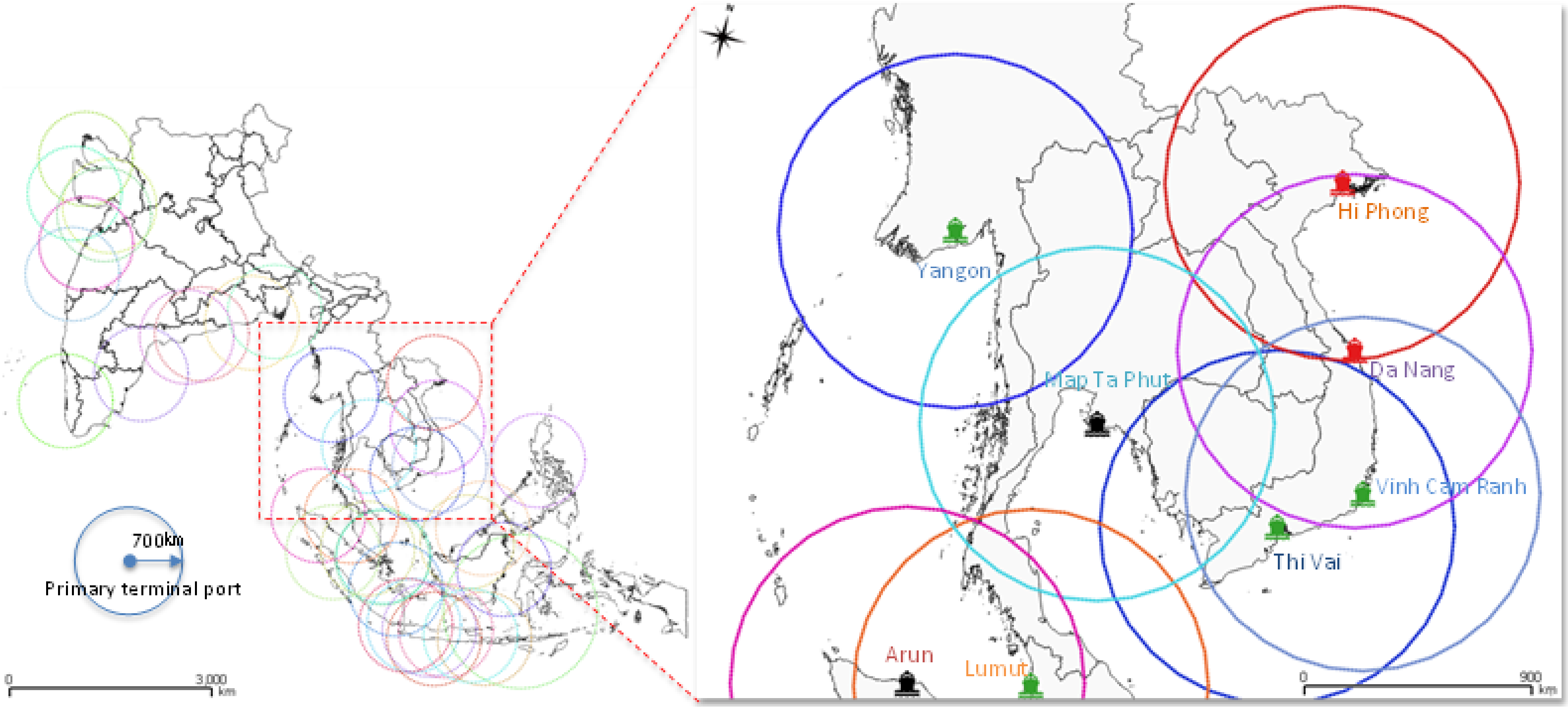
Figure 15. Existing, Planned, and Added Primary LNG Terminals



LNG = liquefied natural gas.

Note: Some of the existing and planned LNG terminals are used as acknowledged name, but it is not the port name.

Figure 16. Cover Area of Each Primary LNG Terminal in 2030



LNG = liquefied natural gas, km = kilometre.

5.3.2 Territorial map of each primary port

Except for northern India, Karnataka, and northern Myanmar, almost all areas in ASEAN and India can be covered by existing, planned, and added primary LNG terminal ports. Interestingly, some of the primary LNG terminals in ASEAN can also cover other countries' area. For example, in the Indochina peninsula, Map Ta Phut can cover southern Thailand, Cambodia, and southern Myanmar. Also, LNG primary terminals in Singapore, Malaysia, and Indonesia can cover each other.

This means that once countries in ASEAN and India cooperate with each other for developing an LNG primary terminal, the economic feasibility of such an LNG primary terminal will be improved and private entities may enter this business opportunity and make their countries save their public funds for investment. LNG transport operators who are expected to be in the private sector can also develop efficient LNG transport networks in ASEAN and India.

5.3.3 Nearest neighbour points analysis between demand points and neighbour ports, and transport mode assignments

The following tables show demand points, demand size, country, nearest port, primary port, distance to railway, distance to the nearest port, and possibility of lorry transport, lorry operability, and pipeline constructability and so on. The table headings show the types of LNG consumption at demand points and transport mode. For example, Table lists new gas thermal power plants which will be supplied by natural gas pipelines from the primary or secondary LNG terminals at the nearest port. Some of the new gas thermal power plants like Thoi Hoa are assumed to use natural gas pipelines for transporting natural gas because of the size of the demand. Railway and lorry cannot transport such a huge amount of LNG so new pipeline construction was assumed.

Table 10. List of New Gas Thermal Power Plants × Pipeline

Plant name	LNG (MTPA)	Country	Nearest port name	Primary port name	Distance to rail (km)	Distance to nearest port (km)	Railroad within 15 km	Possibility of lorry transport (within 700 km)	Lorry operability (24 times/day)	Pipeline constructability (within 32.5 km to port)
Nhon Hoi Refinery	0.819	Viet Nam	Qui Nhon	Vinh Cam Ranh	11	9	Available	Possible		Constructible
Phu My	0.151	Viet Nam	Phu My	Cat Lai	43	9		Possible		Constructible
Thoi Hoa	1.17	Viet Nam	Cat Lai	Cat Lai	6	61	Available	Possible		
Nhon Trach	1.078	Viet Nam	Cat Lai	Cat Lai	29	19		Possible		Constructible
Hiep Phuoc	0.89	Viet Nam	Cat Lai	Cat Lai	5	22	Available	Possible		Constructible
Ca Mau City	1.924	Viet Nam	Duong Dong	Map Ta Phut	214	176		Possible		
Prodair Kochi	0.3	India	Kochi (Cochin)	Kochi (Cochin)	10	17	Available	Possible		Constructible
Pillaiperumalnallur	1.613	India	Karaikal Port	Ennur	7	27	Available	Possible		Constructible
Mangalore Refinery	0.291	India	New Mangalore	Kochi (Cochin)	1	9	Available	Possible		Constructible
Rajahmundry	3.279	India	Kakinada Bay	Kakinada Bay	2	54	Available	Possible		
Trombay	4.935	India	Mumbai (Bombay)	Mumbai (Bombay)	9	5	Available	Possible		Constructible
Sugen	5.946	India	Magdalla	Magdalla	18	34		Possible		
Palatana	1.557	India	Chittagong	Haldia Port	194	142		Possible		
Sultan Iskandar	2.684	Malaysia	Pasir Gudang	Jurong Island	15	2	Available	Possible		Constructible
Bintulu	2.017	Malaysia	Bintulu Port	Bintulu Port	142	11		Possible		Constructible
Kulim Indust Park	1.24	Malaysia	Butterworth	Butterworth	15	23		Possible		Constructible
Kimanis Power	0.867	Malaysia	Sapangar Bay	Bandar Seri Begawan	1	55	Available	Possible		
Khanom	0.53	Thailand	Khanom	Map Ta Phut	367	4		Possible		Constructible
Glow Spp Phase 3–5	0.599	Thailand	Map Ta Phut	Map Ta Phut	242	3		Possible		Constructible

Sriracha Ipt	0.169	Thailand	Si Racha Terminal	Map Ta Phut	238	8		Possible		Constructible
Ratchaburi	1.502	Thailand	Petchburi Terminal	Map Ta Phut	271	71		Possible		
South Bangkok	0.32	Thailand	Bangkok	Map Ta Phut	279	12		Possible		Constructible
North Bangkok	0.466	Thailand	Bangkok	Map Ta Phut	287	34		Possible		
Korat	0.547	Thailand	Bangkok	Map Ta Phut	196	228		Possible		
Nong Chok	0.538	Thailand	Bangkok	Map Ta Phut	227	290		Possible		
Jurong Island	9.373	Singapore	Jurong Island	Jurong Island	16	6		Possible		Constructible
Gadong	0.407	Brunei	Bandar Seri Begawan	Bandar Seri Begawan	82	11		Possible		Constructible
Pemaron	0.59	Indonesia	Celukan Bawang	Celukan Bawang	87	26		Possible		Constructible
Cilegon Nsi	0.94	Indonesia	Banten	Banten	2	5	Available	Possible		Constructible
Cilacap	1.425	Indonesia	Cilacap	Cilacap	6	5	Available	Possible		Constructible
Petorkima Gresik	1.985	Indonesia	Gresik	Gresik	8	2	Available	Possible		Constructible
Bontang Works	0.783	Indonesia	Bontang Lng Terminal	Bontang Lng Terminal	541	1		Possible		Constructible
Paya Pasir	1.312	Indonesia	Belawan	Butterworth	3	8	Available	Possible		Constructible
North Duri	1.183	Indonesia	Dumai	Pelabuhan Sungai Udang	132	2		Possible		Constructible
Muara Tawar	3.969	Indonesia	Jakarta	Jakarta	18	13		Possible		Constructible
Calaca Semirara	0.569	Philippines	Nasugbu	Batangas City	6	25	Available	Possible		Constructible
Santa Rita Batangas	0.58	Philippines	Batangas City	Batangas City	1	1	Available	Possible		Constructible
Therma South	0.165	Philippines	Davao	Bontang Lng Terminal	40	19		Possible		Constructible

km = kilometres, LNG = liquefied natural gas, MTPA = million tonnes per annum.
Source: authors.

The following new gas thermal power plants will use railway to transport LNG because it is difficult to connect them and the ports through pipelines due to the long distance, and both ports and power plants have railway connectivity. For example, from the Jakarta port to Cikarang, a maximum of 12 trains of 1,300 tonnes (40-ft × 100 containers per train) are needed.

Table 11. List of New Gas Thermal Power Plants × Railway

Plant name	LNG (MTPA)	Country	Nearest port name	Primary port name	Distance to rail (km)	Distance to nearest port (km)	Railroad within 15 km	Possibility of lorry transport (within 700 km)	Lorry operability (24 times/day)	Pipeline constructability (within 32.5 km to port)
Pha Lai	0.389	Viet Nam	Hai Phong	Hai Phong	15	46		Possible		
Hai Phong Thermal	0.046	Viet Nam	Nghe Tinh	Hai Phong	2	12	Available	Possible	Operable	Constructible
Ninh Binh	0.195	Viet Nam	Hai Phong	Hai Phong	2	107	Available	Possible		
One Asia Quang Tri	1.404	Viet Nam	Da Nang	Da Nang	0	145	Available	Possible		
Vinh Tan	2.282	Viet Nam	Vinh Cam Ranh	Vinh Cam Ranh	1	74	Available	Possible		
Talcher Kaniha	0.291	India	Paradip	Paradip	37	191		Possible		
Mejia	0.204	India	Haldia Port	Haldia Port	22	188		Possible		
Dholpur	1.125	India	Dahej	Dahej	0	769	Available			
Kathalguri	1.346	India	Chittagong	Haldia Port	6	664	Available	Possible		
Leh District	0.058	India	Dahej	Dahej	9	875	Available		Operable	
Faridabad Ntpc	0.462	India	Dahej	Dahej	9	875	Available			

Dadri	0.252	India	Dahej	Dahej	17	911				
Pragati	1.595	India	Dahej	Dahej	1	894	Available			
Lalkua Mill	0.054	India	Dahej	Dahej	24	1,084			Operable	
Talwandi Sabo	0.058	India	Navlakhi	Mandvi	24	899			Operable	
Klcc/Dcs Cogen	0.086	Malaysia	Port Klang	Port Klang	1	42	Available	Possible	Operable	
Thaton	0.009	Myanmar	Moulmein Harbor	Rangoon	2	55	Available	Possible	Operable	
Cikarang	4.479	Indonesia	Jakarta	Jakarta	3	34	Available	Possible		
Borang-2	1.743	Indonesia	Muntok	Muntok	27	92		Possible		
Navotas Barge	0.348	Philippines	Manila	Batangas City	19	35		Possible		
Malaya	0.122	Philippines	Manila	Batangas City	26	39		Possible		

km = kilometres, LNG = liquefied natural gas, MTPA = million tonnes per annum.

Source: Authors.

The following new gas thermal power plants will have truck transport with 40-ft ISO containers.

Table 12. List of New Gas Thermal Power Plants × Truck Transport with ISO Containers

Plant name	LNG (MTPA)	Country	Nearest port name	Primary port name	Distance to rail (km)	Distance to nearest port (km)	Railroad within 15 km	Possibility of lorry transport (within 700 km)	Lorry operability (24 times/day)	Pipeline constructability (within 32.5 km to port)
O Mon	0.056	Viet Nam	Cat Lai	Cat Lai	161	132		Possible	Operable	
Karaikal	0.117	India	Karaikal Port	Ennur	2	12	Available	Possible	Operable	Constructible
Tribeni	0.058	India	Haldia Port	Haldia Port	50	543		Possible	Operable	
Teluk Gong (Panglima)	0.008	Malaysia	Pelabuhan Sungai Udang	Pelabuhan Sungai Udang	25	16		Possible	Operable	Constructible
Tuanku Jaafar	0.058	Malaysia	Port Dickson	Pelabuhan Sungai Udang	2	3	Available	Possible	Operable	Constructible
Kuala Langat	0.002	Malaysia	Port Klang	Port Klang	3	26	Available	Possible	Operable	Constructible
Kuantan	0.081	Malaysia	Kuantan New Port	Kuala Trengganu	51	22		Possible	Operable	Constructible
Lumut Segari	0.04	Malaysia	Teluk Anson	Port Klang	65	53		Possible	Operable	
Paka Ytl	0.077	Malaysia	Kirteh Oil Terminal	Kuala Trengganu	14	13	Available	Possible	Operable	Constructible

Labuan Methanol	0.027	Malaysia	Victoria	Bandar Seri Begawan	60	2		Possible	Operable	Constructible
Gelugor	0	Malaysia	Butterworth	Butterworth	1	18	Available	Possible	Operable	Constructible
Kota Bharu	0.577	Malaysia	Kuala Trengganu	Kuala Trengganu	13	129	Available	Possible		
Perlis	1.597	Malaysia	Pelabuhan Bass	Butterworth	18	37		Possible		
Prachin Buri Mill	0.065	Thailand	Bangkok	Map Ta Phut	151	111		Possible	Operable	
Navanakorn	0.082	Thailand	Bangkok	Map Ta Phut	280	63		Possible	Operable	
Wang Noi	0	Thailand	Bangkok	Map Ta Phut	260	82		Possible	Operable	
Kaeng Khoi-2	0.163	Thailand	Bangkok	Map Ta Phut	253	126		Possible		
Singburi Promburi	0.069	Thailand	Bangkok	Map Ta Phut	346	154		Possible	Operable	
Shwedaung	0.001	Myanmar	Rangoon	Rangoon	18	237		Possible	Operable	
Mann	0.001	Myanmar	Sittwe	Haldia Port	147	200		Possible	Operable	
Myingyan	0.017	Myanmar	Sittwe	Haldia Port	1	294	Available	Possible	Operable	
Kawthaung	0.024	Myanmar	Khanom	Map Ta Phut	304	171		Possible	Operable	
Ywama	0.011	Myanmar	Rangoon	Rangoon	1	2	Available	Possible	Operable	Constructible
Lhokseumawe Pertamina	0.049	Indonesia	Lhokseumawe	Lhokseumawe	6	2	Available	Possible	Operable	Constructible

Jambi Lontar	0.057	Indonesia	Jabung Batanghari Marine Terminal	Jurong Island	122	86		Possible	Operable	
Tello	0.027	Indonesia	Ujung Pandang	Ujung Pandang	599	8		Possible	Operable	Constructible
Siantan	0.005	Indonesia	Pontianak	Muntok	407	20		Possible	Operable	Constructible
Amamapare Port	0.011	Indonesia	Amamapare	Ujung Pandang	1,854	12		Possible	Operable	Constructible
Ilijan	0.028	Philippines	Batangas City	Batangas City	16	16		Possible	Operable	Constructible
Naga City	0.078	Philippines	Catbalogan	Batangas City	136	45		Possible	Operable	
Gt Barge 207	0.05	Philippines	Port Romblon	Batangas City	117	63		Possible	Operable	
Cotabato Basin	0.067	Philippines	Polloc (Cotabato)	Bontang Lng Terminal	126	65		Possible	Operable	

km = kilometres, LNG = liquefied natural gas, MTPA = million tonnes per annum.

Source: Authors.

Table 13. List of Fuel Conversion Thermal Power Plants × Pipeline

Plant name	LNG (MTPA)	Country	Port name	Primary port	Distance to rail (km)	Distance to nearest port (km)	Railway connectivity at demand points (less than 15 km)	No. of train (1,300 tonnes/day equivalent)	Possibility of lorry supply (less than 700 km)	Impossibility of Lorry supply (more than 700 km)	Possibility of lorry operation	Lorry operability	Pipeline	Connectivity from port to rail
Thu Duc	0.051	Viet Nam	Cat Lai	Cat Lai	2	32	transportable	0.1	transportable		10	operable	Constructible	
Hai Phong Thermal-I	0.025	Viet Nam	Nghe Tinh	Hai Phong	2	12	transportable	0.1	transportable		5	operable	Constructible	connected
Vizag Refinery	0.004	India	Vishakhapatnam	Vishakhapatnam	7	2	transportable	0	transportable		1	operable	Constructible	connected
Vizag Steel Plant	0.127	India	Vishakhapatnam	Vishakhapatnam	7	2	transportable	0.3	transportable		26		Constructible	connected
Kribhco Hazira	0.021	India	Magdalla	Magdalla	4	11	transportable	0	transportable		4	operable	Constructible	
Sikka	0.085	India	Sikka	Mandvi	4	3	transportable	0.2	transportable		17	operable	Constructible	connected
Kochi Refinery	0.002	India	Kochi (Cochin)	Kochi (Cochin)	2	11	transportable	0	transportable		0	operable	Constructible	connected
Mahul Refinery	0.004	India	Mumbai (Bombay)	Mumbai (Bombay)	2	6	transportable	0	transportable		1	operable	Constructible	connected
Mumbai Hll	0.002	India	Mumbai (Bombay)	Mumbai (Bombay)	2	6	transportable	0	transportable		0	operable	Constructible	connected
Thane Plant	0.003	India	Jawaharlal Nehru Port (Nhava Shiva)	Jawaharlal Nehru Port (Nhava Shiva)	3	28	transportable	0	transportable		1	operable	Constructible	connected
Trombay	0.353	India	Mumbai (Bombay)	Mumbai (Bombay)	9	5	transportable	0.7	transportable		72		Constructible	connected

Paradip Works	0.023	India	Paradip	Paradip	3	6	transportable	0	transportable		5	operable	Constructible	connected
Ennore	0.318	India	Ennur	Ennur	1	5	transportable	0.7	transportable		64		Constructible	connected
Madras Southern Petro	0.013	India	Chennai (Madras)	Ennur	1	3	transportable	0	transportable		3	operable	Constructible	connected
Manali Refinery	0.004	India	Chennai (Madras)	Ennur	6	8	transportable	0	transportable		1	operable	Constructible	connected
Tuticorin	0.593	India	Tuticorin	Kochi (Cochin)	12	4	transportable	1.2	transportable		120		Constructible	connected
Durgapur Plant Hfcl	0.025	India	Haldia Port	Haldia Port	27	6		0.1	transportable		5	operable	Constructible	
Sultan Iskandar	0.164	Malaysia	Pasir Gudang	Jurong Island	15	2	transportable	0.3	transportable		33		Constructible	connected
Patau-Patau	0.023	Malaysia	Labuan	Bandar Seri Begawan	62	1		0	transportable		5	operable	Constructible	
Kuantan	0.012	Malaysia	Kuantan New Port	Kuala Trengganu	51	22		0	transportable		2	operable	Constructible	
Perai	0.006	Malaysia	Butterworth	Butterworth	2	2	transportable	0	transportable		1	operable	Constructible	connected
Prai	0.268	Malaysia	Butterworth	Butterworth	2	2	transportable	0.6	transportable		54		Constructible	connected
Sultan Aziz (Kapar)	0.824	Malaysia	Port Klang	Port Klang	16	13		1.7	Transportabl e		167		Constructible	Connected
Sultan Ismail (Paka)	0.481	Malaysia	Kirteh Oil Terminal	Kuala Trengganu	20	8		1	transportable		98		Constructible	
Khanom	0.051	Thailand	Khanom	Map Ta Phut	367	4		0.1	transportable		10	operable	Constructible	
South Bangkok	0.275	Thailand	Bangkok	Map Ta Phut	279	12		0.6	transportable		56		Constructible	

Jurong	0.06	Singapore	Jurong Island	Jurong Island	16	6		0.1	transportable		12	operable	Constructible	connected
Pulau Seraya	0.01	Singapore	Jurong Island	Jurong Island	10	1	transportable	0	transportable		2	operable	Constructible	connected
Mawlamyaing	0.008	Myanmar	Moulmein Harbor	Chittagong	4	1	transportable	0	transportable		2	operable	Constructible	connected
Ywama	0.008	Myanmar	Rangoon	Chittagong	1	2	transportable	0	transportable		2	operable	Constructible	connected
Suralay**a**	0.183	Indonesia	Tanjung Sekong	Banten	8	4	transportable	0.4	transportable		37		Constructible	connected
Tambak Lorok	0.029	Indonesia	Semarang	Semarang	1	3	transportable	0.1	transportable		6	operable	Constructible	connected
Gresik	0.08	Indonesia	Gresik	Gresik	6	2	transportable	0.2	transportable		16	operable	Constructible	connected
Petak	0.026	Indonesia	Surabaya	Gresik	5	1	transportable	0.1	transportable		5	operable	Constructible	connected
Perak	0.011	Indonesia	Surabaya	Gresik	5	1	transportable	0	transportable		2	operable	Constructible	connected
Pulogadung	0.039	Indonesia	Jakarta	Jakarta	5	11	transportable	0.1	transportable		8	operable	Constructible	connected
Tanjung Priok	0.015	Indonesia	Jakarta	Jakarta	2	2	transportable	0	transportable		3	operable	Constructible	connected
Berushaan	0.007	Indonesia	Jakarta	Jakarta	1	18	transportable	0	transportable		1	operable	Constructible	connected
Muara Karang	0.046	Indonesia	Jakarta	Jakarta	4	11	transportable	0.1	transportable		9	operable	Constructible	connected
Belawan	0.03	Indonesia	Belawan	Butterworth	0	2	transportable	0.1	transportable		6	operable	Constructible	connected
Batamindo Industrial	0.003	Indonesia	Sekupang	Jurong Island	39	14		0	transportable		1	operable	Constructible	
Tello	0.017	Indonesia	Ujung Pandang	Ujung Pandang	599	8		0	transportable		4	operable	Constructible	

Padang	0.014	Indonesia	Teluk Bayur	Sibolga	14	14	transportable	0	transportable		3	operable	Constructible	connected
Khanom	0.051	Cambodia	Khanom	Map Ta Phut	367	4		0.1	transportable		10	operable	Constructible	
South Bangkok	0.275	Cambodia	Bangkok	Map Ta Phut	279	12		0.6	transportable		56		Constructible	
Calaca Semirara	0.212	Philippines	Nasugbu	Batangas City	6	25	transportable	0.4	transportable		43		Constructible	connected

km = kilometres, LNG = liquefied natural gas, MTPA = million tonnes per annum.

Source: Authors.

Table 14. List of Fuel Conversion Thermal Power Plants × Railway

Plant name	LNG (MTPA)	Country	Port name	Primary port	Distance to rail (km)	Distance to nearest port (km)	Railway connectivity at demand points (less than 15 km)	No. of train (1,300 tonnes/day equivalent)	Possibility of lorry supply (less than 700 km)	Impossibility of Lorry supply (more than 700 km)	Possibility of lorry operation	Lorry operability	Pipeline	Connectivity from port to rail
Ninh Binh	0.063	Viet Nam	Hai Phong	Hai Phong	2	107	transportable	0.1	transportable		13	operable		connected
Bhadrachalam Mill	0.009	India	Machilipatnam	Kakinada Bay	6	320	transportable	0	transportable		2	operable		connected
Dr Narla Tata Rao	0.593	India	Machilipatnam	Kakinada Bay	4	86	transportable	1.2	transportable		120			connected
Bhilai Works	0.052	India	Vishakhapatnam	Vishakhapatnam	3	434	transportable	0.1	transportable		11	operable		connected
Korba Balco-I	0.191	India	Paradip	Paradip	2	472	transportable	0.4	transportable		39			connected
Korba East	0.311	India	Paradip	Paradip	7	471	transportable	0.7	transportable		63			connected
Korba Stps	1.482	India	Paradip	Paradip	8	474	transportable	3.1	transportable		301			connected
Korba West Hasdeo	0.593	India	Paradip	Paradip	12	475	transportable	1.2	transportable		120			connected
Badarpur	0.498	India	Dahej	Dahej	2	887	transportable	1		impossible	101			connected
Bharuch Gnfc	0.035	India	Dahej	Dahej	1	46	transportable	0.1	transportable		7	operable		connected
Dhuvaran	0.155	India	Dahej	Dahej	0	63	transportable	0.3	transportable		32			connected
Veraval Soda Ash	0.016	India	Veraval	Veraval	2	69	transportable	0	transportable		3	operable		connected
Faridabad	0.116	India	Dahej	Dahej	0	875	transportable	0.2		impossible	24	operable		connected
Panipat	0.459	India	Dahej	Dahej	1	951	transportable	1		impossible	93			connected
Panipat Works	0.021	India	Dahej	Dahej	1	954	transportable	0		impossible	4	operable		connected

Yamunanagar Mill	0.013	India	Navlakhi	Mandvi	3	1,029	transportable	0		impossible	3	operable		connected
Bhadravati Mill	0.018	India	New Mangalore	Kochi (Cochin)	5	138	transportable	0	transportable		4	operable		connected
Hnl Mill	0.021	India	Kochi (Cochin)	Kochi (Cochin)	4	52	transportable	0	transportable		4	operable		connected
Amarkantak	0.169	India	Paradip	Paradip	3	609	transportable	0.4	transportable		34			connected
Nagda Works	0.044	India	Dahej	Dahej	1	353	transportable	0.1	transportable		9	operable		connected
Bhigwan Mill	0.005	India	Jawaharlal Nehru Port (Nhava Shiva)	Jawaharlal Nehru Port (Nhava Shiva)	3	204	transportable	0	transportable		1	operable		connected
Nasik	**0.642**	**India**	**Jawaharlal Nehru Port (Nhava Shiva)**	**Jawaharlal Nehru Port (Nhava Shiva)**	**5**	**151**	**transportable**	**1.4**	**transportable**		**130**			**connected**
Parli	0.445	India	Jawaharlal Nehru Port (Nhava Shiva)	Jawaharlal Nehru Port (Nhava Shiva)	3	378	transportable	0.9	transportable		90			connected
South Bassein	0.018	India	Mumbai (Bombay)	Mumbai (Bombay)	7	47	transportable	0	transportable		4	operable		connected
Angul Smelter	0.424	India	Paradip	Paradip	9	169	transportable	0.9	transportable		86			connected
Brajragnagar Mill	0.006	India	Paradip	Paradip	0	334	transportable	0	transportable		1	operable		connected
Choudwar Imfa	0.076	India	Paradip	Paradip	5	87	transportable	0.2	transportable		15	operable		connected
Damanjodi Refinery	0.039	India	Vishakhapatnam	Vishakhapatnam	1	140	transportable	0.1	transportable		8	operable		connected

Rourkela Works	0.181	India	Paradip	Paradip	1	285	transportable	0.4	transportable		37			connected
Talcher	0.332	India	Paradip	Paradip	2	169	transportable	0.7	transportable		67			connected
Bhatinda Works	0.023	India	Navlakhi	Mandvi	2	915	transportable	0		impossible	5	operable		connected
Guru Nanak Dev	0.318	India	Navlakhi	Mandvi	1	914	transportable	0.7		impossible	64			connected
Ropar	0.593	India	Navlakhi	Mandvi	2	1,070	transportable	1.2		impossible	120			connected
Kota	0.452	India	Dahej	Dahej	10	507	transportable	1	transportable		92			connected
Mettur	0.593	India	Cuddalore	Ennur	7	215	transportable	1.2	transportable		120			connected
Neyveli	0.868	India	Cuddalore	Ennur	10	36	transportable	1.8	transportable		176			connected
Kothagudem	0.508	India	Machilipatnam	Kakinada Bay	2	173	transportable	1.1	transportable		103			connected
Ramagundam	1.526	India	Machilipatnam	Kakinada Bay	3	342	transportable	3.2	transportable		310			connected
Sirpur Mill	0.016	India	Machilipatnam	Kakinada Bay	1	480	transportable	0	transportable		3	operable		connected
Harduaganj	0.078	India	Dahej	Dahej	9	886	transportable	0.2		impossible	16	operable		connected
Muradnagar	0.001	India	Dahej	Dahej	4	922	transportable	0		impossible	0	operable		connected
Parichha	0.155	India	Dahej	Dahej	3	755	transportable	0.3		impossible	32			connected
Tanda	0.233	India	Dahej	Dahej	11	1,020	transportable	0.5		impossible	47			connected

Plant name	LNG (MTPA)	Country	Port name	Primary port	Distance to rail (km)	Distance to nearest port (km)	Railway connectivity at demand points (less than 15 km)	No. of train (1,300 tonnes/ day equivalent	Possibility of lorry supply (less than 700 km)	Impossibility of Lorry supply (more than 700 km)	Possibility of lorry operation	Lorry operability	Pipeline	Connectivity from port to rail
Ninh Binh	**0.063**	**Viet Nam**	**Hai Phong**	**Hai Phong**	**2**	**107**	**transportable**	**0.1**	**transportable**		**13**	**operable**		**connected**
Bhadrachalam Mill	0.009	India	Machilipatnam	Kakinada Bay	6	320	transportable	0	transportable		2	operable		connected
Dr Narla Tata Rao	0.593	India	Machilipatnam	Kakinada Bay	4	86	transportable	1.2	transportable		120			connected
Bhilai Works	0.052	India	Vishakhapatnam	Vishakhapatnam	3	434	transportable	0.1	transportable		11	operable		connected
Korba Balco-I	0.191	India	Paradip	Paradip	2	472	transportable	0.4	transportable		39			connected
Korba East	0.311	India	Paradip	Paradip	7	471	transportable	0.7	transportable		63			connected
Korba Stps	1.482	India	Paradip	Paradip	8	474	transportable	3.1	transportable		301			connected
Korba West Hasdeo	0.593	India	Paradip	Paradip	12	475	transportable	1.2	transportable		120			connected
Badarpur	0.498	India	Dahej	Dahej	2	887	transportable	1		impossible	101			connected
Bharuch Gnfc	0.035	India	Dahej	Dahej	1	46	transportable	0.1	transportable		7	operable		connected
Dhuvaran	0.155	India	Dahej	Dahej	0	63	transportable	0.3	transportable		32			connected
Veraval Soda Ash	0.016	India	Veraval	Veraval	2	69	transportable	0	transportable		3	operable		connected
Faridabad	0.116	India	Dahej	Dahej	0	875	transportable	0.2		impossible	24	operable		connected
Panipat	0.459	India	Dahej	Dahej	1	951	transportable	1		impossible	93			connected
Panipat Works	0.021	India	Dahej	Dahej	1	954	transportable	0		impossible	4	operable		connected
Yamunanagar Mill	0.013	India	Navlakhi	Mandvi	3	1,029	transportable	0		impossible	3	operable		connected
Bhadravati Mill	0.018	India	New Mangalore	Kochi (Cochin)	5	138	transportable	0	transportable		4	operable		connected
Hnl Mill	0.021	India	Kochi (Cochin)	Kochi (Cochin)	4	52	transportable	0	transportable		4	operable		connected
Amarkantak	0.169	India	Paradip	Paradip	3	609	transportable	0.4	transportable		34			connected
Nagda Works	0.044	India	Dahej	Dahej	1	353	transportable	0.1	transportable		9	operable		connected
Bhigwan Mill	0.005	India	Jawaharlal Nehru Port (Nhava Shiva)	Jawaharlal Nehru Port (Nhava Shiva)	3	204	transportable	0	transportable		1	operable		connected

Nasik	**0.642**	**India**	**Jawaharlal Nehru Port (Nhava Shiva)**	**Jawaharlal Nehru Port (Nhava Shiva)**	**5**	**151**	**transportable**	**1.4**	**transportable**		**130**			**connected**
Parli	0.445	India	Jawaharlal Nehru Port (Nhava Shiva)	Jawaharlal Nehru Port (Nhava Shiva)	3	378	transportable	0.9	transportable		90			connected
South Bassein	0.018	India	Mumbai (Bombay)	Mumbai (Bombay)	7	47	transportable	0	transportable		4	operable		connected
Angul Smelter	0.424	India	Paradip	Paradip	9	169	transportable	0.9	transportable		86			connected
Brajragnagar Mill	0.006	India	Paradip	Paradip	0	334	transportable	0	transportable		1	operable		connected
Choudwar Imfa	0.076	India	Paradip	Paradip	5	87	transportable	0.2	transportable		15	operable		connected
Damanjodi Refinery	0.039	India	Vishakhapatnam	Vishakhapatnam	1	140	transportable	0.1	transportable		8	operable		connected
Rourkela Works	0.181	India	Paradip	Paradip	1	285	transportable	0.4	transportable		37			connected
Talcher	0.332	India	Paradip	Paradip	2	169	transportable	0.7	transportable		67			connected
Bhatinda Works	0.023	India	Navlakhi	Mandvi	2	915	transportable	0		impossible	5	operable		connected
Guru Nanak Dev	0.318	India	Navlakhi	Mandvi	1	914	transportable	0.7		impossible	64			connected
Ropar	0.593	India	Navlakhi	Mandvi	2	1,070	transportable	1.2		impossible	120			connected
Kota	0.452	India	Dahej	Dahej	10	507	transportable	1	transportable		92			connected
Mettur	0.593	India	Cuddalore	Ennur	7	215	transportable	1.2	transportable		120			connected
Neyveli	0.868	India	Cuddalore	Ennur	10	36	transportable	1.8	transportable		176			connected
Kothagudem	0.508	India	Machilipatnam	Kakinada Bay	2	173	transportable	1.1	transportable		103			connected
Ramagundam	1.526	India	Machilipatnam	Kakinada Bay	3	342	transportable	3.2	transportable		310			connected
Sirpur Mill	0.016	India	Machilipatnam	Kakinada Bay	1	480	transportable	0	transportable		3	operable		connected
Harduaganj	0.078	India	Dahej	Dahej	9	886	transportable	0.2		impossible	16	operable		connected
Muradnagar	0.001	India	Dahej	Dahej	4	922	transportable	0		impossible	0	operable		connected
Parichha	0.155	India	Dahej	Dahej	3	755	transportable	0.3		impossible	32			connected
Tanda	0.233	India	Dahej	Dahej	11	1,020	transportable	0.5		impossible	47			connected

km = kilometres, LNG = liquefied natural gas, MTPA = million tonnes per annum.

Source: Authors.

Table 15. List of Fuel Conversion Thermal Power Plants × Truck Transport with ISO Containers

Plant name	LNG (MTPA)	Country	Port name	Primary port	Distance to rail (km)	Distance to nearest port (km)	Railway connectivity at demand points (less than 15 km)	No. of train (1,300 tonnes/day equivalent)	Possibility of lorry supply (less than 700km)	Impossibility of lorry supply (more than 700 km)	Possibility of lorry operation	Lorry operability	Pipeline	Connectivity from port to rail
Can Tho	0.009	Viet Nam	Cat Lai	Cat Lai	158	121		0	transportable		2	operable		
Thu Duc	0.051	Viet Nam	Cat Lai	Cat Lai	2	32	transportable	0.1	transportable		10	operable	Constructible	
Nellore	0.021	India	Ennur	Ennur	37	126		0	transportable		4	operable		connected
Bongaigaon Refinery	0.034	India	Chittagong	Chittagong	2	481	transportable	0.1	transportable		7	operable		
Cachar Mill	0.021	India	Chittagong	Chittagong	1	278	transportable	0	transportable		4	operable		
Guwahati Refinery	0.006	India	Chittagong	Chittagong	2	434	transportable	0	transportable		1	operable		
Nagaon Mill	0.021	India	Chittagong	Chittagong	7	434	transportable	0	transportable		4	operable		
Namrup Works	0.005	India	Chittagong	Chittagong	3	646	transportable	0	transportable		1	operable		
Bihar Cea	0.007	India	Haldia Port	Haldia Port	0	437	transportable	0	transportable		1	operable		
Karbigahiya	0.01	India	Haldia Port	Haldia Port	0	437	transportable	0	transportable		2	operable		
Kustore	0.002	India	Haldia Port	Haldia Port	0	437	transportable	0	transportable		0	operable		
Moonidih Washery	0.016	India	Haldia Port	Haldia Port	6	260	transportable	0	transportable		3	operable		
West Bokaro Colliery	0.007	India	Haldia Port	Haldia Port	1	292	transportable	0	transportable		1	operable		
Kutch Gsecl	0.049	India	Mandvi	Mandvi	231	109		0.1	transportable		10	operable		
Mithapur Plant	0.039	India	Navlakhi	Mandvi	39	157		0.1	transportable		8	operable		connected
Chaibasa Plant	0.004	India	Haldia Port	Haldia Port	3	342	transportable	0	transportable		1	operable		
Harihar Polyfibre	0.012	India	Belekeri	Ratnagiri	1	167	transportable	0	transportable		2	operable		

Rajashree Cement	0.013	India	Panaji	Ratnagiri	10	401	transportable	0	transportable		3	operable		
Wadi Cement Plant	0.018	India	Ratnagiri	Ratnagiri	5	379	transportable	0	transportable		4	operable		
Nagothane Complex	0.009	India	Mandwa	Jawaharlal Nehru Port (Nhava Shiva)	68	85		0	transportable		2	operable		
Khetri Mine	0.004	India	Navlakhi	Mandvi	17	585		0	transportable		1	operable		connected
Cpil Tamil Nadu	0	India	Nagappattinam	Ennur	59	132		0	transportable		0	operable		connected
Manuguru	0.064	India	Kakinada Bay	Kakinada Bay	85	204		0.1	transportable		13	operable		
Calcutta Works	0.001	India	Haldia Port	Haldia Port	1	68	transportable	0	transportable		0	operable		
Chinakuri Mine	**0.014**	**India**	**Haldia Port**	**Haldia Port**	**3**	**139**	**transportable**	**0**	**transportable**		**3**	**operable**		
Durgapur Sail-I	0.099	India	Haldia Port	Haldia Port	1	190	transportable	0.2	transportable		20	operable		
Gopalichuck Colliery	0.002	India	Haldia Port	Haldia Port	1	328	transportable	0	transportable		0	operable		
Haldia Refinery	0.022	India	Haldia Port	Haldia Port	2	90	transportable	0	transportable		5	operable		
Kesoram Rayon	0.003	India	Haldia Port	Haldia Port	3	103	transportable	0	transportable		1	operable		
Southern (Cesc)	0.095	India	Haldia Port	Haldia Port	7	63	transportable	0.2	transportable		19	operable		
Korat	0.004	Thailand	Bangkok	Map Ta Phut	196	228		0	transportable		1	operable		
Nakhon Ratchasima	0.004	Thailand	Bangkok	Map Ta Phut	196	228		0	transportable		1	operable		
Pesanggaran	0.006	Indonesia	Celukan Bawang	Celukan Bawang	121	72		0	transportable		1	operable		
Korat	0.004	Cambodia	Bangkok	Map Ta Phut	196	228		0	transportable		1	operable		
Nakhon Ratchasima	0.004	Cambodia	Bangkok	Map Ta Phut	196	228		0	transportable		1	operable		

Gt Barge 207	0.022	Philippines	Port Romblon	Batangas City	117	63		0	transportable		4	operable		
Navotas Barge	0.093	Philippines	Manila	Batangas City	19	35		0.2	transportable		19	operable		connected

km = kilometres, LNG = liquefied natural gas, MTPA = million tonnes per annum.

Source: Authors.

Table 16 shows the list of additional demand points that are supplied by pipelines. Delhi, Gujarat, Maharashtra, Singapore, Jakarta, West Java, and East Java already have existing pipeline connections. Therefore, additional demand is also supposed to use existing pipelines.

Table 16. List of Additional Demand Points × Pipeline

Province/City	NEW LNG Demand (MTPA)	Country	Label	Primary port name	Distance to port	Railway connectivity at demand port (less than 15 km)	No. of train (1,300 ton/day equivalent)	Possibility of lorry supply (less than 700km)	Impossibility of Lorry supply (more than 700km)	Possibility of lorry operation (less than 24 times)	Lorry operability	Pipeline within 32.5 km to ports)	Construction of transmission gas pipeline (287000 ton/d)
Delhi	12.3	India	Dahej	Dahej	890	connected	25.9		impossible	2,496		34	
Gujarat	25.7	India	Navlakhi	Mandvi	121	connected	54.2	transportable		5,216		70	
Maharashtra	17.6	India	Jawaharlal Nehru Port (Nhava Shiva)	Jawaharlal Nehru Port (Nhava Shiva)	336	connected	37.1	transportable		3,572		48	
Singapore	14.27	Singapore	Keppel (East Singapore)	Jurong Island	10	connected	30.1	transportable		2,896		39	
Jakarta Raya	5.801	Indonesia	Jakarta	Jakarta	12	connected	12.2	transportable		1,177		16	
West Java	9.137	Indonesia	Cirebon	Cirebon	108	connected	19.3	transportable		1,854		25	
East Java	5.9	Indonesia	Probolinggo	Gresik	53	connected	12.4	transportable		1,197		16	

km = kilometres, LNG = liquefied natural gas, MTPA = million tonnes per annum.

Source: Authors.

The following demand points do not have enough demand to justify construction of a new pipeline, but the distance is over 700 km. The railway transport with ISO containers is, therefore, assumed.

Table 17. List of Additional Demand Points × Railway

Province/City	NEW LNG Demand (MTPA)	Country	Label	Primary port name	Distance to port	Railway connectivity at demand port (less than 15 km)	No. of train (1,300 tonnes/day equivalent)	Possibility of lorry supply (less than 700 km)	Impossibility of Lorry supply (more than 700 km)	Possibility of lorry operation (less than 24 times)	Lorry operability	Pipeline within 32.5 ㎞ to ports)	Construction of transmission gas pipeline （287,000 tonnes/day）
Chandigarh	0.000	India	Navlakhi	Mandvi	1,052	connected	0.0		impossible	0	operable	0	
Haryana	0.100	India	Navlakhi	Mandvi	897	connected	0.2		impossible	20	operable	0	
Himachal Pradesh	0.000	India	Navlakhi	Mandvi	1,182	connected	0.0		impossible	0	operable	0	
Jammu and Kashmir	0.000	India	Navlakhi	Mandvi	1,326	connected	0.0		impossible	0	operable	0	
Punjab	0.000	India	Navlakhi	Mandvi	993	connected	0.0		impossible	0	operable	0	
Uttaranchal	0.000	India	Dahej	Dahej	1,136	connected	0.0		impossible	0	operable	0	

km = kilometres, LNG = liquefied natural gas, MTPA = million tonnes per annum.

Source: authors.

Table 18 shows the additional demand points. When the demand size is too small, truck transport with ISO containers are assumed.

Table 18. List of Additional Demand Points × Truck Transport with ISO Containers

Province/City	NEW LNG Demand	Country	Label	primary port name	Distance to port	Possibility of lorry supply (less than 700 km)	Impossibility of Lorry supply (more than 700 km)	Possibility of lorry operation (less than 24 times)	Lorry operability
Da Nang City|Da Nang	0.1	Viet Nam	Da Nang	Da Nang	17	transportable		20	operable
Dong Thap	0	Viet Nam	Cat Lai	Cat Lai	125	transportable		0	operable
Dac Nong	0	Viet Nam	Vinh Cam Ranh	Vinh Cam Ranh	165	transportable		0	operable
Dak Lak|Dac Lac	0	Viet Nam	Nha Trang	Vinh Cam Ranh	128	transportable		0	operable
Dien Bien	0	Viet Nam	Hai Phong	Hai Phong	390	transportable		0	operable
An Giang	0	Viet Nam	Duong Dong	Map Ta Phut	138	transportable		0	operable
Ba Ria - VTau|Ba Ria-Vung Tau	0.1	Viet Nam	Phu My	Cat Lai	28	transportable		20	operable
Binh Dinh	0	Viet Nam	Qui Nhon	Vinh Cam Ranh	50	transportable		0	operable
Binh Phuoc	0	Viet Nam	Cat Lai	Cat Lai	132	transportable		0	operable
Binh Thuan	0	Viet Nam	Phu My	Cat Lai	131	transportable		0	operable
Bac Lieu	0	Viet Nam	Cat Lai	Cat Lai	196	transportable		0	operable
Bac Giang	0.1	Viet Nam	Hai Phong	Hai Phong	52	transportable		20	operable
Bac Kan|Bac Can	0	Viet Nam	Hai Phong	Hai Phong	172	transportable		0	operable
Ben Tre	0	Viet Nam	Cat Lai	Cat Lai	59	transportable		0	operable
Ca Mau	0	Viet Nam	Duong Dong	Map Ta Phut	177	transportable		0	operable
Cao Bang	0	Viet Nam	Hai Phong	Hai Phong	210	transportable		0	operable
Can Tho	0	Viet Nam	Cat Lai	Cat Lai	143	transportable		0	operable
Gia Lai	0	Viet Nam	Qui Nhon	Vinh Cam Ranh	115	transportable		0	operable
Ha Giang	0	Viet Nam	Hai Phong	Hai Phong	269	transportable		0	operable
Ha Nam	0.1	Viet Nam	Hai Phong	Hai Phong	88	transportable		20	operable
Ha Tinh	0	Viet Nam	Nghe Tinh	Hai Phong	53	transportable		0	operable
Hoa Binh	0	Viet Nam	Hai Phong	Hai Phong	145	transportable		0	operable
Hung Yen	0.1	Viet Nam	Hai Phong	Hai Phong	68	transportable		20	operable
Hai Duong	0.1	Viet Nam	Hai Phong	Hai Phong	35	transportable		20	operable
Hau Giang	0	Viet Nam	Cat Lai	Cat Lai	151	transportable		0	operable
Khanh Hoa	0	Viet Nam	Nha Trang	Vinh Cam Ranh	23	transportable		0	operable
Kien Giang	0	Viet Nam	Duong Dong	Map Ta Phut	112	transportable		0	operable

Province/City	NEW LNG Demand	Country	Label	primary port name	Distance to port	Possibility of lorry supply (less than 700 km)	Impossibility of Lorry supply (more than 700 km)	Possibility of lorry operation (less than 24 times)	Lorry operability
Kon Tum	0	Viet Nam	Da Nang	Da Nang	154	transportable		0	operable
Lao Cai	0	Viet Nam	Hai Phong	Hai Phong	310	transportable		0	operable
Lam Dong	0	Viet Nam	Vinh Cam Ranh	Vinh Cam Ranh	118	transportable		0	operable
Lai Chau	0	Viet Nam	Hai Phong	Hai Phong	393	transportable		0	operable
Lang Son	0	Viet Nam	Hai Phong	Hai Phong	100	transportable		0	operable
Nam Dinh	0	Viet Nam	Hai Phong	Hai Phong	90	transportable		0	operable
Nghe An	0.1	Viet Nam	Nghe Tinh	Hai Phong	101	transportable		20	operable
Ninh Binh	0	Viet Nam	Hai Phong	Hai Phong	115	transportable		0	operable
Ninh Thuan	0	Viet Nam	Vinh Cam Ranh	Vinh Cam Ranh	38	transportable		0	operable
Phu Tho	0	Viet Nam	Hai Phong	Hai Phong	170	transportable		0	operable
Phu Yen	0	Viet Nam	Qui Nhon	Vinh Cam Ranh	69	transportable		0	operable
Quang Binh	0	Viet Nam	Nghe Tinh	Hai Phong	148	transportable		0	operable
Quang Nam	0.1	Viet Nam	Da Nang	Da Nang	63	transportable		20	operable
Quang Ngai	0	Viet Nam	Da Nang	Da Nang	131	transportable		0	operable
Quang Ninh	0	Viet Nam	Cam Pha	Hai Phong	26	transportable		0	operable
Quang Tri	0	Viet Nam	Da Nang	Da Nang	155	transportable		0	operable
Soc Trang	0	Viet Nam	Cat Lai	Cat Lai	144	transportable		0	operable
Son La	0	Viet Nam	Hai Phong	Hai Phong	274	transportable		0	operable
Tay Ninh	0.1	Viet Nam	Cat Lai	Cat Lai	112	transportable		20	operable
Thai Binh	0	Viet Nam	Hai Phong	Hai Phong	58	transportable		0	operable
Thai Nguyen	0	Viet Nam	Hai Phong	Hai Phong	123	transportable		0	operable
Thua Thien - Hue	0	Viet Nam	Da Nang	Da Nang	81	transportable		0	operable
Thanh Hoa	0.1	Viet Nam	Nghe Tinh	Hai Phong	149	transportable		20	operable
Tien Giang	0	Viet Nam	Cat Lai	Cat Lai	52	transportable		0	operable
Tra Vinh	0	Viet Nam	Cat Lai	Cat Lai	98	transportable		0	operable
Tuyen Quang	0	Viet Nam	Hai Phong	Hai Phong	197	transportable		0	operable
Vinh Long	0	Viet Nam	Cat Lai	Cat Lai	98	transportable		0	operable
Vinh Phuc	0.1	Viet Nam	Hai Phong	Hai Phong	126	transportable		20	operable
Yen Bai	0	Viet Nam	Hai Phong	Hai Phong	239	transportable		0	operable
Andaman and	0	India	Port Blair	Lhokseumawe	56	transportable		0	operable

Province/City	NEW LNG Demand	Country	Label	primary port name	Distance to port	Possibility of lorry supply (less than 700 km)	Impossibility of Lorry supply (more than 700 km)	Possibility of lorry operation (less than 24 times)	Lorry operability
Nicobar									
Arunachal Pradesh	0	India	Chittagong	Chittagong	698	transportable		0	operable
Bihar	0	India	Haldia Port	Haldia Port	476	transportable		0	operable
Chhattisgarh	0	India	Vishakhapatnam	Vishakhapatnam	418	transportable		0	operable
Dadra and Nagar Haveli	0	India	Hazira	Hazira	109	transportable		0	operable
Daman and Diu	0	India	Veraval	Veraval	52	transportable		0	operable
Goa	0	India	Marmagao	Ratnagiri	29	transportable		0	operable
Jharkhand	0	India	Haldia Port	Haldia Port	315	transportable		0	operable
Kerala	0	India	Kochi (Cochin)	Kochi (Cochin)	57	transportable		0	operable
Madhya Pradesh	0	India	Dahej	Dahej	622	transportable		0	operable
Manipur	0	India	Chittagong	Chittagong	343	transportable		0	operable
Meghalaya	0	India	Chittagong	Chittagong	366	transportable		0	operable
Mizoram	0	India	Chittagong	Chittagong	155	transportable		0	operable
Nagaland	0	India	Chittagong	Chittagong	497	transportable		0	operable
Orissa	0	India	Paradip	Paradip	238	transportable		0	operable
Puducherry	0	India	Cuddalore	Ennur	102	transportable		0	operable
Rajasthan	0	India	Navlakhi	Mandvi	524	transportable		0	operable
Sikkim	0	India	Haldia Port	Haldia Port	617	transportable		0	operable
West Bengal	0	India	Haldia Port	Haldia Port	199	transportable		0	operable
Amnat Charoen	0	Thailand	Nghe Tinh	Hai Phong	337	transportable		0	operable
Ang Thong	0	Thailand	Bangkok	Map Ta Phut	125	transportable		0	operable
Bueng Kan	0	Thailand	Nghe Tinh	Hai Phong	228	transportable		0	operable
Buri Ram	0	Thailand	Bangkok	Map Ta Phut	292	transportable		0	operable
Chai Nat	0	Thailand	Bangkok	Map Ta Phut	189	transportable		0	operable
Chaiyaphum	0	Thailand	Bangkok	Map Ta Phut	307	transportable		0	operable
Chanthaburi	0	Thailand	Rayong Tpi Terminal	Map Ta Phut	94	transportable		0	operable
Chiang Mai	0.1	Thailand	Moulmein Harbor	Chittagong	281	transportable		20	operable

Province/City	NEW LNG Demand	Country	Label	primary port name	Distance to port	Possibility of lorry supply (less than 700 km)	Impossibility of Lorry supply (more than 700 km)	Possibility of lorry operation (less than 24 times)	Lorry operability
Chiang Rai	0	Thailand	Moulmein Harbor	Chittagong	441	transportable		0	operable
Chumphon	0	Thailand	Bang Saphan	Map Ta Phut	110	transportable		0	operable
Kalasin	0	Thailand	Nghe Tinh	Hai Phong	329	transportable		0	operable
Kamphaeng Phet	0	Thailand	Moulmein Harbor	Chittagong	206	transportable		0	operable
Kanchanaburi	0.1	Thailand	Petchburi Terminal	Map Ta Phut	196	transportable		20	operable
Khon Kaen	0.1	Thailand	Bangkok	Map Ta Phut	383	transportable		20	operable
Krabi	0	Thailand	Krabi	Butterworth	14	transportable		0	operable
Lampang	0	Thailand	Moulmein Harbor	Chittagong	286	transportable		0	operable
Loei	0	Thailand	Moulmein Harbor	Chittagong	439	transportable		0	operable
Lop Buri	0	Thailand	Bangkok	Map Ta Phut	178	transportable		0	operable
Mae Hong Son	0	Thailand	Moulmein Harbor	Chittagong	261	transportable		0	operable
Maha Sarakham	0	Thailand	Bangkok	Map Ta Phut	388	transportable		0	operable
Mukdahan	0	Thailand	Nghe Tinh	Hai Phong	278	transportable		0	operable
Nakhon Nayok	0	Thailand	Bangkok	Map Ta Phut	99	transportable		0	operable
Nakhon Pathom	0	Thailand	Bangkok	Map Ta Phut	70	transportable		0	operable
Nakhon Phanom	0	Thailand	Nghe Tinh	Hai Phong	208	transportable		0	operable
Nakhon Sawan	0	Thailand	Bangkok	Map Ta Phut	244	transportable		0	operable
Nakhon Si Thammarat	0	Thailand	Khanom	Map Ta Phut	91	transportable		0	operable
Nan	0	Thailand	Moulmein Harbor	Chittagong	428	transportable		0	operable
Narathiwat	0	Thailand	Songkhla Harbor	Kuala Trengganu	170	transportable		0	operable
Nong Bua Lam Phu	0	Thailand	Nghe Tinh	Hai Phong	408	transportable		0	operable
Nong Khai	0	Thailand	Nghe Tinh	Hai Phong	325	transportable		0	operable

Province/City	NEW LNG Demand	Country	Label	primary port name	Distance to port	Possibility of lorry supply (less than 700 km)	Impossibility of Lorry supply (more than 700 km)	Possibility of lorry operation (less than 24 times)	Lorry operability
Nonthaburi	0	Thailand	Bangkok	Map Ta Phut	50	transportable		0	operable
Pattani	0.1	Thailand	Songkhla Harbor	Kuala Trengganu	101	transportable		20	operable
Phangnga	0	Thailand	Krabi	Butterworth	88	transportable		0	operable
Phatthalung	0	Thailand	Kantang Harbor	Butterworth	62	transportable		0	operable
Phayao	0	Thailand	Moulmein Harbor	Chittagong	407	transportable		0	operable
Phetchabun	0	Thailand	Bangkok	Map Ta Phut	309	transportable		0	operable
Phichit	0.1	Thailand	Moulmein Harbor	Chittagong	293	transportable		20	operable
Phitsanulok	0	Thailand	Moulmein Harbor	Chittagong	317	transportable		0	operable
Phrae	0	Thailand	Moulmein Harbor	Chittagong	321	transportable		0	operable
Phuket	0	Thailand	Phuket	Lhokseumawe	16	transportable		0	operable
Prachuap Khiri Khan	0.1	Thailand	Bang Saphan	Map Ta Phut	84	transportable		20	operable
Ranong	0	Thailand	Khanom	Map Ta Phut	156	transportable		0	operable
Roi Et	0	Thailand	Nghe Tinh	Hai Phong	378	transportable		0	operable
Sa Kaeo	0	Thailand	Rayong Tpi Terminal	Map Ta Phut	169	transportable		0	operable
Sakon Nakhon	0	Thailand	Nghe Tinh	Hai Phong	256	transportable		0	operable
Samut Songkhram	0	Thailand	Petchburi Terminal	Map Ta Phut	33	transportable		0	operable
Satun	0	Thailand	Port Langkawi	Butterworth	47	transportable		0	operable
Si Sa Ket	0	Thailand	Rayong Tpi Terminal	Map Ta Phut	412	transportable		0	operable
Sing Buri	0.1	Thailand	Bangkok	Map Ta Phut	157	transportable		20	operable
Sukhothai	0	Thailand	Moulmein Harbor	Chittagong	239	transportable		0	operable

Province/City	NEW LNG Demand	Country	Label	primary port name	Distance to port	Possibility of lorry supply (less than 700 km)	Impossibility of Lorry supply (more than 700 km)	Possibility of lorry operation (less than 24 times)	Lorry operability
Suphan Buri	0	Thailand	Bangkok	Map Ta Phut	142	transportable		0	operable
Surat Thani	0	Thailand	Khanom	Map Ta Phut	91	transportable		0	operable
Surin	0	Thailand	Rayong Tpi Terminal	Map Ta Phut	356	transportable		0	operable
Tak	0	Thailand	Moulmein Harbor	Chittagong	128	transportable		0	operable
Trang	0	Thailand	Kantang Harbor	Butterworth	15	transportable		0	operable
Trat	0	Thailand	Rayong Tpi Terminal	Map Ta Phut	138	transportable		0	operable
Ubon Ratchathani	0.1	Thailand	Da Nang	Da Nang	349	transportable		20	operable
Udon Thani	0.1	Thailand	Nghe Tinh	Hai Phong	342	transportable		20	operable
Uthai Thani	0	Thailand	Bangkok	Map Ta Phut	235	transportable		0	operable
Uttaradit	0	Thailand	Moulmein Harbor	Chittagong	338	transportable		0	operable
Yala	0	Thailand	Penang Port	Butterworth	130	transportable		0	operable
Yasothon	0	Thailand	Nghe Tinh	Hai Phong	352	transportable		0	operable
Banteay Meanchey	0	Cambodia	Rayong Tpi Terminal	Map Ta Phut	220	transportable		0	operable
Battambang	0	Cambodia	Rayong Tpi Terminal	Map Ta Phut	199	transportable		0	operable
Kampot	0	Cambodia	Duong Dong	Map Ta Phut	73	transportable		0	operable
Kampong Cham	0	Cambodia	Cat Lai	Cat Lai	235	transportable		0	operable
Kampong Chhnang	0	Cambodia	Kampong Saom	Map Ta Phut	205	transportable		0	operable
Kampong Speu	0	Cambodia	Kampong Saom	Map Ta Phut	133	transportable		0	operable
Kampong Thom	0	Cambodia	Kampong Saom	Map Ta Phut	295	transportable		0	operable
Kandal	0.05	Cambodia	Duong Dong	Map Ta Phut	175	transportable		10	operable
Koh Kong	0	Cambodia	Kampong	Map Ta Phut	92	transportable		0	operable

Province/City	NEW LNG Demand	Country	Label	primary port name	Distance to port	Possibility of lorry supply (less than 700 km)	Impossibility of Lorry supply (more than 700 km)	Possibility of lorry operation (less than 24 times)	Lorry operability
			Saom						
Kep	0	Cambodia	Duong Dong	Map Ta Phut	53	transportable		0	operable
Kratie	0	Cambodia	Cat Lai	Cat Lai	236	transportable		0	operable
Pailin	0	Cambodia	Rayong Tpi Terminal	Map Ta Phut	147	transportable		0	operable
Preah Sihanouk	0	Cambodia	Phsar Ream	Map Ta Phut	26	transportable		0	operable
Mondulkiri	0	Cambodia	Cat Lai	Cat Lai	244	transportable		0	operable
Oddar Meanchey	0	Cambodia	Rayong Tpi Terminal	Map Ta Phut	312	transportable		0	operable
Pursat	0	Cambodia	Kampong Saom	Map Ta Phut	192	transportable		0	operable
Preah Vihear	0	Cambodia	Kampong Saom	Map Ta Phut	386	transportable		0	operable
Prey Veng	0	Cambodia	Cat Lai	Cat Lai	171	transportable		0	operable
Ratanakiri	0	Cambodia	Qui Nhon	Vinh Cam Ranh	232	transportable		0	operable
Siem Reap	0	Cambodia	Rayong Tpi Terminal	Map Ta Phut	312	transportable		0	operable
Stung Treng	0	Cambodia	Qui Nhon	Vinh Cam Ranh	331	transportable		0	operable
Svay Rieng	0	Cambodia	Cat Lai	Cat Lai	116	transportable		0	operable
Takeo	0	Cambodia	Duong Dong	Map Ta Phut	122	transportable		0	operable
Tbong Khmum	0	Cambodia	Cat Lai	Cat Lai	178	transportable		0	operable
Ayeyarwady	0.1	Myanmar	Rangoon	Chittagong	112	transportable		20	operable
Bago	0	Myanmar	Rangoon	Chittagong	170	transportable		0	operable
Chin	0	Myanmar	Chittagong	Chittagong	175	transportable		0	operable
Kachin	0	Myanmar	Chittagong	Chittagong	695	transportable		0	operable
Kayah	0	Myanmar	Rangoon	Chittagong	301	transportable		0	operable
Kayin	0	Myanmar	Moulmein Harbor	Chittagong	75	transportable		0	operable
Magway	0.1	Myanmar	Sittwe	Chittagong	206	transportable		20	operable
Mandalay	0.1	Myanmar	Sittwe	Chittagong	344	transportable		20	operable
Mon	0	Myanmar	Moulmein Harbor	Chittagong	8	transportable		0	operable

Province/City	NEW LNG Demand	Country	Label	primary port name	Distance to port	Possibility of lorry supply (less than 700 km)	Impossibility of Lorry supply (more than 700 km)	Possibility of lorry operation (less than 24 times)	Lorry operability
Naypyitaw	0	Myanmar	Rangoon	Chittagong	327	transportable		0	operable
Rakhine	0	Myanmar	Sittwe	Chittagong	98	transportable		0	operable
Sagaing	0.1	Myanmar	Chittagong	Chittagong	413	transportable		20	operable
Shan	0	Myanmar	Sittwe	Chittagong	569	transportable		0	operable
Tanintharyi	0	Myanmar	Mergui	Lhokseumawe	30	transportable		0	operable
Aceh	0.1	Indonesia	Lhokseumawe	Lhokseumawe	110	transportable		20	operable
Bangka Belitung	0.093	Indonesia	Pangkalpinang	Muntok	61	transportable		19	operable
Bengkulu	0.077	Indonesia	Bengkulu	Anyer Lor	28	transportable		16	operable
Gorontalo	0.038	Indonesia	Gorontalo	Ujung Pandang	78	transportable		8	operable
West Papua	0.038	Indonesia	Fakfak	Ujung Pandang	125	transportable		8	operable
West Kalimantan	0.1	Indonesia	Pontianak	Muntok	205	transportable		20	operable
Centre Kalimantan	0.096	Indonesia	Banjarmasin	Gresik	230	transportable		19	operable
North Kalimantan	0.029	Indonesia	Lingkas	Bontang Lng Terminal	158	transportable		6	operable
North Maluku	0.025	Indonesia	Ternate	Bontang Lng Terminal	66	transportable		5	operable
Maluku	0.043	Indonesia	Bula	Ujung Pandang	195	transportable		9	operable
East Nusa Tenggara	0.078	Indonesia	Maumere	Ujung Pandang	70	transportable		16	operable
Papua	0.06	Indonesia	Amamapare	Ujung Pandang	193	transportable		12	operable
West Sulawesi	0.023	Indonesia	Parepare	Ujung Pandang	173	transportable		5	operable
Centre Sulawesi	0.083	Indonesia	Poso	Ujung Pandang	65	transportable		17	operable
South east Sulawesi	0.069	Indonesia	Pomalaa	Ujung Pandang	54	transportable		14	operable
Abra	0.002	Philippines	San Fernando Harbor	Batangas City	119	transportable		0	operable
Agusan del Norte	0.008	Philippines	Butuan City	Batangas City	6	transportable		2	operable
Agusan del Sur	0.007	Philippines	Hinatuan	Batangas City	64	transportable		1	operable
Aklan	0.007	Philippines	Port Capiz	Batangas City	51	transportable		1	operable
Albay	0.013	Philippines	Legazpi Port	Batangas City	16	transportable		3	operable
Antique	0.006	Philippines	Iloilo	Batangas City	74	transportable		1	operable

Province/City	NEW LNG Demand	Country	Label	primary port name	Distance to port	Possibility of lorry supply (less than 700 km)	Impossibility of Lorry supply (more than 700 km)	Possibility of lorry operation (less than 24 times)	Lorry operability
Apayao	0.001	Philippines	Aparri	Batangas City	55	transportable		0	operable
Aurora	0.002	Philippines	San Fernando Harbor	Batangas City	168	transportable		0	operable
Basilan	0.003	Philippines	Basilian City (Isabela)	Batangas City	16	transportable		1	operable
Bataan	0.064	Philippines	Subic Bay	Batangas City	25	transportable		13	operable
Batanes	0	Philippines	Basco	Batangas City	14	transportable		0	operable
Batangas	0.029	Philippines	Batangas City	Batangas City	15	transportable		6	operable
Benguet	0.009	Philippines	San Fernando Harbor	Batangas City	43	transportable		2	operable
Biliran	0.002	Philippines	Catbalogan	Batangas City	48	transportable		0	operable
Bohol	0.013	Philippines	Tubigan	Batangas City	28	transportable		3	operable
Bukidnon	0.014	Philippines	Bugo	Batangas City	61	transportable		3	operable
Bulacan	0.039	Philippines	Manila	Batangas City	44	transportable		8	operable
Cagayan	0.013	Philippines	Aparri	Batangas City	33	transportable		3	operable
Camarines Norte	0.006	Philippines	Jose Panganiban	Batangas City	16	transportable		1	operable
Camarines Sur	0.02	Philippines	Tabaco	Batangas City	63	transportable		4	operable
Camiguin	0.001	Philippines	Gingoog	Batangas City	55	transportable		0	operable
Capiz	0.007	Philippines	Port Capiz	Batangas City	27	transportable		1	operable
Catanduanes	0.003	Philippines	Virac	Batangas City	22	transportable		1	operable
Cavite	0.061	Philippines	Nasugbu	Batangas City	33	transportable		12	operable
Cebu	0.066	Philippines	Toledo	Batangas City	14	transportable		13	operable
Compostela Valley	0.007	Philippines	Mati	Batangas City	72	transportable		1	operable
Davao del Norte	0.011	Philippines	Davao	Bontang Lng Terminal	57	transportable		2	operable
Davao del Sur	0.028	Philippines	Davao	Bontang Lng Terminal	46	transportable		6	operable
Davao Oriental	0.008	Philippines	Mati	Batangas City	35	transportable		2	operable
Dinagat Islands	0.001	Philippines	Surigao City	Batangas City	44	transportable		0	operable

Province/City	NEW LNG Demand	Country	Label	primary port name	Distance to port	Possibility of lorry supply (less than 700 km)	Impossibility of Lorry supply (more than 700 km)	Possibility of lorry operation (less than 24 times)	Lorry operability
Eastern Samar	0.005	Philippines	Port Borongan	Batangas City	8	transportable		1	operable
Guimaras	0.002	Philippines	Jordan	Batangas City	11	transportable		0	operable
Ifugao	0.002	Philippines	San Fernando Harbor	Batangas City	100	transportable		0	operable
Ilocos Norte	0.006	Philippines	Claveria	Batangas City	62	transportable		1	operable
Ilocos Sur	0.007	Philippines	San Fernando Harbor	Batangas City	72	transportable		1	operable
Iloilo	0.023	Philippines	Iloilo	Batangas City	34	transportable		5	operable
Isabela	0.015	Philippines	Aparri	Batangas City	157	transportable		3	operable
Kalinga	0.002	Philippines	Aparri	Batangas City	109	transportable		0	operable
La Union	0.009	Philippines	San Fernando Harbor	Batangas City	13	transportable		2	operable
Laguna	0.035	Philippines	Manila	Batangas City	52	transportable		7	operable
Lanao del Norte	0.01	Philippines	Port Ozamis	Batangas City	25	transportable		2	operable
Lanao del Sur	0.01	Philippines	Iligan	Batangas City	48	transportable		2	operable
Leyte	0.022	Philippines	Ormoc	Batangas City	17	transportable		4	operable
Maguindanao	0.011	Philippines	Polloc (Cotabato)	Bontang Lng Terminal	39	transportable		2	operable
Marinduque	0.002	Philippines	Santa Cruz (Marinduque Isl)	Batangas City	17	transportable		0	operable
Masbate	0.009	Philippines	Masbate	Batangas City	13	transportable		2	operable
Misamis Occidental	0.015	Philippines	Jimenez	Batangas City	20	transportable		3	operable
Misamis Oriental	0.009	Philippines	Villanueva	Batangas City	7	transportable		2	operable
Mountain Province	0.001	Philippines	San Fernando Harbor	Batangas City	103	transportable		0	operable
Negros Occidental	0.03	Philippines	Pulupandan	Batangas City	32	transportable		6	operable
Negros Oriental	0.013	Philippines	Bais	Batangas City	9	transportable		3	operable
North Cotabato	0.013	Philippines	Polloc (Cotabato)	Bontang Lng Terminal	72	transportable		3	operable

Province/City	NEW LNG Demand	Country	Label	primary port name	Distance to port	Possibility of lorry supply (less than 700 km)	Impossibility of Lorry supply (more than 700 km)	Possibility of lorry operation (less than 24 times)	Lorry operability
Northern Samar	0.006	Philippines	Laoang	Batangas City	29	transportable		1	operable
Nueva Ecija	0.021	Philippines	Manila	Batangas City	114	transportable		4	operable
Nueva Vizcaya	0.004	Philippines	San Fernando Harbor	Batangas City	96	transportable		1	operable
Occidental Mindoro	0.005	Philippines	Calapan	Batangas City	58	transportable		1	operable
Oriental Mindoro	0.008	Philippines	Calapan	Batangas City	51	transportable		2	operable
Palawan	0.011	Philippines	Puerto Princesa	Batangas City	28	transportable		2	operable
Pampanga	0.039	Philippines	Subic Bay	Batangas City	51	transportable		8	operable
Pangasinan	0.032	Philippines	Masinloc	Batangas City	63	transportable		6	operable
Quezon	0.021	Philippines	Hondagua	Batangas City	38	transportable		4	operable
Quirino	0.002	Philippines	San Fernando Harbor	Batangas City	142	transportable		0	operable
Rizal	0.028	Philippines	Manila	Batangas City	34	transportable		6	operable
Romblon	0.003	Philippines	Port Romblon	Batangas City	16	transportable		1	operable
Samar	0.008	Philippines	Catbalogan	Batangas City	12	transportable		2	operable
Sarangani	0.005	Philippines	General Santos	Bontang Lng Terminal	9	transportable		1	operable
Siquijor	0.001	Philippines	Lazi	Batangas City	8	transportable		0	operable
Sorsogon	0.008	Philippines	Sorsogon	Batangas City	15	transportable		2	operable
South Cotabato	0.015	Philippines	General Santos	Bontang Lng Terminal	40	transportable		3	operable
Southern Leyte	0.004	Philippines	Maasin	Batangas City	26	transportable		1	operable
Sultan Kudarat	0.008	Philippines	General Santos	Bontang Lng Terminal	91	transportable		2	operable
Sulu	0.008	Philippines	Jolo	Bandar Seri Begawan	12	transportable		2	operable
Surigao del Norte	0.006	Philippines	Surigao City	Batangas City	29	transportable		1	operable
Surigao del Sur	0.006	Philippines	Hinatuan	Batangas City	56	transportable		1	operable
Tarlac	0.016	Philippines	Masinloc	Batangas City	59	transportable		3	operable

Province/City	NEW LNG Demand	Country	Label	primary port name	Distance to port	Possibility of lorry supply (less than 700 km)	Impossibility of Lorry supply (more than 700 km)	Possibility of lorry operation (less than 24 times)	Lorry operability
Tawi-Tawi	0.004	Philippines	Siasi	Bontang Lng Terminal	110	transportable		1	operable
Zambales	0.008	Philippines	Masinloc	Batangas City	37	transportable		2	operable
Zamboanga del Norte	0.01	Philippines	Santa Clara	Bontang Lng Terminal	33	transportable		2	operable
Zamboanga del Sur	0.018	Philippines	Margosatubig	Bontang Lng Terminal	22	transportable		4	operable
Zamboanga Sibugay	0.006	Philippines	Santa Clara	Bontang Lng Terminal	12	transportable		1	operable

km = kilometres, LNG = liquefied natural gas, MTPA = million tonnes per annum.

Source: Authors.

The following demand points are exceptional cases because the frequency of truck transport with ISO containers is beyond operability (more than 24 times per day). On the other hand, it is considered that the truck transport might be the most efficient because there is no demand intensity to construct middle-pressure gas pipelines. Of course, railway transport is possible when considering urban agglomeration, but direct transport from the ports is assumed.

Table 19. List of Additional Demand Points x Truck Transport with ISO Containers (expansion)

Province/City	NEW LNG Demand (MTPA)	Country	Label	Primary port name	Distance to port	Railway connectivity at demand port (less than 15km)	No. of train (1,300 tonnes/day equivalent)	Possibility of lorry supply (less than 700 km)	Impossibility of Lorry supply (more than 700 km)	Possibility of lorry operation (less than 24 times)	Lorry operability	Pipeline transport volume (1000 ton/day)	Construction of transmission gas pipeline(287,000 tonnes/day)
Bac Ninh	0.200	Viet Nam	Hai Phong	Hai Phong	64	connected	0.4	transportable		41		1	
Ha Noi City|Hanoi	1.200	Viet Nam	Hai Phong	Hai Phong	104	connected	2.5	transportable		244		3	
Hai Phong City|Haiphong	0.300	Viet Nam	Hai Phong	Hai Phong	16	connected	0.6	transportable		61		1	
Andhra Pradesh	0.200	India	Machilipatnam	Kakinada Bay	143	connected	0.4	transportable		41		1	
Lakshadweep	0.200	India	Azhikal (Azhikkal)	Kochi (Cochin)	305	connected	0.4	transportable		41		1	
Tamil Nadu	0.200	India	Nagappattinam	Ennur	157	connected	0.4	transportable		41		1	
Telangana	0.300	India	Machilipatnam	Kakinada Bay	291	connected	0.6	transportable		61		1	
Negeri Sembilan	0.500	Malaysia	Port Dickson	Pelabuhan Sungai Udang	53	connected	1.1	transportable		101		1	
Perak	0.400	Malaysia	Teluk Anson	Port Klang	99	connected	0.8	transportable		81		1	
Pulau Pinang	0.600	Malaysia	Butterworth	Butterworth	5	connected	1.3	transportable		122		2	
Selangor	2.100	Malaysia	Port Klang	Port Klang	33	connected	4.4	transportable		426		6	
Lamphun	0.400	Thailand	Moulmein Harbor	Chittagong	230	connected	0.8	transportable		81		1	
Yangon	0.700	Myanmar	Rangoon	Chittagong	22	connected	1.5	transportable		142		2	
Banten	2.298	Indonesia	Anyer Lor	Anyer Lor	49	connected	4.8	transportable		466		6	
Central Java	3.296	Indonesia	Semarang	Semarang	41	connected	6.9	transportable		669		9	
Lampung	0.635	Indonesia	Panjang	Anyer Lor	69	connected	1.3	transportable		129		2	

West Sumatera	0.645	Indonesia	Teluk Bayur	Sibolga	20	connected	1.4	transportable		131		2	
Yogyakarta	0.302	Indonesia	Semarang	Semarang	104	connected	0.6	transportable		61		1	
Metropolitan Manila	0.288	Philippines	Manila	Batangas City	8	connected	0.6	transportable		58		1	

km = kilometres, LNG = liquefied natural gas, MTPA = million tonnes per annum.

Source: Authors.

Chapter 6
Investment in LNG supply chain infrastructure estimation

6.1 Introduction

This chapter presents the investment estimates for developing additional LNG supply chain infrastructures. These estimates are based on the unit investment costs of Japanese companies in the case studies. The main outputs are total estimated investments for LNG supply chain infrastructures by country and by infrastructure type.

6.2 Methodology

6.2.1 Unit investment costs of LNG infrastructures and facilities

The scope of the estimation is as follows:

- ✓ Primary and secondary LNG terminal construction cost (not included in port development);
- ✓ Maximum 32.5 km natural gas transmission pipeline construction cost from the nearest port;
- ✓ ISO containers for railway freight services and truck transports; and
- ✓ LNG satellite storage facilities.

The following are not included in the estimation:

- ✓ Land acquisition costs;
- ✓ Secondary transport for SSLNG tankers;
- ✓ Investment for port development like water channels, water brakes, and so on;
- ✓ Natural gas transmission and distribution pipelines that are more than 32.5 km from the nearest port;
- ✓ Rail tracks and the like, and road and bridge enhancements or enforcement costs;
- ✓ Trailer heads; and
- ✓ Financial costs like interests.

The unit costs of investment estimation were taken from Japanese cases. Unit costs were collected for the primary LNG-receiving terminal, secondary terminal, satellite, and the like.

Table 20. Scope of the Cost Component

Value Chain	LNG Carrier	LNG-Receiving Terminals	Satellite	Pipeline	Lorry	Train Container
Component	Ocean tanker	Primary (onshore)	Satellite	Pipeline	Lorry	Train Container
	Coastal tanker	Primary (FSRU)	-	-	-	-
	-	Secondary (onshore)	-	-	-	-

FSRU = floating storage and regasification units, LNG = liquefied natural gas.
Source: Authors.

The investment cost for SSLNG carriers is higher per tonne compared to the cost for large-scale LNG vessels. The primary LNG terminal of Sendai City Gas in Japan has a capacity of 80 thousand kilolitre (kl) and its size is close to the usual secondary terminals in Japan. An ocean tanker of 18,800 m^3 (approximately 8,200 tonnes) serves the terminal and makes a maximum of 20 x approximately 5,200 km trips annually between Malaysia and Japan. This tanker is in the smallest category in Table 21. LNG ocean tankers used by Japanese utility companies are usually in the range of 60,000–90,000 tonnes.

Thus, the unit cost for an ocean tanker serving a large primary terminal is US$6,000/$m^3$, while the cost for a coastal tanker serving a secondary terminal is US$15,000/$m^3$. The unit cost is much higher for a small tanker.

Table 21. Typical Investment Cost for LNG Carriers, Crew, and Harbour Cost (Shell Historic STS database)

Size (m^3)	CAPEX (US$ million)	CAPEX (US$ Thousand/ m^3)	Typical crew number	Typical harbour cost (Europe)
215,000	250	6.0	30–35	US$100-200K /visit
135,000	170	6.5	25–35	US$75-150K /visit
28,000	80	15.0	15–20	US$25-40 K /visit

K = thousand, LNG = liquefied natural gas, m^3 = cubic metre.
Source: Adapted from International Gas Union (2015).

An onshore LNG terminal could cost up to JPY100 billion, while FSRUs cost up to JPY30 billion for a new build and JPY8 billion for a remodelled used ship. Primary and secondary terminals are structurally the same, and the size is different.

Table 22. Comparison of Onshore LNG Terminal and FSU/FSRU

	Onshore LNG Terminal	FSU/FSRU
Capex	>= US$100 billion	>= US$30 billion (New build; almost equal to a new build LNG ship) >= US$8 billion (LNG ship remodelled)
EPC Period	5–7+ years (EPC, Environment Assessment and Approval)	3 years (new build) 1 year (LNG ship remodelled)
Environmental Impacts and Regulations	Large environmental impacts Stringent regulations	Small environmental impacts Little regulations
Atmospheric and Marine Phenomena	N.A.	Calm atmospheric and marine conditions are required (Impacts of waves are large)
Removal	Permanent usage is considered	Moving and removal are easy (Temporary use is possible)
Expansion	Flexible	Incremental by adding ships

EPC = engineering, procurement, and construction, FSRU = floating storage and regasification units, FSU = floating storage units, LNG = liquefied natural gas, N.A. = not applicable.
Source: Japan Oil, Gas and Metals National Corporation (JOGMEC) (2013)

An engineering company and a pipeline manufacturer were interviewed to see the cost of each component in the LNG network infrastructure. The engineering company interviewed had a prototype estimate for a primary terminal and a gas-fired power plant package. The cost of each component in the package is in Table 23

Table 23. Typical Cost of a Primary Terminal and Gas-Fired Power Plant Package

Facilities	Capacity	Unit Cost	Consideration
LNG-receiving terminals	5 MTPA/ terminal	US$50 billion ± US$10 billion for a 5.0 MTPA terminal	Gasification facilities + tank (180,000 m^3) Cost varies depending on the ground conditions, the degree of earthquake preparedness, and availability of LNG piers
LNG satellite	200 kl/satellite	US$2 billion	
Loading facility		US$5 billion	
LNG tankers		US$20 billion /ship	Three to four tankers are needed for an LNG-receiving terminal with 5.0 MTPA
Trucks, lorries		US$0.1 billion /vehicle (conforms to	Approximately 10 vehicles are needed for an LNG-receiving terminal with 5 MTPA

Facilities	Capacity	Unit Cost	Consideration
		Japanese standards) A Chinese vehicle would cost a third of this figure	
Gas turbine generator	50 MW × 2	US$15–20 billion	A 5 MTPA terminal can supply 10 power plants with 100 MW.
Pipeline	Costs for pipeline is minimal, however the cost for land expropriation is approximately US$.3 billion/km		

kl = kilolitre, km = kilometre, LNG = liquefied natural gas, MPTA = million tonnes per annum, MW = megawatt.
Source: Interview with an engineering company.

Figure 17 shows the investments and capacity of primary LNG terminals in Japan. When considering the capacity of LNG terminals and construction types (underground or on the ground), the estimated unit investment for the construction of an LNG terminal is JPY450 million/1,000 tonnes of LNG. This number will be applied for the estimation of primary and secondary LNG terminals in the following subsection.

Figure 17: Estimation of Unit Investment on LNG Terminal Construction in Japan

Owner	Name of terminal	Total investment (approximate：100million JPY)	Capacity of facility (kl)	Area (m²)	LNG vaporizer (t/h)	Type of construction (underground=1)
Hokkaido Gas	Ishikari	400	180,000	96,902	200	0
City gas of Sendai	Sendai	369	80,000	96,459	90	1
Tokyo Electric	Futtsu	1,145	360,000	210,000	570	1
Tokyo Gas	Ogishima	1,700	200,000	312,000	300	1
Impex	Naoetsu	1,000	360,000	250,000	370	1
Shimizu LNG	Sodeshi	500	177,200	89,000	110	0
Chita LNG	Chita LNG	915	480,000	319,540	650	0
Toho gas	Yokkaichi	290	80,000	86,959	40	0
Chubu Electric	Yokkaichi LNG	780	320,000	141,000	560	0
Osaka gas	Himeji	700	320,000	465,000	120	0
Kansai Electric	Himeji LNG	625	280,000	190,000	600	0
Hiroshima Gas	Hatsuka ichi	240	85000	34808	42	0
Chugoku Electric	Yanai LNG	660	240000	500000	110	0
Saibu Gas	Fukukita LNG	230	35000	64000	40	1
Oita LNG	Oita LNG	820	240000	296000	380	0
Nihon Gas	Kagoshima LNG	130	36000	67000	15	0

Dependent variables

Explanatory variables

	Coefficients	Standard errors	t	P-value
Intercept	91.219	145.891	0.625	0.543
Capacity of facility (kkl)	2.07390	0.541	3.834	0.002
Type of construction (underground=1)	368.283	148.885	2.474	0.028

Regression statistics	
R	0.777
R2	0.604
Adjusted R2	0.544
Standard errors	276
Observation	16

Y=2.0739(100 million JPY/kkl)*Capacity(kkl)+91.219(100 million JPY)
Y=2.0739(100 million JPY/1000m³)*Capacity(1000m³)+91.219(100 million JPY)
Y=4.508486(100 million JPY/1000 ton)*Capacity(1000 ton)+ 91.219(100 million JPY)

kl = kilolitre, kkl = please supply, LNG = liquefied natural gas, m^2 = square metre, m^3 = cubic metre, t/h = ton per hour..
Source: authors.

The cost of developing a pipeline varies considerably, depending on the country. The cost has a strong regional character as the pipeline development task is very labour intensive. Half of the cost is allocated to civil engineering and the share of labour cost is large. The price of the pipeline itself does not vary much among countries. The cost of eminent domain of right-of-way for pipeline deployment is also high. The state and municipalities often carry out the land clearance task, though sometimes contractors must do it at their own cost. If the project is backed by official development assistance, municipalities are responsible for the land clearance.

Table 24. Unit Investment on Natural Gas Transmission Pipeline in Japan

Name of line	Owner	Completion year	Diameter	Investment (JPY million)	Length （m）	Unit investment/m （JPY1,000/m）
Tochigi Line	Tokyo Gas	2005	400A	16,800	69,400	**242**
Fukushima Line	JAPEX	2007	400A	20,000	95,000	**211**
Gunma Trunk Line	Tokyo Gas	2009	500A	5,700	15,700	**363**
Chiba Kashima	Tokyo Gas	2010	600A	25,700	73,100	**352**
New Negishi Trunk	Tokyo Gas	2013	600A	15,500	14,100	**1,099**
Yokohama Trunk ph2	Tokyo Gas	2013	750A	7,700	6,300	**1,222**
Central Trunk	Tokyo Gas	2010	600A	4,500	10,400	**433**
New Oumi	IMPEX	2009	500A	9,500	49,000	**194**
S-H Line	Shizuoka Gas	2013	400A 500A	35,000	113,000	**310**
Himeji Okayama	Osaka Gas	2014	600A	30,000	85,000	**353**
Mie Shiga Line	Chubu Electric and Osaka Gas	2011	600A	20,000	60,000	**333**
Circle Trunk Line	Toho Gas	2009	600A	52,000	117,000	**444**
West Circle Line	Toho Gas	2009	600A	6,000	14,000	**429**

m = metre, NG = natural gas.
Source: http://www.meti.go.jp/meti_lib/report/H28FY/000610.pdf.

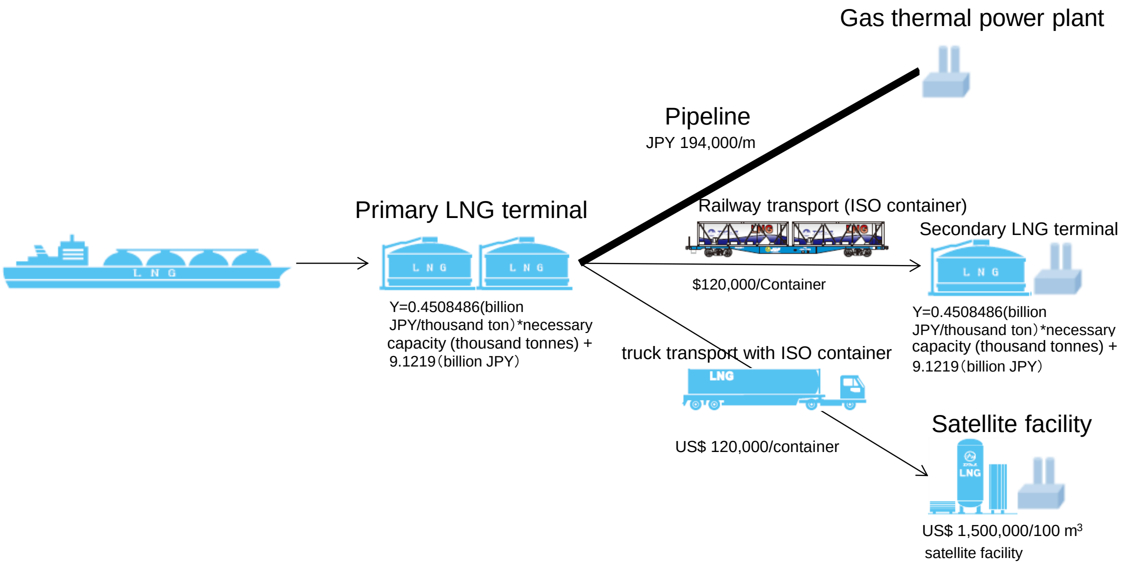
Table 24 shows the cases of natural gas transmission pipeline construction. The range of unit investment per metre is from JPY194–JPY1,222 thousand. When considering the difference in labour costs between ASEAN, India, and Japan, the higher unit investment will lead to over estimation. Therefore, the minimum unit investment of JPY194,000/m can be regarded as the unit investment for the following estimation.

PTT of Thailand conducted a pre-feasibility study on lorry LNG delivery system serving a mountainous remote area. In the study, the loading system at a terminal costs a couple of hundred million yen, and the lorry and off-loading facility costs another a couple of hundred million yen.

The unit investment of satellite facility development was confirmed through interviews of Japanese engineering or manufacturing companies. The unit investment per 100 m^2 capacity satellite facility is JPY1.5 million. The unit price of a 40-feet ISO container is US$120, 000.

Figure 18 shows the summary of unit investment on LNG supply chain infrastructure development.

Figure 18: Summary of Unit Investment on LNG Supply Chain Infrastructure Development



ISO = International Standard Organization, JPY = Japanese Yen, LNG = liquefied natural gas, m = metre, m^3 = cubic metre,

6.2.2 Estimation methods

When estimating investment amount for LNG supply chain infrastructure development, the facility capacity of LNG terminals and satellite facilities is decided through dividing the total LNG demands (MTPA) by 52 weeks. This means that each storage facility can have 1 week LNG volume as a buffer.

Next, the formula of 'capacity' multiplied by the unit of investment for construction was used for the estimation. Formulas (1), (2), (3), and (4) were applied for each demand point and ports (LNG terminals).

LNG terminal construction investment
= LNG terminal capacity (1,000 tonnes)× JPY450 million/1,000 tonnes of LNG (1)

Transmission pipeline construction investment
= Length of transmission pipeline (m) × JPY194,000/m (2)

Satellite facility construction investment
= Satellite facility capacity (m^2)/ 100× 1,500,000 JPY/100m^2 (3)

40ft ISO container procurement investment
= Number of necessary 40-ft ISO container× US$120,000/unit (4)

6.3 Results

Table 25 to Table 26 show the results of the investment estimation.

About US$31.9 billion for primary LNG terminals and about US$8.8 billion for secondary LNG terminals were estimated in total.

Table 25. Estimated Investment for Primary Terminal until 2030

Name of Primary LNG Terminal	Country	MTPA (Integrated)	Investment (US$ billion)
Cat Lai	Viet Nam	232	1.03
Hai Phong	Viet Nam	121	0.58
Ennur	India	79	0.40
Vishakhapatnam	India	9	0.12
Haldia Port	India	376	1.62
Paradip	India	295	1.29
Dahej	India	743	3.13
Mandvi	India	520	2.21
Ratnagiri	India	11	0.13
Kochi (Cochin)	India	34	0.22
Jawaharlal Nehru Port (Nhava Shiva)	India	719	3.03
Kakinada Bay	India	229	1.02
Mumbai (Bombay)	India	204	0.92
Pasir Gudang	Malaysia	55	0.31
Butterworth	Malaysia	158	0.73
Jurong Island	Singapore	641	2.71
Rangoon	Myanmar	43	0.26
Celukan Bawang	Indonesia	45	0.27
Semarang	Indonesia	139	0.65
Jakarta	Indonesia	552	2.35
Ujung Pandang	Indonesia	30	0.20
Da Nang	Viet Nam	66	0.35
Vinh Cam Ranh	Viet Nam	104	0.51
Bintulu Port	Malaysia	101	0.50
Map Ta Phut	Thailand	425	1.82
Bandar Seri Begawan	Brunei	63	0.34
Lhokseumawe	Indonesia	6	0.11
Banten	Indonesia	98	0.48
Cilacap	Indonesia	55	0.31
Bontang Lng Terminal	Indonesia	47	0.28
Muntok	Indonesia	87	0.44
Batangas City	Philippines	84	0.43
Hazira	India	143	0.67
Melaka	Malaysia	10	0.12
Cirebon	Indonesia	351	1.52
Probolinggo	Indonesia	113	0.55
Sibolga	Indonesia	53	0.30

LNG= liquefied natural gas, MTPA = million tonnes per annum.

Source: authors.

Table 26. Estimated Investment for Secondary Terminals until 2030

Name of secondary LNG terminal	Country	MTPA (Integrated)	Investment (US$ billion)
Nghe Tinh	Viet Nam	7	0.11
Machilipatnam	India	61	0.33
Chittagong	Myanmar	75	0.39
Bhavnagar	India	12	0.13
Magdalla	India	143	0.67
Navlakhi	India	516	2.20
New Mangalore	India	6	0.11
Belekeri	India	10	0.12
Nagappattinam	India	4	0.10
Cuddalore	India	28	0.20
Tuticorin	India	11	0.13
Kuantan New Port	Malaysia	9	0.12
Port Klang	Malaysia	58	0.32
Kirteh Oil Terminal	Malaysia	11	0.13
Bangkok	Thailand	190	0.86
Khanom	Thailand	23	0.18
Moulmein Harbor	Myanmar	12	0.13
Gresik	Indonesia	40	0.25
Belawan	Indonesia	26	0.19
Teluk Bayur	Indonesia	13	0.13
Nasugbu	Philippines	16	0.15
Manila	Philippines	28	0.20
Qui Nhon	Viet Nam	16	0.15
Phu My	Viet Nam	11	0.13
Duong Dong	Viet Nam	40	0.25
Karaikal Port	India	33	0.22
Pelabuhan Sungai Udang	Malaysia	92	0.46
Port Dickson	Malaysia	11	0.13
Teluk Anson	Malaysia	8	0.12
Sapangar Bay	Malaysia	17	0.15
Kuala Trengganu	Malaysia	144	0.67
Pelabuhan Bass	Malaysia	36	0.23
Si Racha Terminal	Thailand	28	0.20
Petchburi Terminal	Thailand	67	0.36
Sittwe	Myanmar	4	0.10
Dumai	Indonesia	23	0.18
Davao	Philippines	4	0.10
Tanjung Leman	Malaysia	10	0.12

Name of secondary LNG terminal	Country	MTPA (Integrated)	Investment (US$ billion)
Tanjung Tokong	Malaysia	6	0.11
Pelabuhan Sandakan	Malaysia	27	0.19
Rayong Tpi Terminal	Thailand	23	0.18
Songkhla Harbor	Thailand	6	0.11
Keppel (East Singapore)	Singapore	274	1.21
Anyer Lor	Indonesia	44	0.26
Stagen	Indonesia	5	0.10
Kijang	Indonesia	9	0.12
Panjang	Indonesia	12	0.13
Parepare	Indonesia	15	0.14

LNG= liquefied natural gas, MTPA = million tonnes per annum.
Source: Authors.

The estimate for a natural gas pipeline from an LNG terminal to a new gas thermal power plant is US$2.56 billion.

Table 27. Estimated Investment for Pipelines of New Gas Thermal Power Plants until 2030

Plant name	LNG (MTPA)	Country	Port name	Distance to nearest port (km)	Investment (US$ billion)
Nhon Hoi Refinery	0.819	Viet Nam	Nhon Hoi Refinery	9	0.016
Phu My	0.151	Viet Nam	Phu My	9	0.017
Thoi Hoa	1.170	Viet Nam	Thoi Hoa	61	0.107
Nhon Trach	1.078	Viet Nam	Nhon Trach	19	0.034
Hiep Phuoc	0.890	Viet Nam	Hiep Phuoc	22	0.038
Ca Mau City	1.924	Viet Nam	Ca Mau City	176	0.310
Prodair Kochi	0.300	India	Prodair Kochi	17	0.030
Pillaiperumalnallur	1.613	India	Pillaiperumalnallur	27	0.048
Mangalore Refinery	0.291	India	Mangalore Refinery	9	0.015
Rajahmundry	3.279	India	Rajahmundry	54	0.096
Trombay	4.935	India	Trombay	5	0.010
Sugen	5.946	India	Sugen	34	0.061
Palatana	1.557	India	Palatana	142	0.250
Sultan Iskandar	2.684	Malaysia	Sultan Iskandar	2	0.004
Bintulu	2.017	Malaysia	Bintulu	11	0.020
Kulim Indust Park	1.240	Malaysia	Kulim Indust Park	23	0.041
Kimanis Power	0.867	Malaysia	Kimanis Power	55	0.097
Khanom	0.530	Thailand	Khanom	4	0.008
Glow Spp Phase 3-5	0.599	Thailand	Glow Spp Phase 3-5	3	0.006

Plant name	LNG (MTPA)	Country	Port name	Distance to nearest port (km)	Investment (US$ billion)
Sriracha Ipt	0.169	Thailand	Sriracha Ipt	8	0.014
Ratchaburi	1.502	Thailand	Ratchaburi	71	0.126
South Bangkok	0.320	Thailand	South Bangkok	12	0.021
North Bangkok	0.466	Thailand	North Bangkok	34	0.060
Korat	0.547	Thailand	Korat	228	0.402
Nong Chok	0.538	Thailand	Nong Chok	290	0.511
Jurong Island	9.373	Singapore	Jurong Island	6	0.011
Gadong	0.407	Brunei	Gadong	11	0.019
Pemaron	0.590	Indonesia	Pemaron	26	0.046
Cilegon Nsi	0.940	Indonesia	Cilegon Nsi	5	0.009
Cilacap	1.425	Indonesia	Cilacap	5	0.010
Petorkima Gresik	1.985	Indonesia	Petorkima Gresik	2	0.003
Bontang Works	0.783	Indonesia	Bontang Works	1	0.002
Paya Pasir	1.312	Indonesia	Paya Pasir	8	0.014
North Duri	1.183	Indonesia	North Duri	2	0.003
Muara Tawar	3.969	Indonesia	Muara Tawar	13	0.024
Calaca Semirara	0.569	Philippines	Calaca Semirara	25	0.043
Santa Rita Batangas	0.580	Philippines	Santa Rita Batangas	1	0.002
Therma South	0.165	Philippines	Therma South	19	0.033

LNG= liquefied natural gas, MTPA = million tonnes per annum.
Source: Authors.

The estimate for the development of a natural gas pipeline from an LNG terminal to a converted gas thermal power plant is US$406 million.

Table 28. Estimated Investment for Pipelines of Converted Gas Thermal Power Plants until 2030

Plant	LNG (MTPA)	Country	Port name, C,254	Distance to nearest port (km)	Investment (US$ billion)
Hai Phong Thermal-I	0.025	Viet Nam	Nghe Tinh	12	0.021
Vizag Refinery	0.004	India	Vishakhapatnam	2	0.004
Kribhco Hazira	0.021	India	Magdalla	11	0.019
Sikka	0.085	India	Sikka	3	0.005
Kochi Refinery	0.002	India	Kochi (Cochin)	11	0.020
Mahul Refinery	0.004	India	Mumbai (Bombay)	6	0.010
Mumbai Hll	0.002	India	Mumbai (Bombay)	6	0.010

Plant	LNG (MTPA)	Country	Port name, C,254	Distance to nearest port (km)	Investment (US$ billion)
Thane Plant	0.003	India	Jawaharlal Nehru Port (Nhava Shiva)	28	0.049
Paradip Works	0.023	India	Paradip	6	0.010
Madras Southern Petro	0.013	India	Chennai (Madras)	3	0.005
Manali Refinery	0.004	India	Chennai (Madras)	8	0.014
Durgapur Plant Hfcl	0.025	India	Haldia Port	6	0.010
Patau-Patau	0.023	Malaysia	Labuan	1	0.001
Kuantan	0.012	Malaysia	Kuantan New Port	22	0.038
Perai	0.006	Malaysia	Butterworth	2	0.004
Khanom	0.051	Thailand	Khanom	4	0.008
Jurong	0.060	Singapore	Jurong Island	6	0.011
Pulau Seraya	0.010	Singapore	Jurong Island	1	0.002
Mawlamyaing	0.008	Myanmaer	Moulmein Harbor	1	0.003
Ywama	0.008	Myanmaer	Rangoon	2	0.004
Tambak Lorok	0.029	Indonesia	Semarang	3	0.005
Gresik	0.080	Indonesia	Gresik	2	0.003
Petak	0.026	Indonesia	Surabaya	1	0.002
Perak	0.011	Indonesia	Surabaya	1	0.002
Pulogadung	0.039	Indonesia	Jakarta	11	0.019
Tanjung Priok	0.015	Indonesia	Jakarta	2	0.004
Berushaan	0.007	Indonesia	Jakarta	18	0.032
Muara Karang	0.046	Indonesia	Jakarta	11	0.019
Belawan	0.030	Indonesia	Belawan	2	0.003
Batamindo Industrial	0.003	Indonesia	Sekupang	14	0.025
Tello	0.017	Indonesia	Ujung Pandang	8	0.014
Padang	0.014	Indonesia	Teluk Bayur	14	0.025
Khanom	0.051	Cambodia	Khanom	4	0.008
Total					**0.406**

LNG= liquefied natural gas, MTPA = million tonnes per annum.
C,254 = please include in notes?
Source: Authors.

About 10,253 ISO containers are needed and almost US$1.177 billion are needed.

Table 29. Estimated Investment for ISO Containers until 2030

Country	Number of ISO containers/day	Investment (US$ billion)
Cambodia	12	0.001
India	3,650	0.435
Indonesia	3,261	0.322
Malaysia	771	0.137
Myanmar	246	0.027
Philippines	471	0.052
Thailand	342	0.038
Viet Nam	1,501	0.164
Total	**10,253**	**1.177**

ISO = International Standard Organization.
Source: Authors.

The number of 100 m^3 eq. satellite tanks are estimated at 23,509 and investment amount is estimated at about US$32.06 billion (condition: 1 week amount of LNG will be stored in each satellite facility).

Table 30. Estimated Investment for Satellite Facilities until 2030

	Number of satellite facilities	Investment (US$ billion)
Brunei	63	0.086
Cambodia	25	0.034
India	8,353	11.390
Indonesia	6,817	9.296
Malaysia	2,590	3.532
Myanmar	491	0.670
Philippines	1,359	1.853
Thailand	752	1.025
Viet Nam	3,059	4.171
Total	**23,509**	**32.058**

Source: Authors.

The total additional necessary investment for LNG supply chain infrastructures in ASEAN and India, in addition to the current LNG supply chain infrastructures, is estimated at US$81.369 billion. Most investments will occur in India and Indonesia. Primary LNG terminal and satellite facilities are major investment areas.

Table 31. Estimated Investment for LNG Supply Chain Infrastructures in ASEAN and India

US$ billion	Primary terminal	Secondary terminal	Pipeline	Satellite facilities	ISO containers	Total by countries
Brunei	0.340		0.019	0.086		**0.445**
Cambodia			0.008	0.034	0.001	**0.043**
India	14.768	4.207	0.666	11.390	0.435	**31.467**
Indonesia	7.456	1.511	0.261	9.296	0.322	**18.846**
Lao PDR						**0.000**
Malaysia	1.655	2.750	0.205	3.532	0.137	**8.279**
Myanmar	0.261	0.621	0.006	0.670	0.027	**1.584**
Philippines	0.427	0.444	0.078	1.853	0.052	**2.854**
Singapore	2.712	1.208	0.025			**3.945**
Thailand	**1.824**	**1.876**	**1.155**	**1.025**	**0.038**	**5.919**
Viet Nam	**2.473**	**0.635**	**0.542**	**4.171**	**0.164**	**7.985**
ASEAN and India	**31.916**	**13.253**	**2.965**	**32.058**	**1.177**	**81.369**

ISO = International Standard Organization, LNG = liquefied natural gas.

Source: Authors.

Chapter 7
Legal Framework for LNG supply chain infrastructure

7.1 Introduction

Most countries in Southeast Asia have limited or no experience using LNG domestically, although some have exported LNG to other countries. Some ASEAN countries also have little experience using city gas/natural gas delivered through pipe networks. The use of LNG requires special safety considerations as it is flammable. It is important to let countries in Southeast Asia know about the legal and regulatory system, with emphasis on the safety standards for LNG and city gas supply.

The study of the legal framework of LNG and city gas aims to show:

- the legal and regulatory system regarding city gas business in Japan;
- the list of laws, government documents, and voluntary regulations by industrial associations; and
- the suggestions from the Japanese legal and regulatory system.

7.2 Methodology

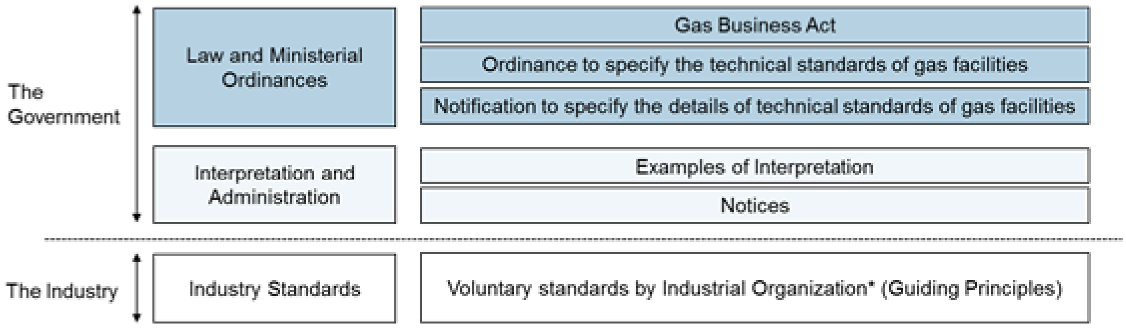
7.2.1 Scope of the study

The scope of the legal framework study covers LNG/NG value chains after LNG-receiving terminal to city gas use at customers' sites.

7.2.2 Literature review

There are three layers of regulations on Japan's gas business: law and ordinances; interpretation and administration; and industry standards (see Figure 19). The Gas Business Act was enacted by the Diet in 1954 and it has been amended many times. Ordinances and notifications were issued by the Ministry of Economy, Trade and Industry to supplement the details not specified in the law. Even ordinances are sometimes not considered concrete enough. Thus, the ministry issues examples of interpretations and notices. Those documents were reviewed for this chapter.

Figure 19. Legal and Regulation Layers of Japan's Gas Business



*Japan Gas Association.

Source: Ministry of Economy, Trade and Industry, Japan.

7.2.3 Interviews

Interviews with five institutions consisting of a plant engineering company, a pipeline manufacturing company, a city gas company, a trading company, and Japan Gas Association (JGA) were conducted.

7.3 Results

Japan has a well-organized legal and regulatory system regarding LNG/NG. Experts agree that the law on gas business must be the basis of regulations and manuals, and those documents must be a package. As laws may differ from country to country, straight importation of the Japanese system will not be very effective.

Also, the Japanese system is very complicated and the ASEAN countries and India may not need it. However, Japan's governmental as well as industrial regulations and standards based on the Gas Business Act could be a good reference for the countries in Southeast Asia and India.

The standard on operation and maintenance (O&M) is another important area, though such standards are not usually stipulated in laws and regulations. The transfer of O&M expertise may be necessary. Japan is one of the few countries in Asia which succeeded in deploying dense piped-gas networks underneath the metropolitan areas. Also, many of Japan's standards on gas are aseismic. Thus, countries in metropolitan areas with earthquake risks may be interested in the Japanese regulations and standards.

There may be exceptions, but the Japanese system might help policy makers of countries that have not introduced LNG supply system yet.

JGA is an industrial organization and it has issued many documents on voluntary standards regarding LNG/NG. JGA's documents (see Table 32) are very detailed, and companies in the gas business usually only need to follow the instructions in the documents. If the documents are followed, the user automatically follows the laws and ministerial ordinances.

Table 32. JGA Documents Regarding Industrial Standards

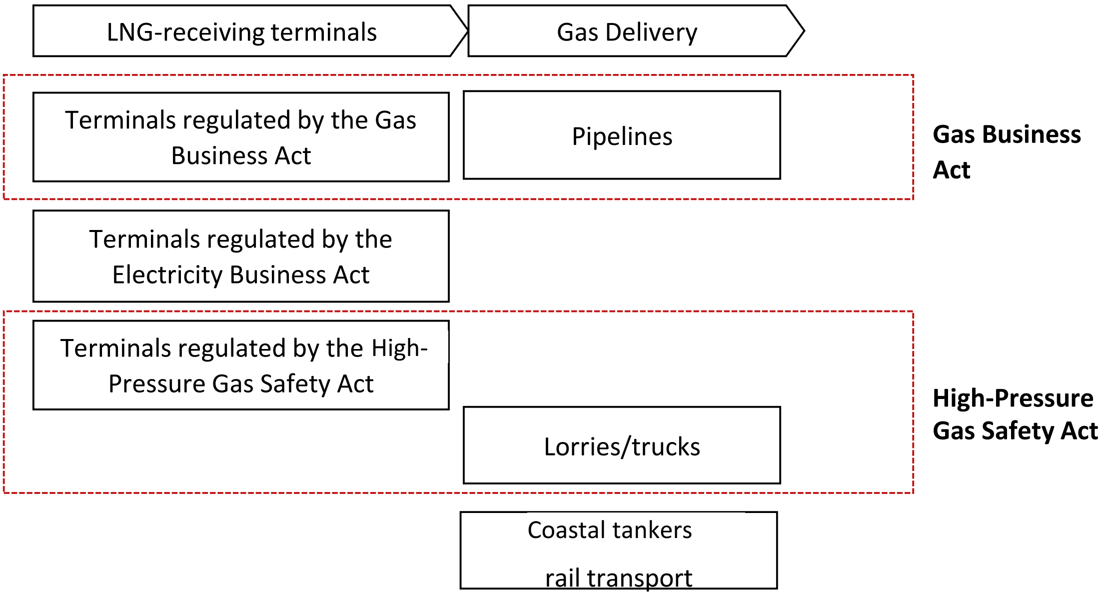
Category	Date of Issue	Documents	Pages
Manufacturing	2015.07	Direction on LPG tanks	387
	2015.03	Direction on facilities of LNG-receiving terminals	257
	2014.07	Direction on the test, evaluation, and maintenance of erosion and fatigue cracks of containers and pipes	115
	2014.06	Examples of memorandum on the self-inspection of gas production facilities prior to use	111
	2014.06	Guidelines on self-inspection of gas facilities prior to use	179
	2014.06	Guidelines on periodical self-inspection of gas facilities	118
	2014.04	Direction on spherical gas holders	329
	2012.04	Direction on underground LNG tanks	305
	2012.04	Direction on ground type LNG tanks	295
	2012.03	Direction on the aseismic design of the manufacturing facilities, and the like	280
Delivery	2016.07	Direction on main branch conduits (operation and maintenance)	234
	2016.07	Direction on main branch pipe, supply pipe, and internal pipe (supplementary on medium-pressure polyethylene pipe)	58
	2016.03	Direction and materials on aseismic (liquefaction) design of high-pressure gas conduits	530
	2014.06	Direction on high-pressure conduits	387
	2014.06	Implementation guidelines on recommendation labelling of polyethylene gas pipe, and the like (5th revision)	157
	2014.06	Training manual for education and work on polyethylene gas pipe bonding	127
	2014.06	Technical materials on polyethylene gas conduits	117
	2013.04	Direction on the aseismic design of high-pressure gas conduits	357

Category	Date of Issue	Documents	Pages
	2013.04	Direction on aseismic design of middle- and low-pressure gas conduits	131
	2013.04	Direction on aseismic design for the prevention of column buckling	82
Customer appliances	2010.07	Commentaries on laws regarding industrial installation	309
	2009.07	Gas cogeneration system	24
	2009.01	Safety technical indices for industrial gas combustion facilities	127
	2004.06	Technical indices for small gas engine cogeneration units for business use	24
	2003.05	Qualifications for comfortable kitchen	CD-ROM
	2002.10	Qualifications for comfortable kitchen	89
	2001.05	Home gas appliances	123
	2002.06	Safety technical indices for gas boiler combustion facility	127
	1996.06	Gas shut-off valve	391
	1988.10	Safety technical direction on gas appliances such as simple boilers, and the like	86
Laws and regulations	2015.04	Commentaries on technical standard and examples of interpretation of gas facilities (5th revision) digital book version	CD-ROM
	2015.04	Commentaries on technical standards and examples of interpretation of gas facilities (5th revision) paper book version	678
Examination for a chief gas engineer's licence	2016.04	Commentaries on the examination for a chief gas engineer's licence (2015)	620

JGA = Japan Gas Association, LNG = liquefied natural gas, LPG = liquefied petroleum gas.
Source: Japan Gas Association.

The Gas Business Act is not the sole law governing LNG/NG in Japan. As Figure 20 shows, an LNG terminal could be regulated by one of the three laws, depending on its use. The scope of high-pressure gas safety act is broader than LNG/NG, and its scope, for example, includes liquefied petroleum gas. Lorries and trucks used for LNG transport are regulated by this law. Experts, in general, comment that Japanese regulations are often very complicated and stringent.

Figure 20. Legal Framework of LNG/NG Terminal and Delivery



LNG = liquefied natural gas, NG = natural gas.
Source: Authors.

In countries other than Japan, an engineering, procurement, and construction contractor does not need to observe laws and regulations as stringent as those of the Japanese. Almost all LNG projects globally are based on either the US or European codes. Though such codes are quite looser than the Japanese standards, they are usually considered adequate. To our knowledge, Taiwan adopted similar standards to the Japanese.

As an engineering and manufacturing company, we expect only knowledgeable experts to handle LNG/NG-related equipment and facilities since the use of gas has its risks. On the other hand, decent users such as energy companies know the risks posed by gas and observe the above-mentioned codes. LNG users in developing countries also know the danger of gas leakage and are thus committed to at least a minimum quality control. Due to such practice, there are seldom serious problems.

The local risks in Southeast Asia regarding gas projects include inconsistency in the construction approvals. There are a variety of approvals, often ambiguous, and the authorities often have a large discretion. Some countries have used domestic natural gas, but only few of them have experience in handling LNG. They would be at a loss once they replace domestic natural gas with LNG. Thus, these countries need laws and technical standards on LNG.

The packaging of projects, regimes, and legal systems are required. However, the standards and manuals of Japan are formulated in accordance with Japanese laws. Thus, the simple transfer of the Japanese legal and regulatory system is not enough. Each ASEAN country needs to enact their own laws before formulating the standards and manuals on LNG and city gas.

To spread the use of city gas, the government/regulator as well as city gas company needs to establish systems through which proper pricing is established and use of city gas is promoted, including cross subsidy. The operation and maintenance of LNG facilities, especially inspection works, are not determined in laws and regulations. Training for personnel engaged in LNG is often considered difficult. The transfer of such O&M expertise many be needed.

Developing countries often want to develop an LNG/NG network as soon as possible, and do not like very stringent regulations that require the developers use a lot of time on compliance. Retail price regulation is another issue. Though developing countries like cheap retail price, for a project to achieve a reasonable return, higher retail price is often required. Time to market and reasonable return for developers are important factors in developing countries.

Chapter 8
Policy implications

Promoting LNG supply chain infrastructure development in ASEAN and India has three policy implications.

First, LNG supply chain development beyond national boarders will bring investment savings and achieve efficient LNG supply chain development for ASEAN and India. To realize cross-border LNG supply chain network using sea route, the flexibility of LNG tanker operations must be improved. This is because most ASEAN countries have introduced Cabotage regulation and domestic transport by vessels should be operated by national sailors. Cross-border LNG terminals will not only supply LNG for domestic demand but also for overseas demand. On the other hand, LNG tankers transporting LNG from an LNG terminal can go to both domestic and overseas users. To save on transport costs, the same sailors can operate the same tanker for both destinations. For this to occur, the Cabotage regulation must be relaxed.

Second, railway and sea transport is another option for LNG supply in ASEAN and India. They can utilize existing infrastructures like national railway systems and ports, but existing infrastructures are not reviewed from an LNG supply chain infrastructure development perspective. Also, in most cases, the last 1-mile infrastructure for final demand points and ports and LNG terminals is not well developed. These additional infrastructure developments are expected to be led by each country.

Third, LNG terminals can supply cool heat as a new industry resource. However, some LNG storage and regasification facilities are assumed as FSRUs. As such, it cannot utilize cool heating well. When hinterland LNG demand developments, including cool heat and other derivatives are prioritized, onshore LNG storage facilities or onshore mooring FSRUs are expected. In Japan, these are big refrigerators for preserving frozen foods, air separation plants to produce liquid oxygen, liquid argon, liquid nitrogen, and liquid carbon dioxide, as well as powder manufacturing facilities using extremely low temperatures to utilize such extreme cold heat. These kinds of industries are expected to be developed around the LNG terminal as a new business in those countries.

Chapter 9
Concluding remarks

9.1 Summary

This chapter discusses how much LNG supply infrastructures are needed in ASEAN and India by 2030. LNG consumption points and supply transport modes were identified and assigned, and LNG terminals were listed. A total of US$ 81.369 billion was assumed as the necessary investment for LNG supply chain infrastructure development by 2030 in ASEAN and India.

This study also reviewed the regulatory framework for the LNG supply chain based on the Japanese regulatory framework. In Japan, two laws and the JGA guidelines on standards were used as regulatory frameworks. The JGA standards are useful for ASEAN and India to develop their own standards to operate LNG supply chain infrastructures.

9.2 Further research tasks

This study is still in its preliminary phase and it only estimated the rough investment amount for LNG supply chain infrastructure development, in particular, onshore facilities, because of the limited study period and budget. Consequently, there are other research tasks that can be conducted. These include:

First, to improve the accuracy of the investment amount, more detailed cost studies are required. The detailed conditions of existing infrastructures like roads and railways were not included in this study. These studies are necessary for improving the accuracy of investment amount projections.

Second, this study could not reflect the latest natural gas pipeline information in ASEAN and India. In India and Indonesia, there are some LNG pipeline development projects but published LNG pipeline information from the ASEAN Council of Petroleum was not updated fully. Natural gas pipeline is the best transport mode if it is there is enough natural gas consumption and it can be used. So, the results of transport mode for LNG consumption points may be changed based on this study. The cooperation of the ministries in ASEAN and India are expected.

Third, domestic regulations and allowance on road structures were not taken into consideration. Before the implementation of LNG supply infrastructure development, a technical feasibility study, including checking of regulations, was necessary.

Fourth, some LNG terminal ports are not registered in the marine transport distance table. Once reflected, the location of LNG terminals in the national plan, the maritime distance, should be calculated again by requesting aquaplot service.

Fifth, the location of industrial and household consumption of natural gas is regarded as occurring in the centre of the province. If more detailed information on population with higher spatial resolution is supplied, the final consumption points should be broken down and transport modes should be recalculated.

Sixth, none of the countries in ASEAN and India provides detailed plans to implement the LNG supply chain and further discussions are needed to develop a detailed roadmap of LNG supply chain infrastructure implementation.

Seventh, this study only considers the onshore facility of the LNG supply chain and does not include investments for small LNG tankers to transport LNG within ASEAN or the Indian coast. This is because this study proposes cross-country LNG infrastructure development and LNG tankers will transport LNG among several countries as milk-run transport. Accordingly, the ownership of LNG tankers and the business model of LNG transport are not in the scope of this study.

To conduct further studies on the above-mentioned points, the study team needs to cooperate more with countries in ASEAN and India. The study team hopes that countries interested in this study would collaborate with ERIA in the near future.

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