Chapter 3

LNG Supply Chain Infrastructure Configuration

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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.

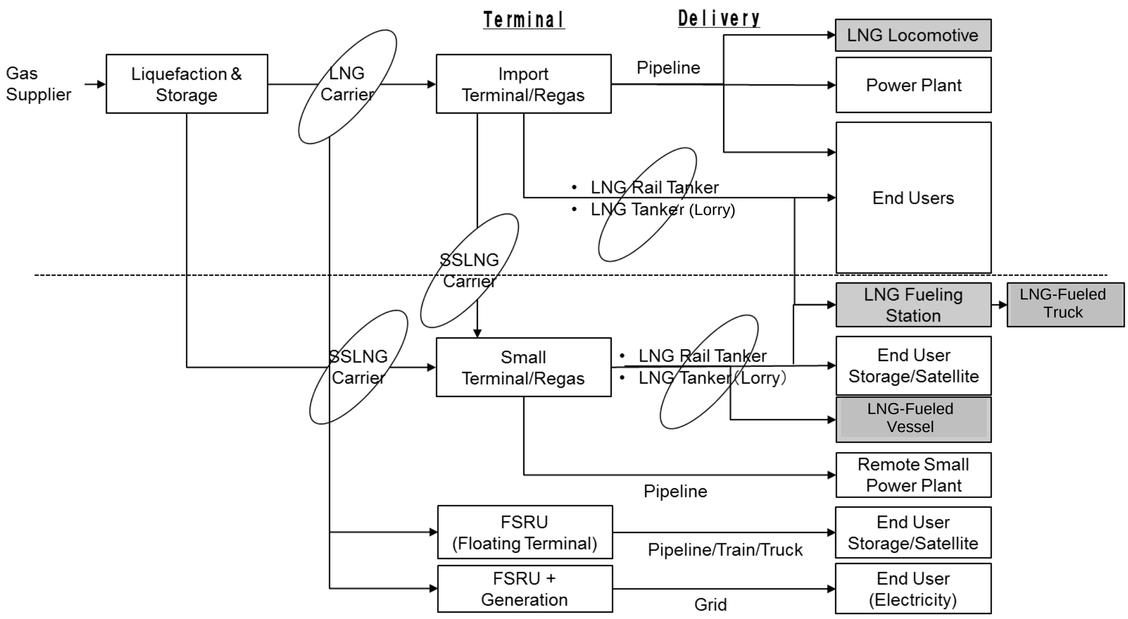
3.2.3. Interviews

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.

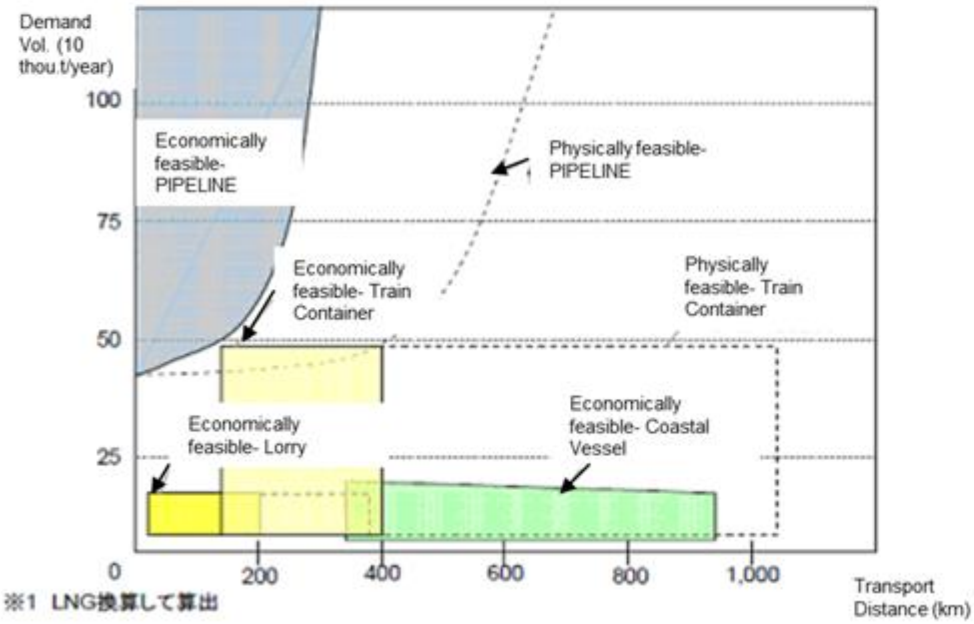
In terms of pipeline network, most Southeast Asian countries do not have a city gas network that is comparable to the size of the Japanese cities, except for Singapore and Kuala Lumpur where certain city gas networks exist. Usually, in other cities, propane gas cylinders are delivered instead. Tokyo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

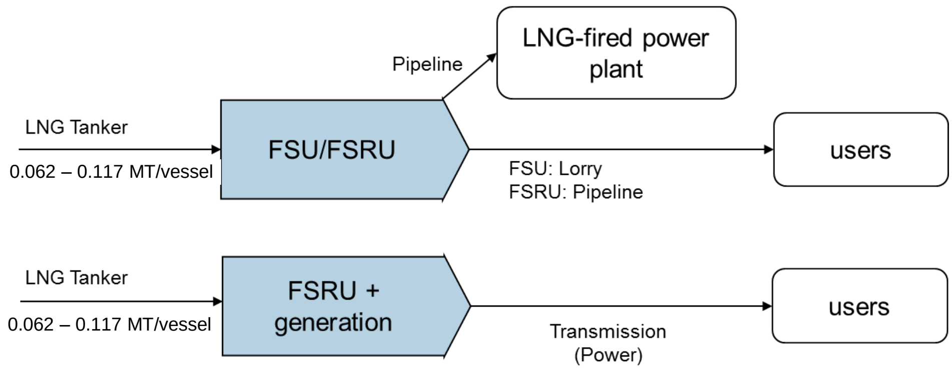
In the ASEAN region, LNG-receiving terminals have been completed and are operational in Singapore and Indonesia. Thailand also has a large-scale terminal and new ones are expected in the Philippines and Viet Nam. The new LNG-receiving terminals in Asia are often the consequences of the depletion of the 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

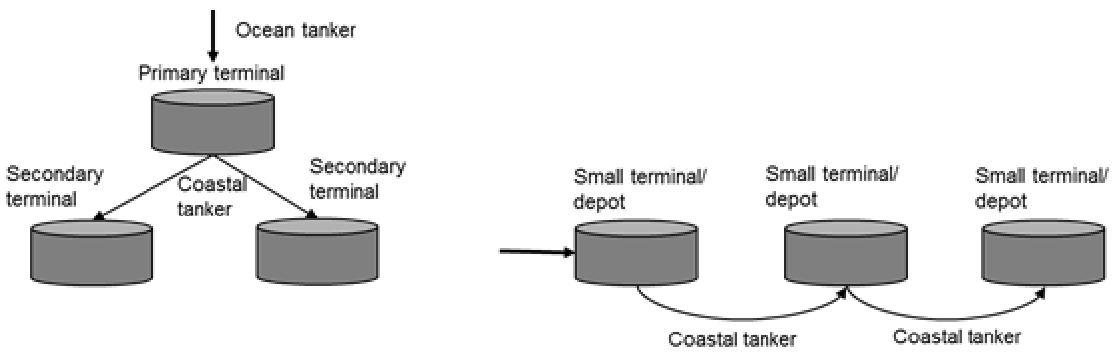


FSRU = floating storage and regasification unit, FSU = floating supply unit, MT = megatonne.

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.

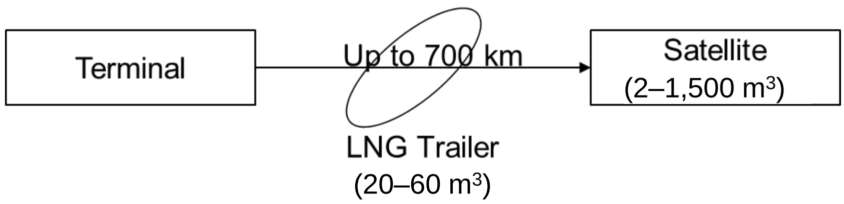
Small-scale receiving terminals need minimal size to be economically competitive. LNG is usually used in place of coal or petroleum, and for LNG to be economically competitive, the receiving terminal must be between 1–3 MTPA. For example, Minato terminal in Sendai City gas has 0.2 MTPA because it was 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.

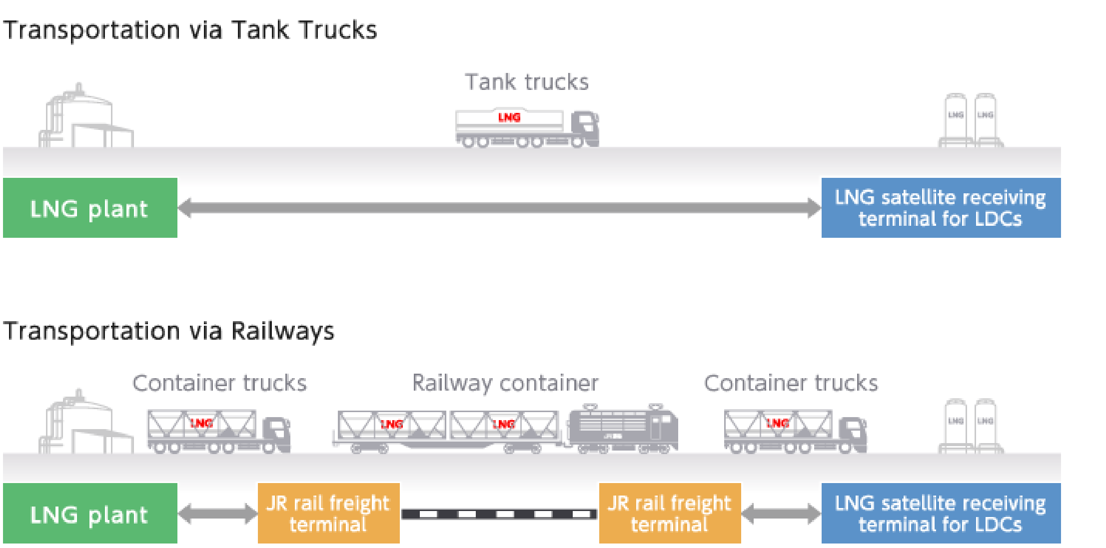
Table 4. Typical Radius of Onshore LNG Transport

	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:

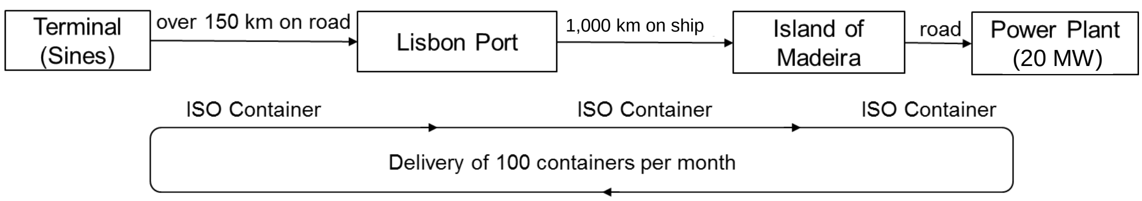
- makes use of existing LNG fleet;
- shares shipping cost between more locations; and
- takes advantage of economies of scale related to conventional LNG carriers (big volume).

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.