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Small-scale LNG in Asia Pacific

APEC Energy Working Group

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Foreword

Interest in the use of small-scale LNG (SSLNG) has increased in recent years as demand for natural gas in the Asia-Pacific region continues to increase. SSLNG has the advantages of lower initial investment costs compared with conventional LNG, which means that supplies can come online in a relatively short period of time, and it also has flexibility in terms of logistics and operation not found in pipeline supply. Because many outlying island regions in the Asia-Pacific use aging and inefficient oil-fired power plants to supply electricity, introducing SSLNG could mean a transition to more efficient and cleaner gas-fired power. Also, LNG is expected to have a greater role as an alternative fuel for fuel oil with the International Maritime Organization set to strengthen fuel oil sulphur regulations and greenhouse gas emissions in international shipping from 2020.

While SSLNG comprises an interesting alternative for supplying natural gas to remote areas, there are still several challenges for its expansion in the Asia-Pacific region. The greatest challenge is cost-competitiveness, mainly because it lacks the advantage of the economies of scale enjoyed by conventional LNG. There are other associated difficulties such as supply chain optimization, training large numbers of people skilled in handling LNG, and trying to accurately predict future demand in remote areas.

This study aims to assess the possibility and challenges of introducing SSLNG in the Asia-Pacific region and considers case-studies and policies that may promote regional expansion. For this study, gas experts at the Institute of Energy Economics, Japan worked for the Asia Pacific Energy Research Centre on a part-time basis.

Kazutomo Irie

Dr. Kazutomo Irie
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July 2019

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Executive Summary

Small-scale LNG (SSLNG) has the advantages of lowering initial investment costs compared with conventional LNG, which means that supply can come online in a relatively short period of time, and with greater operational flexibility than conventional LNG or pipeline supply. SSLNG refers in general to LNG-related facilities (receiving terminals, storage units, vessels, etc.) of similar characteristics but with a lower magnitude compared with conventional LNG infrastructure. However, there is not yet a clear commonly accepted definition. This paper follows the International Gas Union (IGU) criteria and defines SSLNG as any facility with a liquefaction and regasification capacity of 0.05–1.0 million tonnes per annum (mtpa) and vessels with a capacity of 60,000 cubic meters (m^3) or less.

Interest in SSLNG has increased in recent years because of its environmental potential to reduce greenhouse gas (GHG) and sulphur dioxides (SOx) emissions. There are also other factors at work, such as the divergence of the price between crude oil and LNG, policies promoting the use of gas by governments, and natural gas market development strategies by major oil and gas companies. While SSLNG has the advantage of lower initial investment costs compared with conventional LNG, the high complexity of its value chain makes its cost per unit relatively more expensive. Additionally, SSLNG provides more flexibility on logistics and transport.

As of 2014, the global market size for SSLNG was estimated to be around 20 million tonnes. Compared with conventional LNG, SSLNG is used in a wide range of fields, such as power generation, residential and industrial demand in remote areas, and as a land and marine transportation fuel. SSLNG provides an opportunity to use natural gas as an alternative fuel for aging oil-fired power plants and industrial oil-fired boilers in remote areas and on outlying islands. Historically, natural gas has been used for land transportation in the form of compressed natural gas (CNG) in a variety of places across the globe, while LNG as a fuel for transportation has increased in recent years mainly in China and the United States. LNG is mainly used as a fuel for long-haul trucks, and its growing use is driven by factors such as its relatively low price compared with diesel and the environmental benefits of natural gas. It has spread as a fuel for marine vessels, mainly in Europe and the United States, as a measure to comply with SOx emission regulations by the International Maritime Organization (IMO). In 2020, it is expected that the introduction of regulations on marine fuels by the IMO will further boost LNG's use as fuel for marine vessels.

This paper includes a case study that assumes the substitution of diesel for natural gas, using SSLNG technology in different sectors and taking into consideration prices and costs in Japan. The results find that the development of SSLNG and the switch away from diesel could bring significant savings. In the electricity sector, these savings are estimated at about USD 1.6 million per year, resulting from using SSLNG for a 4 megawatt power plant. In industrial uses, on the other hand, the annual cost reduction effect of substituting oil in a small steam boiler is about USD 240,000 per year, a small reduction effect compared with its use in power generation. In contrast, SSLNG for residential use may increase costs about 1.8 times when compared with conventional LNG, depending on the number of clients. Moreover, developing SSLNG in emerging economies might face additional challenges if there is not already a base demand from power generation or industrial users.

This paper includes three regional case studies on the use of SSLNG that share commonalities but with different drivers, uses and magnitude; in China, Southeast Asia, and Nordic and Northwestern Europe. Globally, China leads SSLNG capacity development with around 15 mtpa in more than 200 small-scale liquefaction facilities. China's gas supply includes domestic production and imports by pipeline and via LNG. However, most small-scale liquefaction plants are found in major gas and coal producing areas of the Northwestern and central provinces. SSLNG is an alternative for inland consumers and regions with no access to gas pipelines. While current demand is mostly for industrial, residential and power generation applications, the greatest potential lies in the transport sector. In particular, the number of trucks running on LNG fuel is rapidly increasing as LNG is cheaper than diesel even with the cost of liquefaction factored in. Demand is also increasing for LNG as a fuel for marine vessels, and it is expected that more than 40 LNG supply terminals for ships will be built in China by 2020.

In Southeast Asia, the government of Singapore is implementing proactive policies aimed at becoming a major hub for LNG bunkering. Singapore has already built ship-to-ship (STS) LNG supply facilities, and the government has also introduced a subsidy for LNG-fuelled ship construction and cooperation with other ports and ship-owners to promote LNG as a bunker fuel. Although there is little possibility that LNG demand for maritime fuel will increase greatly in the short term, there is significant long term potential as a consequence of the implementation of the IMO standards in 2020. In Indonesia, SSLNG may be a substitute for aging and inefficient oil-fired power generation on outlying islands. In Bali, an SSLNG receiving facility and a gas-fired power plant are already in operation. In general, since the cost of supplying SSLNG is relatively higher than other fuels, it is difficult for it to be commercially viable unless enough demand can be secured. But, going forward, there are great expectations for improved economic efficiency given potential cost reductions through optimising logistics and modularising equipment.

In some regions in Europe, increasing environmental awareness has driven the use of lower carbon energy. This has helped the development of SSLNG as a lower carbon energy, particularly in Nordic and Northwestern Europe. In Nordic Europe, given that the region has natural gas resources, that the demand for natural gas is relatively small and that it is not connected by a pipeline, are factors in the spread of small-scale LNG. In Northwestern Europe, the use of SSLNG is being driven by the low utilisation of LNG terminals and the increasing demand for natural gas for industrial use and power generation in remote areas due to greater environmental awareness.

One of the main challenges to expanding SSLNG in the Asia-Pacific region will be the extent to which the relative price competitiveness of LNG can be maintained versus petroleum products. Currently in Asia, most LNG prices are linked to the price of crude oil, but if the gap between the price of LNG and the price of crude oil widens, it will serve to boost demand for SSLNG. The expansion of LNG pricing mechanisms that reflect the fundamentals of LNG supply and demand, such as spot pricing, will contribute positively to SSLNG development. In doing so, most long-term contracts that currently have destination restrictions may have to be reviewed and the volume of spot trading expanded. Accompanying this, reducing supply side costs may be necessary to enhance SSLNG competitiveness through measures such as the standardisation and modularisation of equipment and the optimisation of logistics.

Additionally, the development of SSLNG-related domestic infrastructure presents both challenges and opportunities in regions with no access to natural gas. In particular, natural gas for industrial and residential uses requires the construction of pipelines from the SSLNG terminal to end users. This makes coordination and collaboration for investment in such infrastructure a key element for relevant stakeholders, including governments, LNG companies, end-users (power generators, industries, etc.) and local authorities. With regards to LNG use in the transportation sector, a key determinant will be progress on the adoption of new vehicles and ships using LNG, as well as the construction of fuelling facilities in strategic routes and locations.

Chapter 1: What is small-scale LNG?

1-1 Definition

Small-scale LNG (SSLNG) refers in general to LNG-related facilities (receiving terminals, storage units, vessels, etc.) of similar characteristics but with a lower magnitude than conventional LNG infrastructure. Since LNG is an industry driven by economies of scale (where larger facilities and supply chains decrease per unit costs), there are few SSLNG facilities. Moreover, no strict classification of scale therefore has been made so far and there is no a commonly accepted and clear definition or classification for SSLNG.

The growing interest in SSLNG has led to different definitions of SSLNG. For example, Klimczak uses two million tonnes per annum (mtpa) as the standard for classifying liquefaction capacity as large-scale LNG.[1] Brown, on the other hand, distinguishes LNG-related facilities with a liquefaction capacity of more than one million tonnes per annum as "large-scale" and those with less as "small-scale".[2] The accounting and consulting firm, PwC, uses 500,000 tonnes per annum as a standard for small-scale liquefaction facilities.[3] Furthermore, GOC and Linde have identified SSLNG infrastructure mainly based on the scale of their storage capacity, and adopt 10,000m^3 as their criteria.[4]

This paper follows the criteria of the International Gas Union (IGU) which is thought to show a nearly "median value" of these various definitions. The IGU has established the following criteria for each SSLNG value chain.[5]

- Liquefaction, Regasification, Import: 0.05–1mtpa
- Transportation of LNG in wholesale: maximum 60,000m^3 (Carrier capacity)

1-2 Benefits of small-scale LNG

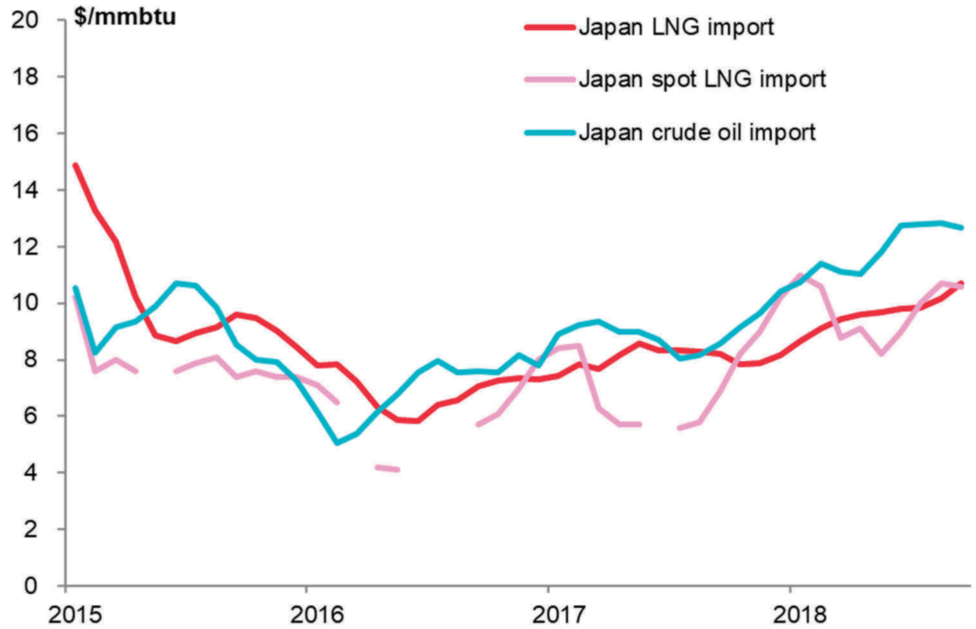
Several factors are behind the recent growing interest in SSLNG. One is the reduction of GHG emissions and its impact on improving air quality. Since natural gas is the cleanest among fossil fuels, demand for power generation and industrial uses has increased. The natural gas value chain requires a large amount of investment and infrastructure development (mostly pipelines or LNG terminals) to transport gas from production centres to end-users. When demand centres are located in remote areas, the laying of pipeline networks becomes costlier. This constitutes an opportunity for SSLNG, particularly in outlying island or isolated regions. On the other hand, in Europe and elsewhere, gas has been supplied using small LNG tankers and LNG trucks to remote areas despite its higher supply cost with the aim of improving air quality and further reducing GHG emissions. Successive investments are being made to increase the supply capacity of SSLNG at terminals such as the Gate terminal in the Netherlands and the Zeebrugge terminal in Belgium.

In the future, the strengthening of environmental regulations is highly likely to increase the demand for LNG, in particular as bunkering fuel. In October 2016, the International Maritime Organization (IMO) decided to limit the sulphur content of marine fuel to less than 0.5% from 2020. On the other hand, the shipping industry is expected to respond by switching from its existing high sulphur fuel oil to low sulphur fuel oil but is also considering options to replace fuel with LNG.[6]

Apart from lower greenhouse gas emissions when compared with other fuels like coal or oil, natural gas also has lower particulate matters (PM), nitrogen oxides (NOx) and sulphur oxides (SOx) emissions. Moreover, during the liquefaction process of natural gas, additional impurities are removed, reducing LNG emissions of SOx and NOx when compared with pipeline natural gas. Moreover, there is a possibility that the new IMO regulations not only includes a restriction for sulphur contents but also for GHG emissions. In fact, the IMO has already set a goal of halving GHG emissions from ships by 2050. If an actual GHG emission regulation is introduced in 2020, it cannot be achieved which petroleum fuels, in which case, LNG use as a bunkering fuel may significantly increase in the long term.

Another reason for the growing interest in SSLNG is that its relative economic efficiency is improving. Unlike in Asia, in Europe and the United States, natural gas prices are determined by the balance of the natural gas supply and demand. In these markets, since LNG prices are based on price benchmarks determined by gas-to-gas competition and disassociated from crude oil prices, LNG can be highly competitive compared with petroleum products. For instance, if natural gas continues to be cheaper than some petroleum products and the price difference between crude oil and natural gas expands over the long term, more investment on infrastructure to substitute for petroleum products would be expected. As far as Europe and the United States are concerned, since the beginning of the 2010s, the price gap between natural gas and crude oil has tended to expand, creating an environment favourable for LNG relative competitiveness.

Figure 1-1 Crude oil and natural gas prices



Source: IEA, EIA 2018.

In contrast, Asian natural gas prices are mainly based using crude oil prices as a benchmark for LNG or, alternatively, by regulated prices set by governments. While LNG trade using spot prices (consequently not benchmarked against crude oil prices) has increased, the spot LNG trade share still remains low when compared to the total. For this reason, LNG price competitiveness against petroleum products in the Asian markets is more limited and challenging, especially when compared with Europe or North America. In the future, relatively new practices like using LNG-specific benchmarks (like JKM) or reselling LNG volumes to third parties (excluding destination clauses) may make Asian LNG prices less reactive to international crude oil prices.

Another reason for the increased use of SSLNG is that infrastructure development and initial capital investments are shorter and smaller, compared with conventional LNG infrastructure. Although the investment per unit of supply may be higher, there is a lower hurdle to its introduction, especially in regions with insufficient capital. In addition, given the shorter infrastructure construction time, SSLNG can be an effective energy supply option for emerging economies where energy demand is growing fast and where there is a need to rapidly develop energy infrastructure.

Moreover, the marketing activities by the oil and gas industry also help to create demand for SSLNG. Several large liquefaction projects have started to come online in the United States and Australia, so global LNG supply capacity is expected to exceed demand in the short term. International oil and gas companies (IOCs) operating liquefaction equipment are pressed to sell LNG volumes not only to their traditional markets but also to new potential consumers. Under these circumstances, it is noteworthy that Shell, which has a large presence in LNG markets, has a particularly proactive attitude toward promoting the introduction of SSLNG. In September 2012, Shell started its SSLNG supply business by making Norwegian gas wholesaler Gasnor a wholly owned subsidiary. Shell then acquired the usage rights to Gate terminal, an LNG terminal in the Netherlands. From there, it is expanding its SSLNG supply business in Northwestern European markets such as Germany using LNG trucks and its LNG supply business to the Nordic Europe market using small LNG tankers. Also in May 2018, Shell signed a memorandum of understanding with the Sultanate of Oman to study LNG bunkering in Oman.[7] In May 2018, French oil and gas company Total also spent USD 83.4 million on acquiring a 25% stake in Clean Energy Fuels, a US-based gas company, and announced plans to develop a natural gas supply network for transportation in the United States.[8]

Furthermore, an LNG bunkering project in Japan to provide a supply hub has come online. Chubu Electric Power established a joint venture in May 2018 with Kawasaki Kisen Kaisha, Toyota Tsusho and Nippon Yusen Kaisha to supply LNG fuel in the Chubu region of Japan. In March 2018, Sumitomo Corporation established a joint venture company with Uyeno Transtech and Yokohama-Kawasaki International Port Corporation to supply LNG fuel in the Port of Yokohama, and also began studying the commercialization of LNG as a bunkering fuel.

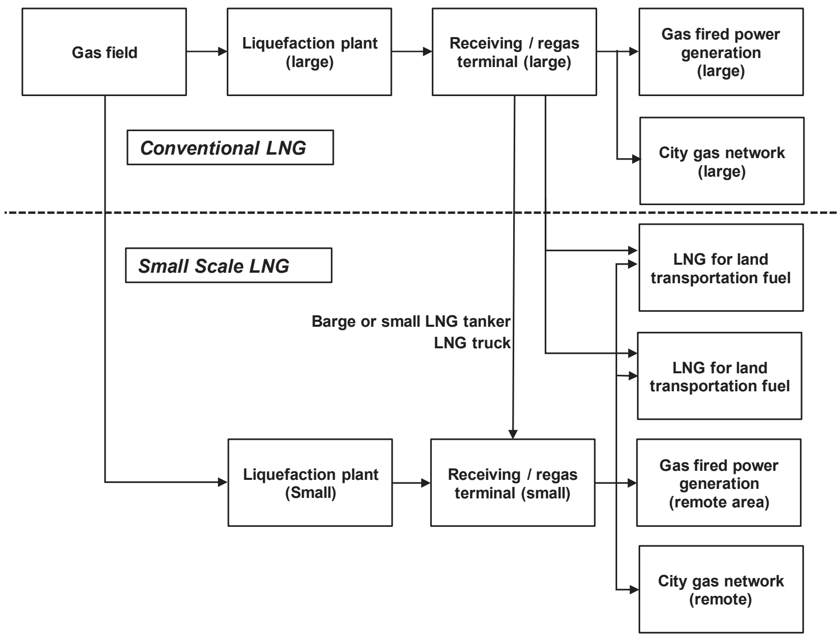
There are places where the introduction of SSLNG is progressing because of geographical conditions. For example, in economies with many outlying islands, such as Indonesia and the Philippines, electric power is provided by thermal power generation using diesel and other petroleum products, but due to higher demand and deteriorating power generation facilities, there is an opportunity for increasing gas-fired power generation. However, since the scale of demand on some islands is limited, developing a gas pipeline network might not be feasible, providing an important opportunity for the development of SSLNG. Indonesia already imports LNG from a large LNG receiving terminal in Singapore and Indonesia could increase the use of SSLNG to meet growing electricity demand in the future.

In some places, the government's gas policy has led to the adoption of SSLNG. The clearest example is China, where the government aims to increase the use of natural gas to 8% of domestic energy demand by 2020. As a measure to promote the switch to natural gas, China is using SSLNG domestically by liquefying natural gas from production areas and transporting it via truck tankers to remote areas. Singapore is proceeding with the construction of a domestic LNG terminal and introducing equipment that can reload it onto small LNG carriers. Singapore aims to secure its position as the SSLNG supply hub for outlying islands in the region. While efforts by the Chinese and Singaporean governments may not necessarily be aimed at promoting the introduction of SSLNG itself, SSLNG is still expected to play an increasingly important role as a means for increasing natural gas demand in the Asia-Pacific region.

1-3 Value chain of SSLNG

With conventional LNG, natural gas is liquefied in a conventional liquefaction plant and then transported by large LNG tankers to receiving terminals. Then, LNG is regasified in a conventional receiving terminal. Finally, this gas is either use in-site as a fuel for power generation or injected to the distribution pipeline network to be used in the industrial, residential and commercial sectors. On the other hand, there are two types of supply paths in the SSLNG value chain. In the first case, supply comes directly from the gas field (as with conventional LNG) and is liquefied with a small-scale liquefaction plant. Alternatively, LNG from a large-scale terminal is reloaded into a SSLNG tanker or an LNG transport truck and taken to a SSLNG regasification terminal. After that, natural gas is then supplied to small-scale gas-fired power plants, city gas distribution networks or end-use demand sites to fuel vehicles or vessels (Figure 1-1).

Figure 1-1 Value chains of conventional LNG and SSLNG



Source: IEEJ, 2018.

A first challenge to SSLNG development is the difficulty in deciding the appropriate scale of each facility in the value chain. This is particularly true in emerging economies, where information and data tend to be limited or insufficient to accurately assess and forecast energy demand and its growth path. LNG-related facilities have economies of scale at work and it is necessary to capture a wider demand when it comes to making actual investments. Additionally, they must also simultaneously meet diversified and geographically dispersed demand. In the SSLNG value chain, finding such an optimum scale and actually carrying out optimal logistics are big challenges.

1-4 Market

It is difficult to estimate the market size of SSLNG because official statistics are not widely available. According to the IGU, the SSLNG market in 2014 was 20 million tonnes (liquefaction capacity base), which is equivalent to about 8% of global LNG production for the same year.[9] There are more than 1,000 terminals in the world for receiving SSLNG, with terminals in places as diverse as China, Turkey, Chile, Japan and the Netherlands, amongst others.[10] However, about three quarters of total liquefaction capacity of SSLNG (15 million tonnes) are located in China, where there are more than 100 such terminals. The production capacity of SSLNG in China continues to expand because of the growing domestic production of natural gas and growing domestic demand. It is estimated that in 2020 production will exceed 20 million tonnes.[11]

Figure 1-2 World SSLNG market, 2020-2035

Organisation	Sector	2020	2025	2030	2035
International Gas Union	Total	30	-	-	-
Engie		-	-	75 -96	-
PwC				100	
IEA (New Policies Scenario)	Marine	-	12	19	27
IEA (Sustainable Development Scenario)			24	30	36
Engie				24-30	
Engie	Land			32-40	
Engie	Remote			20-25	

Unit: million tonnes per annum

Source: IEA, World Energy Outlook 2017, p339, p452; PWC, Small Going Big: Why small-scale LNG may be the next big wave (July 2017), p6.

Given the relative scarcity of data, it is hard to estimate SSLNG growth in upcoming years, with estimates around 100 mtpa by 2030. For instance, French electricity and gas company Engie estimates that there is a possibility that the market will expand from 75 million tonnes to 95.5 million tonnes by 2030. The US accounting and consulting firm PwC expects the market to expand up to 100 million tonnes by 2030. Several organisations are predicting the outlook for the size of the SSLNG market, but there are many uncertainties surrounding the size of demand in the future, and the scale differs greatly depending on the outlook.

Chapter 2: End-use applications of SSLNG

SSLNG has a wide range of uses such as power generation, residential and industrial demand in remote areas, and as a fuel for marine and land transportation. However, the largest demand sector for SSLNG in the future is thought to be in the transportation sector.

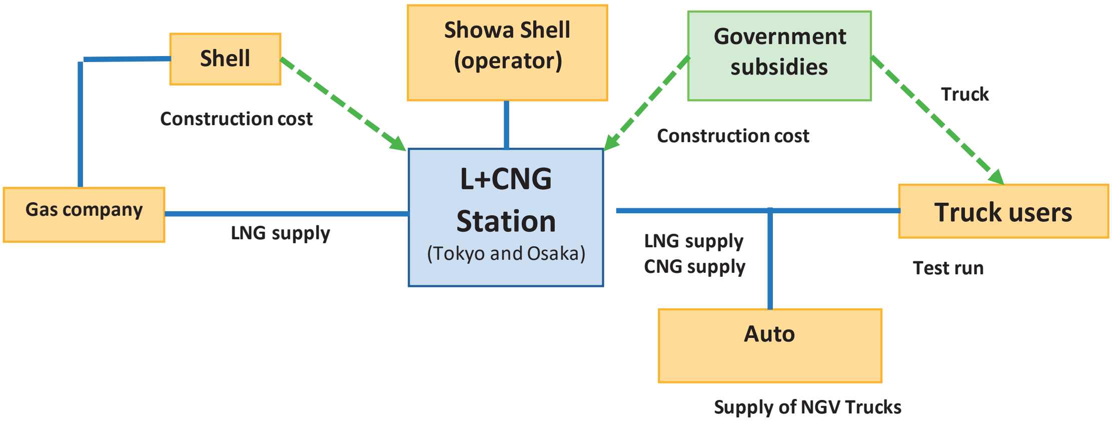
2-1 Land transportation fuel

One of the main uses of SSLNG is as a fuel for land transportation in natural gas-fired vehicles. Natural gas vehicles (NGVs) include CNG fuelled vehicles that store gas in high-pressure containers and LNG fuelled vehicles that store natural gas in a liquid state in ultra-low temperature containers. CNG vehicles are currently the most common natural gas-fired vehicles and have been mainly used as a means of transportation in places where gas is produced domestically, such as China, Iran, and Argentina. Recently, LNG vehicles are becoming popular in the United States, China and elsewhere, and trucks that use LNG as a fuel have become increasingly widespread around the world due to the increased relative competitiveness of fuel prices.

There are about 4,000 large LNG trucks on the road in Europe,[12] about 10,000 vehicles, including LNG buses, in the United States and more than 200,000 in China.[13] Table 2-1 compares LNG trucks and CNG trucks. An advantage of LNG trucks is that the fuel tank can be filled with about three times as much natural gas as CNG trucks. This dramatically increases the driving range, providing an efficient option for long-distance freight transport. In addition, since LNG-fuelled trucks can load fuel while LNG carriers are unloading their cargoes at regasification terminals, time and labour on distribution processes are saved, reducing refuelling times to a level comparable to diesel-fuelled vehicles. On the other hand, there are some technical hurdles, including higher costs and safety concerns for loading LNG-fuelled trucks and keeping it at ultra-low temperatures for extended periods, especially when compared with diesel. Addressing these issues and mitigating the risks may boost the adoption of LNG use as a transport fuel.

Japan’s first commercial LNG station, “L+CNG Osaka Nanko Station,” opened in June 2018. It was built by Isuzu Motors, Shell Japan and the Organisation for the Promotion of Low Emission Vehicles (LEVO) as part of the Ministry of the Environment-subsidised project to boost the uptake of LNG trucks and fuel charging infrastructure.

Figure 2-1 Shell Japan plan for L+CNG station



Source: Shell Japan, 2018.

2-2 Marine transportation fuel

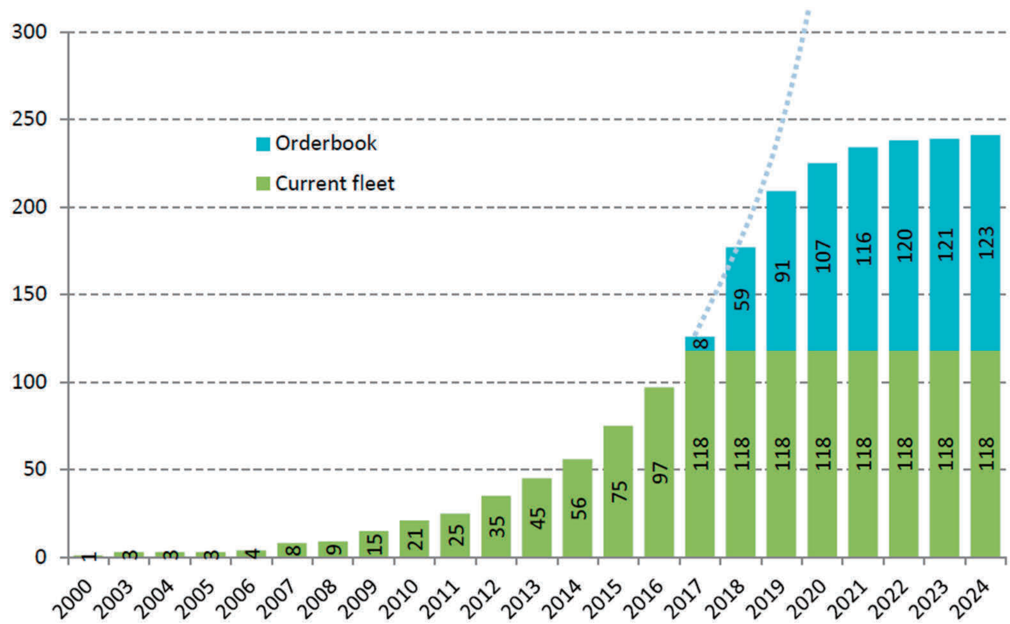
The use of SSLNG as fuel for marine transportation is advanced mainly in Europe and the United States. The major factor for this is environmental regulations related to shipping. Environmental regulations concerning international shipping are handled by the IMO, an international organisation based in London with 171 members. IMO regulations for the prevention of marine pollution are defined by the International Convention for the Prevention of Pollution from Ships (commonly referred to as the MARPOL 73/78 Convention). The current SOx regulations were established separately for specific Emissions Control Areas (ECAs) and other general sea areas, with the sulphur content of fuel oil in ECAs set to 0.5% or less. The following four oceanic regions are set as ECAs:

- The Baltic Sea area
- The North Sea area
- The North American area (covering designated coastal areas off the United States and Canada)
- The United States Caribbean Sea area (around Puerto Rico and the United States Virgin Islands)

In these ECAs, LNG can be used as an alternative fuel that meets the sulphur content restriction. In addition to these existing regulations, the IMO decided on 2020 as the implementation date for strengthening the regulated sulphur content in fuel oil (currently 3.5% or less) in general sea areas to 0.5% or less. Some viable alternatives to meet this new regulation include: converting oil-fuelled marine ships to LNG fuel, switching to compliant fuels like very low-sulphur fuel oil or gasoil, or installing exhaust gas scrubbers. Converting to LNG fuel and installing scrubbers requires important investment, so it is expected that switching to very low-sulphur fuel oil or gasoil will become the mainstream alternative fuel for the near future. However, in the medium term, it is expected that the conversion to LNG, which has a superior environmental upside, will proceed given its other aspects apart from its sulphur concentration.

With respect to LNG hubs for bunkering, a refuelling station that is fed with small vessels is already operational in Singapore. Also, in May 2018, Chubu Electric Power, together with Kawasaki Kisen, Toyota Tsusho and Nippon Yusen Kaisha, established a joint venture company to supply LNG fuel in the Chubu region. Additionally, Nippon Yusen completed construction of the "Sakigake" LNG fuel tug boat in 2015. In 2016, it also completed the world's first car carrier with a duel-fuel engine capable of using LNG and heavy fuel oil.14 In January 2017, Mitsui O.S.K. Lines, together with Rio Tinto, BHP Billiton, Woodside Energy and others, agreed to advance the study of an LNG-fuelled Capesize bulker, and in December 2017, together with Tohoku Electric Power and others, signed an agreement in principle from Lloyd's Register of the UK for the design of a new LNG-powered coal carrier. Mitsui O.S.K. Lines also concluded a contract in January 2018 to build an LNG-powered tug boat.

Figure 2-2 LNG fuel carriers in service in the world, 2000-24

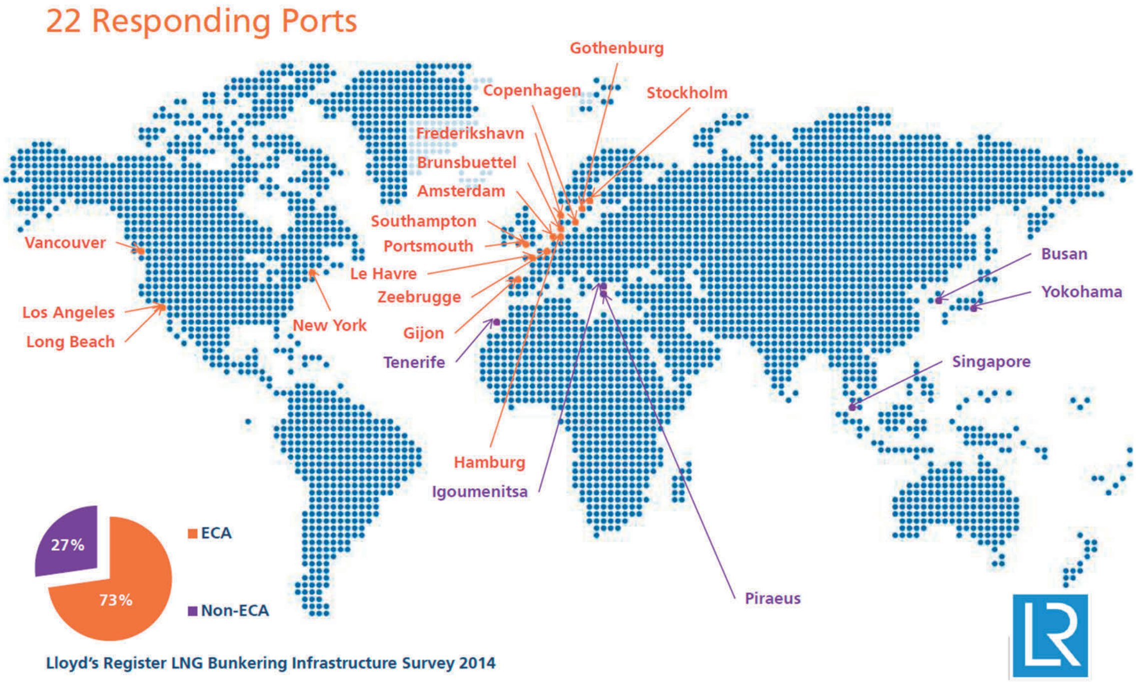


Source: International Transport Forum, "Fuelling Maritime Shipping with Liquefied Natural Gas" (April 2018)

According to DNV GL, there were 118 LNG fuelled ships (excluding LNG tankers and domestic shipping vessels) in service in the world as of December 2017 (Figure 2-2). Considering there are 123 outstanding orders for ships through 2024, the number of LNG fuel carriers is expected to double soon. Ferries, offshore ships and tugboats have been the main types of ships, but the introduction of other types of vessels, such as container ships and tankers, is also expected to increase.

Figure 2-3 is a survey of 22 ports worldwide by Lloyd's Register of the UK. Since LNG-powered ships have been introduced mainly in the ECAs of Northern Europe, existing and planned LNG bunkering ports are concentrated in Northern Europe, in particular. In order to promote the introduction of LNG-powered ships, it is necessary to develop an LNG supply infrastructure at major ports in the world in parallel with ship construction. However, 59% of ports already have LNG bunkering facilities that are in service or being planned.[15]

Figure 2-3 Ports engaged in LNG bunkering or studying it



Source: "LNG Bunkering Infrastructure Survey 2014," Lloyd's Register

2-3 Remote area demand

In remote communities, there are cases in which there is economic and environmental merit for procuring LNG and supplying it for its use in power generation, transport, industry and residential sectors.

LNG is making inroads in China. China is encouraging the curtailment of coal use and substituting it with natural gas, as part of the Xi Jinping administration's efforts to improve air quality in China. In fact, China reduced the use of coal by imposing PM emission reduction targets in each province, while its gas demand increased by 15% from

2016 to 2017. The policies aimed at increasing the use of gas include the replacement of coal and petroleum products also in inland regions with no access to pipelines, where gas needs to be either liquefied from domestic production regions or imported from large LNG terminals and then transported as SSLNG inland.

In Japan as well, there are seven secondary LNG receiving terminals, and LNG imported from overseas to primary terminals is transported and supplied to the secondary terminals using small LNG tankers. In addition, there are cases where LNG trucks are used to supply gas to remote customers.

In Peru, Lantera Energy, a subsidiary of the American oil company Okra Energy, is constructing a SSLNG supply hub for remote areas (to be operational in 2019). This SSLNG facility will use Lantera's modular construction to build low-cost liquefaction facilities to supply natural gas customers in northern Peru,[16] Lantera announced that gas supply contracts were already formalised with a steelworks plant and power generators in the north of Peru.[17]

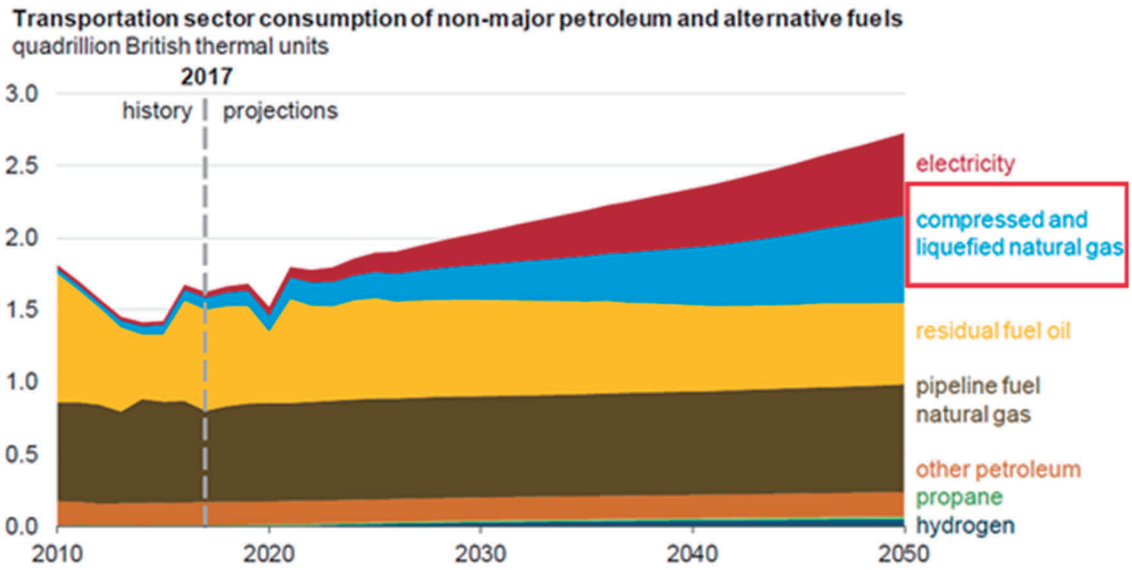
In Canada's northern territories, there are areas in which remote communities are cooperating with regional power plants and introducing SSLNG by purchasing LNG instead of diesel.[18]

2-4 New applications for SSLNG: industry and transport

A potential demand segment for SSLNG is the industrial sector. In the United States and Canada, attempts have been made to use LNG in heavy machinery and trucks in the mining and resource sectors, and at construction sites. For example, Westport, which makes natural gas engines, has agreed with Caterpillar on the joint development of dual fuel, high pressure, and direct injection technology for off-road vehicles. Shell Canada is also conducting tests of an engine and fuel mixing for a new mining truck powered by LNG in the oil sands in the northern part of the province of Alberta.

In addition, in North America, there are efforts underway to utilise LNG for train fuel. In the 1980s and 1990s, Burlington Northern Railroad (currently BNSF Railway) started operating natural gas-powered freight engines in Los Angeles, California, and in March 2013, BNSF announced plans for trial operations of LNG-powered freight engines from the latter half of the year. As the introduction of LNG as a fuel for long-haul trucks has already shown important progress in the United States and given the low gas prices in the region, demand for LNG in the railway sector has potential to grow substantially. Figure 2-5 shows the outlook for the introduction of alternative fuels in the United States transport sector to 2050. As the use of LNG in the railway sector proceeds, its demand volume is also expected to grow.

Figure 2-4 Outlook for the introduction of alternative fuels in the US transport sector, 2010-50



Source: "Annual Energy Outlook 2018," US Energy Information Administration

Chapter 3: The economics of SSLNG

Since the cost of supplying SSLNG fluctuates greatly depending on various factors, such as transport volume (demand amount), the price of LNG, personnel expenses, transport distance and facilities cost, it is difficult to uniformly evaluate its economic efficiency. In this chapter, we assumed a model case with certain premises, evaluated the transportation cost, the supply cost for both power generation and industrial use and the price competitiveness versus competing fuels. For residential use, we illustrate how much the cost will increase compared with conventional LNG supply based on the case of Japan and evaluate the transportation costs of SSLNG provided by the International Energy Agency (IEA).

3-1 Assumptions

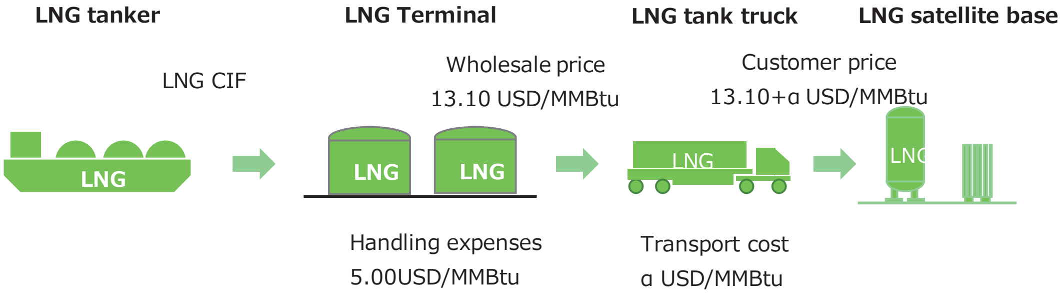
The common conditions used for the estimates in this chapter are provided in Table 3-1. Fuel prices and exchange rates use the average values for 2017. The price of LNG is assumed to be the wholesale price when loaded on an LNG carrier, which is based on JLC (Japan LNG CIF), a general price benchmarks in Asia. An administrative and handling expense of USD 5/MMBtu is added to this wholesale price as noted in Table 3-1. The price posted with transportation costs for this wholesale price is the customer price at the actual demand site (Figure 3-1). The petroleum product price survey value published by the Ministry of Economy, Trade and Industry of Japan was adopted for the prices for diesel and fuel oil as competing fuels for LNG in order to match the conditions with the above LNG price. This price is the delivery price to the customer and includes the transportation cost to the demand site.

Table 3-1 Common conditions

Gross Heat Value	LNG	54.60 MJ/kg
	Diesel oil	37.70 MJ/L
	Heavy oil	39.1 MJ/L
Fuel price (2017 average in Japan)	LNG	13.10 USD/MMBtu
	Diesel oil	828 USD/kL
	Heavy oil	533 USD/kL
Economy condition	Exchange	111.88 JPY/USD
	Personal cost per capita	9,000,000 JPY/yr
	Annual interest rate	5.5 %

Source: IEEJ analysis, 2018.

Figure 3-1　SSLNG price estimation



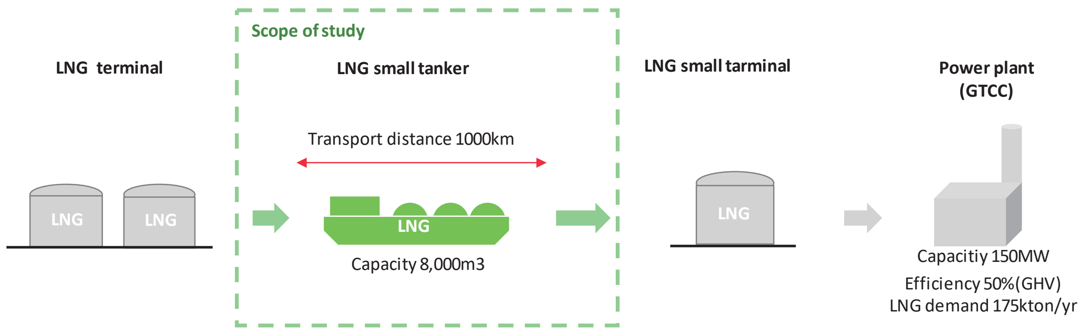
Source: IEEJ, 2018.

3-2 Transportation cost of SSLNG

3-2-1　Marine transportation costs

In this case, it was assumed that LNG is transported by a small LNG tanker with a tank capacity of 8,000 m3 to a small LNG receiving terminal for a power plant located 1,000 kilometres (km) away. The gas demand is assumed to be a gas turbine combined cycle power plant with a generation capacity of 150 MW (power generation efficiency of 50%), and the annual transport volume is assumed to be around 175 000 tonnes.

Figure 3-2 Illustration of model case



Source: IEEJ, 2018.

For the transportation costs in this estimation, a 1.5% annual interest rate, a 20-year repayment period and equal repayment of principal and interest were assumed as CAPEX, and OPEX (crew expenses, maintenance costs, etc.) were assumed as fixed costs, while fuel and port costs were assumed as variable costs. The conditions used for these calculations are shown below (Table 3-2).

Table 3-2: Main assumptions

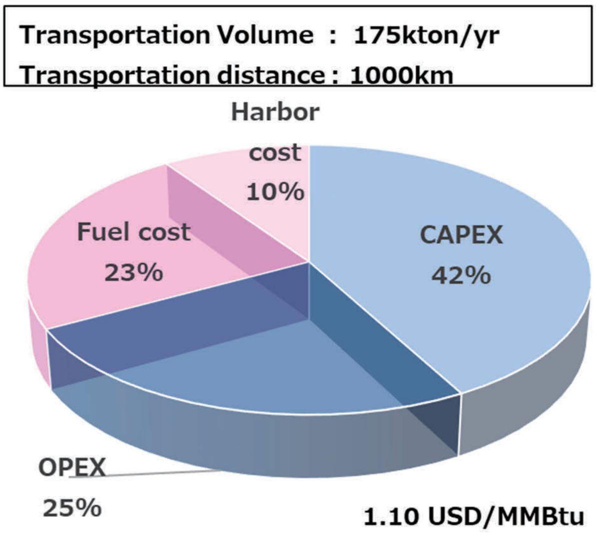
Small LNG Tanker	Capacity	8,000 m3
		3,680 ton
	Speed	26 km/hr
	CAPEX	40,000,000 USD
	OPEX	2,500,000 USD/yr
Fuel consumption	Sailing	18.4 kL/day
	Anchoring	4.9 kL/day
Fuel price (Heavy oil)		533 USD/kL
Harbor cost		10,000 USD/visit

Source: IEEJ, 2018.

The transportation cost of LNG in this model case is estimated to be about USD 9.99 million annually, with a transport unit price of USD 0.81/MMBtu. As a breakdown, fixed costs account for 67%, which is the total value of CAPEX and OPEX, including capital costs and operating expenses, while the variable costs, such as the remaining fuel cost and port cost, account for 33%.

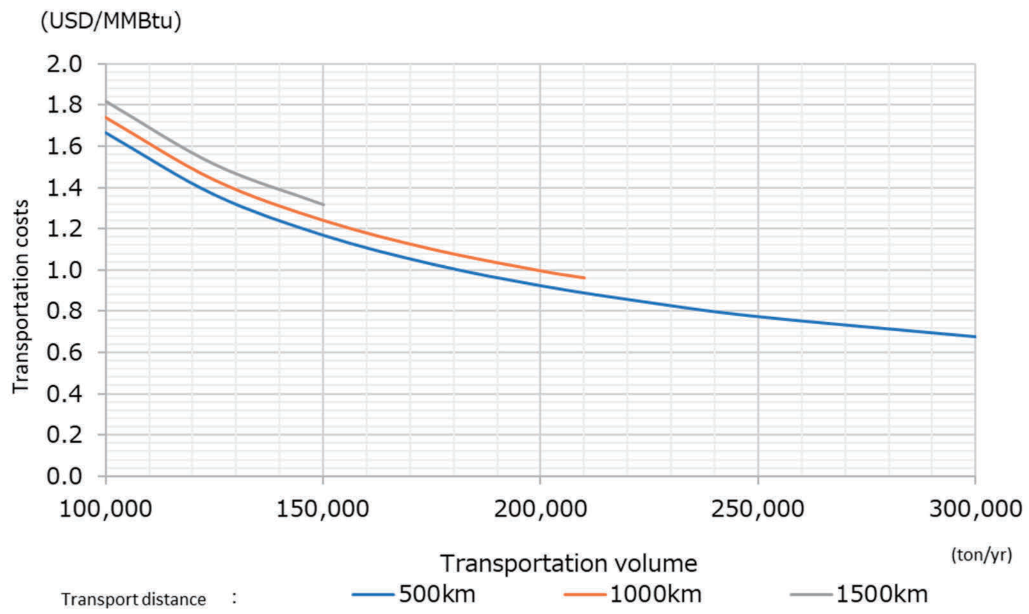
Transport unit prices are affected by the transportation distance, fuel prices, and port costs, among others, but they are most influenced by the volume transported. In transporting to multiple demand sites, improving the availability of ships by devising measures, such as creating an optimal transportation schedule, will contribute to the reduction of overall transport unit price.

Figure 3-3 Composition of transport unit prices in the model case



Source: IEEJ, 2018.

Figure 3-4 Influence of changes in transportation distance and volume in the transport unit price in the model case

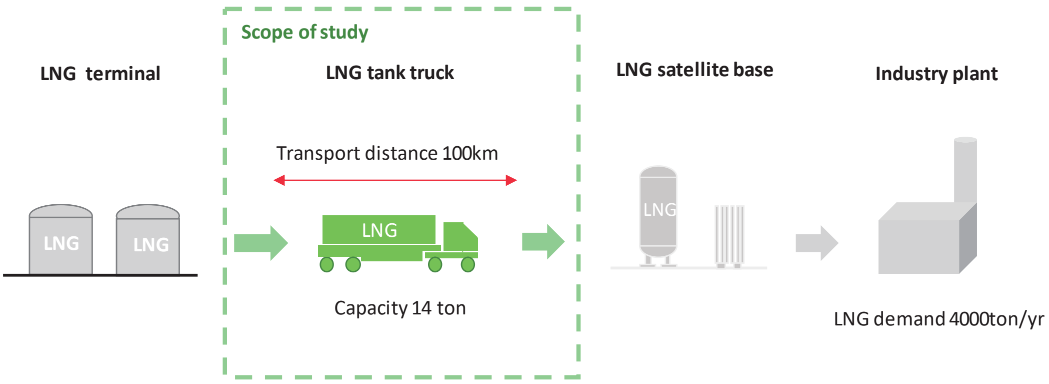


Source: IEEJ, 2018.

3-2-2 Land transportation costs

As for the unit cost of land transportation, we assumed a case where LNG is transported by an LNG tanker truck with a capacity of 14 tonnes to an industrial customer located 100 km away (Figure 3-5). The annual transportation volume was assumed to be 4,000 tonnes.

Figure 3-5 Illustration of model case



Source: IEEJ, 2018.

For the transportation costs in this estimation, we assumed CAPEX (1.5% annual interest rate, five-year repayment period, equal repayment of principal and interest), and OPEX (driver expenses, maintenance costs, etc.) as fixed costs and fuel costs and highway tolls as variable costs. The conditions used for these calculations are shown in Table 3-3.

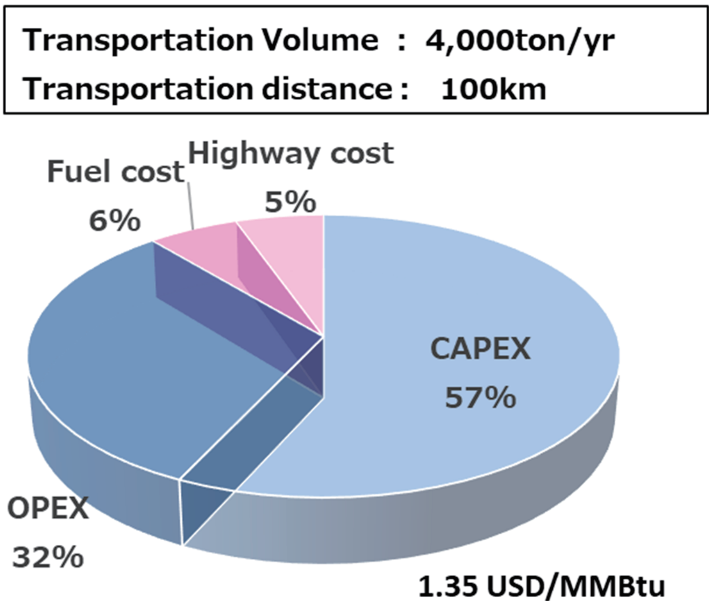
Table 3-3 Land transport estimated conditions

LNG tank truck	Capacity	14 ton
	Speed	70 km/hr
	CAPEX	626,000 USD
	OPEX	89,000 USD/yr
Fuel efficiency		3.0 km/L
Fuel price (Diesel oil)		828 USD/kL
Highway cost		0.27 USD/km

Source: IEEJ, 2018.

The transportation cost of LNG in this model case is estimated to be about USD 280,000 annually, with a transport unit price of 1.35 USD/MMBtu. As a breakdown, fixed costs account for 89% while variable costs account for 11%, in which fixed costs occupy a high percentage compared with transportation by small vessel. This means a high ratio between personnel expenses, depreciation and amortisation of facilities and actual transportation costs. The annual transportation volume when the assumed tanker truck makes one delivery per day is about 4,000 tonnes, which is a relatively high operational availability.

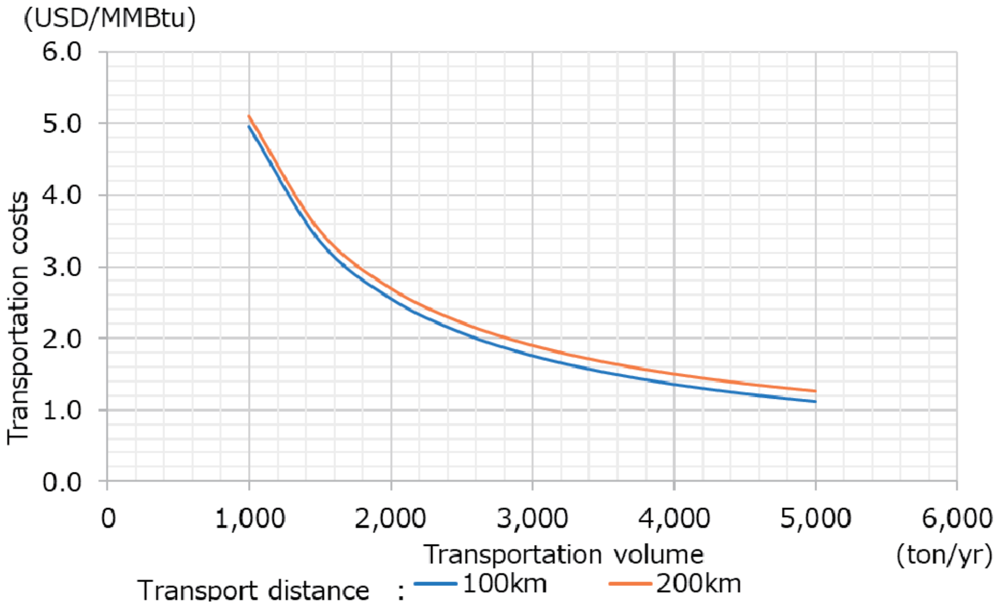
Figure 3-5 Composition of transportation prices in the model case



Source: IEEJ, 2018.

At the same time, it is also possible to make deliveries twice a day to multiple, geographically close destinations, so further reductions in transportation costs should be possible by incorporating such operations. However, since the transport unit price for an annual transportation volume of 1,000 tonnes (delivery cycle of about five days/delivery) is about 4.5 USD/MMBtu, transport unit prices may become too expensive without a relatively concentrated demand for natural gas.

Figure 3-6 Influence of changes in transportation distance and volume in the transport unit price in the model case

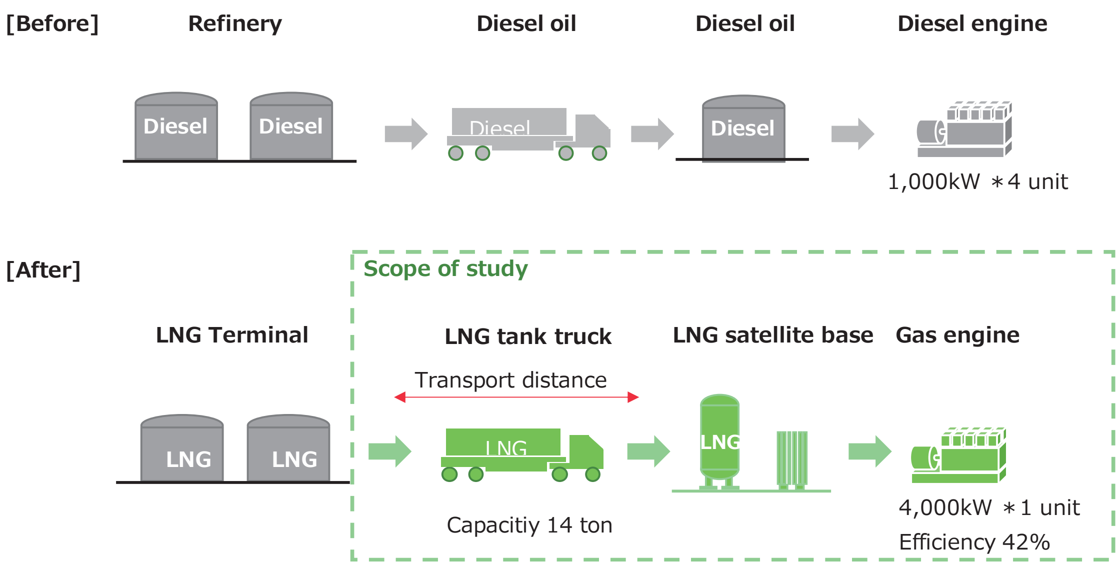


Source: IEEJ, 2018.

3-3 Economic efficiency in the power generation sector

In this case, it is assumed that an aged diesel engine generator (1,000kW × 4 units) located 100 km away from an LNG receiving terminal is replaced with a gas engine generator (4,000kW × 1 unit) (Figure 3-7).

Figure 3-7 Illustration of diesel replacement in power generation



Source: IEEJ, 2018.

The various conditions used for the estimate are shown in Table 3-4. In this scheme, it is assumed that the LNG trucks themselves are owned and used to transport LNG.

Table 3-4 Assumptions for diesel replacement in power generation

Equipment operation	Operating days	300 day/yr
	Operating time	24 hr/day
	Operater	2 person
Diesel engine power generater (Replace target)	Generation capacity	1,000 kW
	Generation efficiency(GHV base)	37.0 %
	Number	4 unit
	Total generation capacity	4,000 kW
	Maintenance cost	0.020 USD/kWh
Gas engine power generater (Planned equipment)	Generation capacity	4,000 kW
	Generation efficiency(GHV base)	42.0 %
	Number	1 unit
	Total generation capacity	4,000 kW
	CAPEX	7,300,000 USD
	Maintenance cost	0.017 USD/kWh
LNG satellite base	LNG strage tank	140 kL
	Vaporization capacity	1,000 kg/hr
	CAPEX	900,000 USD

Source: IEEJ, 2018.

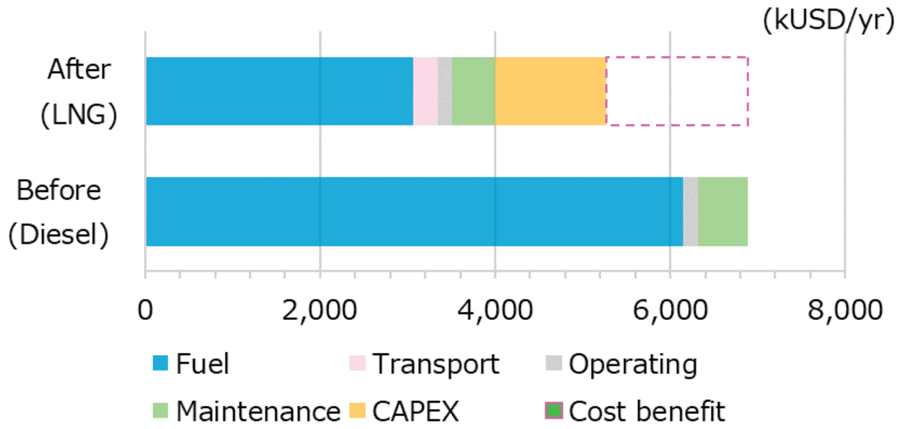
An annual interest rate of 5.5%, a 10-year repayment term, and equal repayment of principal and interest are included in the initial investment of the gas engine power generation facility and the LNG satellite facility for the economic efficiency estimation. The results of the estimation are shown in Table 3-5. How to recover the initial capital outlay is the fundament issue for this replacement case. In this assumption, gas power generation by SSLNG resulted in an estimated cost savings of about USD 1.6 million or more per year versus the case where diesel thermal power generation continues to be used. Lower operational and fuel costs help recover the initial capital investments.

Table 3-5 Results for diesel replacement in power generation

		Before (Diesel oil)	After (Small-Scale LNG)
Generated energy		28,800 MWh/yr	28,800 MWh/yr
Fuel consumption		7,433 kL/yr	4,521 ton/yr
Fuel cost		6,151,917 USD/yr	3,065,240 USD/yr
Transport cost		Included above	283,775 USD/yr
Operation cost		160,887 USD/yr	160,887 USD/yr
Maintenance cost		576,000 USD/yr	489,600 USD/yr
CAPEX	LNG satellite	-	139,500 USD/yr
(Annual repayment)	Power generater	-	1,131,500 USD/yr
Total cost		**6,888,803 USD/yr**	**5,270,502 USD/yr**
Unit price of electricity generation		**0.24 USD/kWh**	**0.18 USD/kWh**
Cost benefit			**1,618,302 USD/yr**

Source: IEEJ, 2018.

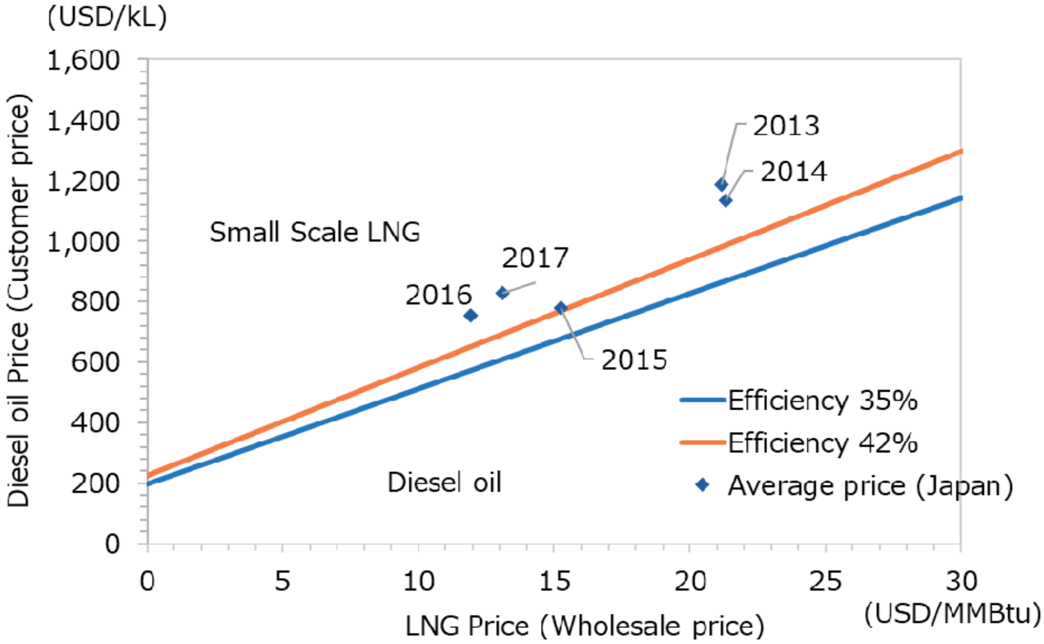
Figure 3-8 Cost reductions in power generation



Source: IEEJ, 2018.

The replacement target in this estimate is an old diesel generator that has a low power generation efficiency. If the replacement target had the same power generation efficiency as the gas engine, the cost advantage drops to USD 885,000 per year. Also, every time the wholesale price of LNG rises by 1 USD/MMBtu, the annual cost advantage is reduced by about USD 230,000. Therefore, it is difficult to quantitatively evaluate the cost competitiveness of the replacement because it is greatly influenced by the efficiency of the target equipment and the correlation of unit fuel prices. Figure 3-9 shows the break-even price of fuel. The area above the break-even point indicates that SSLNG has a cost advantage. The dots of the figure illustrate that recent historical fuel prices support the replacement of a diesel generator, with all years illustrating a cost advantage at both levels of generator efficiency. However, low diesel prices in 2015 almost eliminated that cost advantage.

Figure 3-9 Break-even prices depending on efficiency



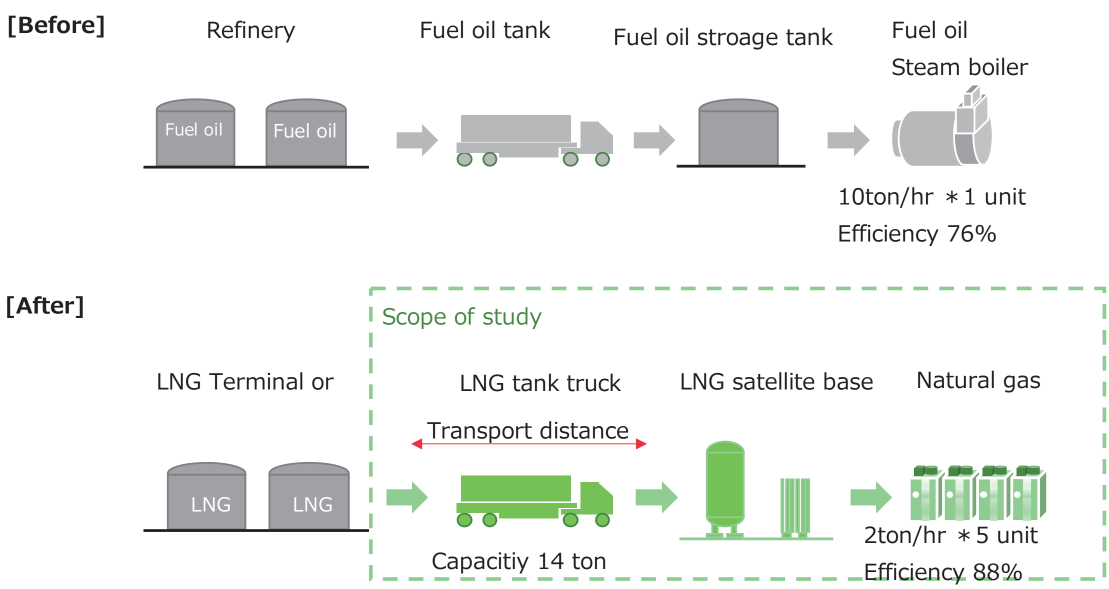
Source: IEEJ, 2018.

In this assumption, the unit price of generated electricity is a relatively high, 0.18 USD/kWh, making it less cost competitive as base load power. In order to be cost competitive for power generation, it would be necessary to make effective use of waste heat (cogeneration), increase the capacity utilisation rate, reduce fuel costs (improve delivery efficiency) and improve operating efficiency (increase the scale). Also, in this case, since it is assumed that the vaporiser of the LNG satellite base uses a warm air type, it is assumed that no fuel is used for regasification. There are cases where hot water vaporisers must be used in gas consumption facilities that use 1 ton/hr or more of LNG or in cold climates. In such cases, note that the cost competitiveness decreases as about 3% of fuel consumption must be used for regasification.

3-4 Economic efficiency in the industrial sector

The next case analyses a replacement of an aging diesel-fired boiler in the industrial sector. In this case, it is assumed that an old fuel oil-fired smoke tube boiler (10 tonnes/hr × 1 unit) located 100 km away from an LNG receiving terminal is replaced with a gas-fired once-through boiler (2 tonnes/hour × 5 units) , as shown in Figure 3-10.

Figure 3-10 Replacement for SSLNG in the industrial sector



Source: IEEJ, 2018.

The conditions used for the estimate are provided in Table 3-6. The basic idea regarding the conditions is similar to the case study in section 3-3. The facility to be replaced is an old oil-fired boiler with relatively lower efficiency and higher maintenance cost than a new natural gas-fired boiler. The replacement requires additional CAPEX, including the LNG satellite base, but its economics on an operational basis are superior to the conventional oil-based boiler.

An annual interest rate of 5.5%, repayment term of 10 years and equal repayment of principal and interest are included in the initial investment of the gas-fired boiler and the LNG satellite facility for the economic efficiency estimation. In addition, the demand for LNG in this case is about 4,018 tonnes per year and the unit price of transportation was calculated as 1.23 USD/MMBtu using the estimate method detailed in section 3-3-2.

Table 3-6 Assumptions for industrial boiler replacement

Steam condition	Type of steam	Saturated steam
	Steam pressure	0.8 MpaG
	Feed water temperature	30 ℃
	Blow rate	5 %
Equipment operation	Operating days	300 day/yr
	Operating time	24 hr/day
	Operater	2 person
Reactor tube smoke tube boiler [Heavy oil] (Replace target)	Steam boiler capacity	10 ton/hr
	Boiler efficiency(GHV base)	76.0 %
	Number	1 unit
	Total generation capacity	10 ton/hr
	Maintenance cost	15,600 USD/kWh
Through-flow boiler [Natural gas] (Planned equipment)	Steam boiler capacity	2 ton/hr
	Boiler efficiency(GHV base)	88.0 %
	Number	5 unit
	Total generation capacity	10 ton/hr
	CAPEX	500,000 USD
	Maintenance cost	13,000 USD/kWh
LNG satellite base	LNG strage tank	140 kL
	Vaporization capacity	1,000 kg/hr
	CAPEX	900,000 USD

Source: IEEJ, 2018.

The table below shows the results of the estimate (Table 3-7). In this assumption, the gas-fired boiler by SSLNG resulted in an estimated cost advantage of about 243,000 USD per year versus the fuel oil-fired boiler. This is because the overall cost advantage is generally small in each cost segment due to its smaller consumption volume than the power generation case.

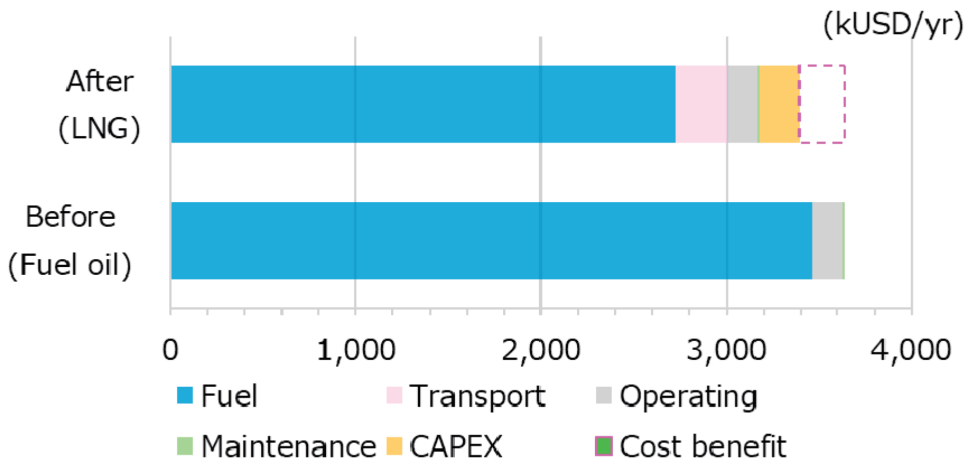
Table 3-7 Results of industrial boiler replacement study

		Before (Heavy oil)	**After (Small-Scale LNG)**
Steam production		72,000 ton/yr	72,000 ton/yr
Fuel consumption		6,494 kL/yr	4,018 ton/yr
Fuel cost		3,461,515 USD/yr	2,723,819 USD/yr
Transport cost		Included above	279,858 USD/yr
Operation cost		160,887 USD/yr	160,887 USD/yr
Maintenance cost		15,600 USD/yr	13,000 USD/yr
CAPEX (Annual repayment)	LNG satellite	-	139,500 USD/yr
	Steam boiler	-	77,500 USD/yr
Total cost		**3,638,002 USD/yr**	**3,394,563 USD/yr**
Unit price of steam		**50.53 USD/ton**	**47.15 USD/ton**
Cost benefit			**243,439 USD/yr**

Source: IEEJ, 2018.

Similar to the replacement target of this calculation is an old, inefficient smoke tube boiler. If the replaced boiler had the same efficiency as the once-through boiler, costs increase by around USD 148,000 per year, and the economic efficiency of the replacement could be secured. For every 1 USD/MMBtu increase in the wholesale price of LNG, the annual cost advantage is reduced by about USD 208,000.

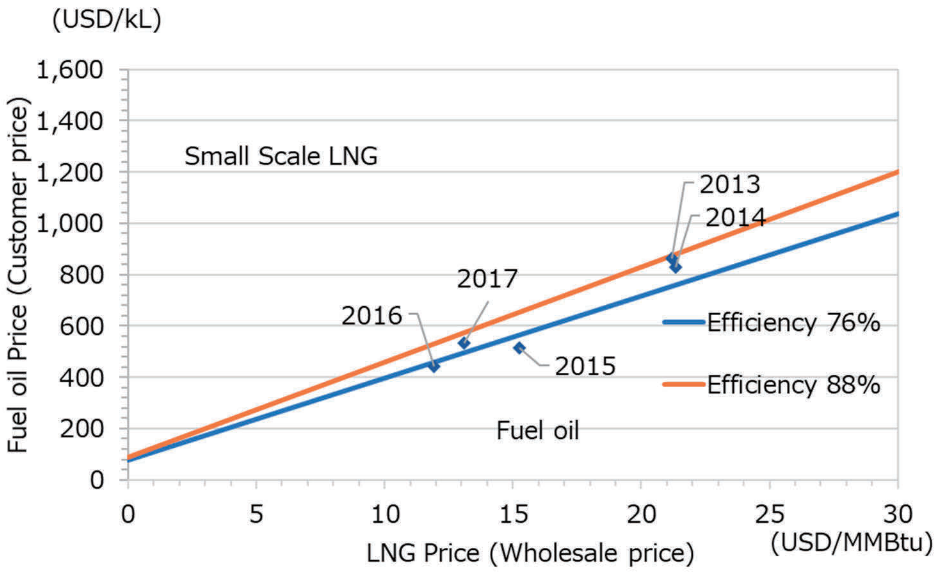
Figure 3-11 Cost reductions in the industrial sector



Source: IEEJ, 2018.

The uncertainties in fuel prices and the efficiency of targeted equipment make it difficult to quantitatively evaluate its replacement. To assist in this analysis, Figure 3-12 charts the break-even price of fuel for 76% and 88% efficient boilers. The area above the break-even lines indicate fuel oil and LNG prices where SSLNG supply has a cost advantage over fuel oil. The historical scatterplot of recent fuel prices illustrates that the competitiveness of SSLNG has not been very responsive to changes in fuel prices or boiler efficiency. In fact, replacing an 88% efficiency boiler yields no immediate cost benefit. For this reason, governments will probably need to provide policy support that focuses on environmental factors.

Figure 3-12 Break-even prices depending on efficiency

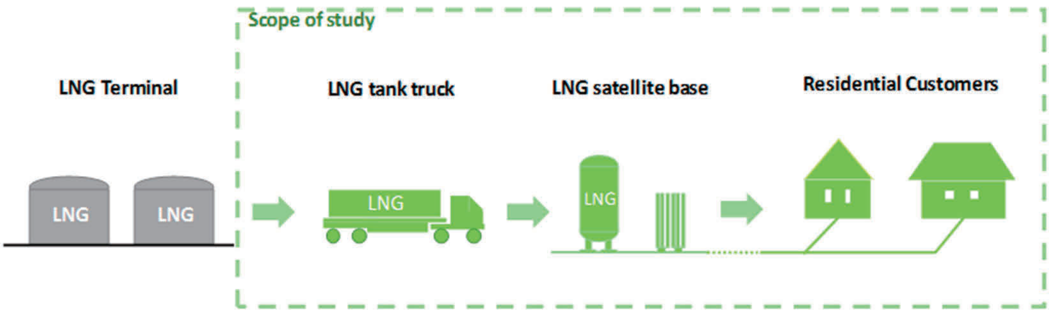


Source: IEEJ, 2018.

3-5 SSLNG in the residential sector

When SSLNG is used to supply natural gas in the residential sector, LNG is transported by trucks to satellite receiving terminals and regasified for the supply to customers by city gas pipeline network.

Figure 3-13 Illustration of SSLNG in the residential sector



Source: IEEJ, 2018.

The cost of SSLNG in the residential sector is estimated using a Japanese case study. Of the 203 gas distribution companies in Japan (as of March 2018), there are 15 relatively small operators who have less than 10 000 residential customers, procure LNG from other operators, and, do not possess facilities such as gas holders and other equipment. The costs of supplying residential natural gas from these 15 small operators were examined and compared with the costs of the top 10 gas distribution companies in Japan.

Most SSLNG operators often receive wholesale supply by LNG trucks from other gas distribution companies. Because of this, the differences in cost between SSLNG operators and major gas distribution companies are driven by: (1) transportation costs by LNG trucks (2) gross profit of major gas distribution operators and (3) the cost of receiving and regasifying LNG at satellites bases. Accounting for these differences, the production cost of SSLNG operators is about 1.8 times the average sales volume of the top ten city gas companies in Japan (Table 3-8). Supply by SSLNG facilities in the residential sector is expensive even in Japanese regions where the SSLNG infrastructure is already developed. Because energy supply to the residential sector is highly cost sensitive, it will be very difficult to economically supply gas with SSLNG for the residential sector in emerging economies that do not have similar infrastructure advantages. However, other factors, such as air quality and public health concerns in some regions may drive policies to substitute natural gas for coal and petroleum fuels, as has been the case in China. Similar policies, could represent an opportunity for SSLNG in the residential sector.

Table 3-8 Average gas distribution costs in Japan, 2016

(1) Top 10 companies in city gas sales volumes*2	USD 9.3/MMBtu
(2) SSLNG operators	USD 16.6/MMBtu
(2)÷(1)	1.8x

Source: *Gasu jigyōnenpō heisei 28-nendo* (Gas Business Report FY2016)
*1 The average exchange rate of USD 1=108.43 Japanese yen is used for FY2016.
*2 Sales volume of the top 10 city gas companies in Japan

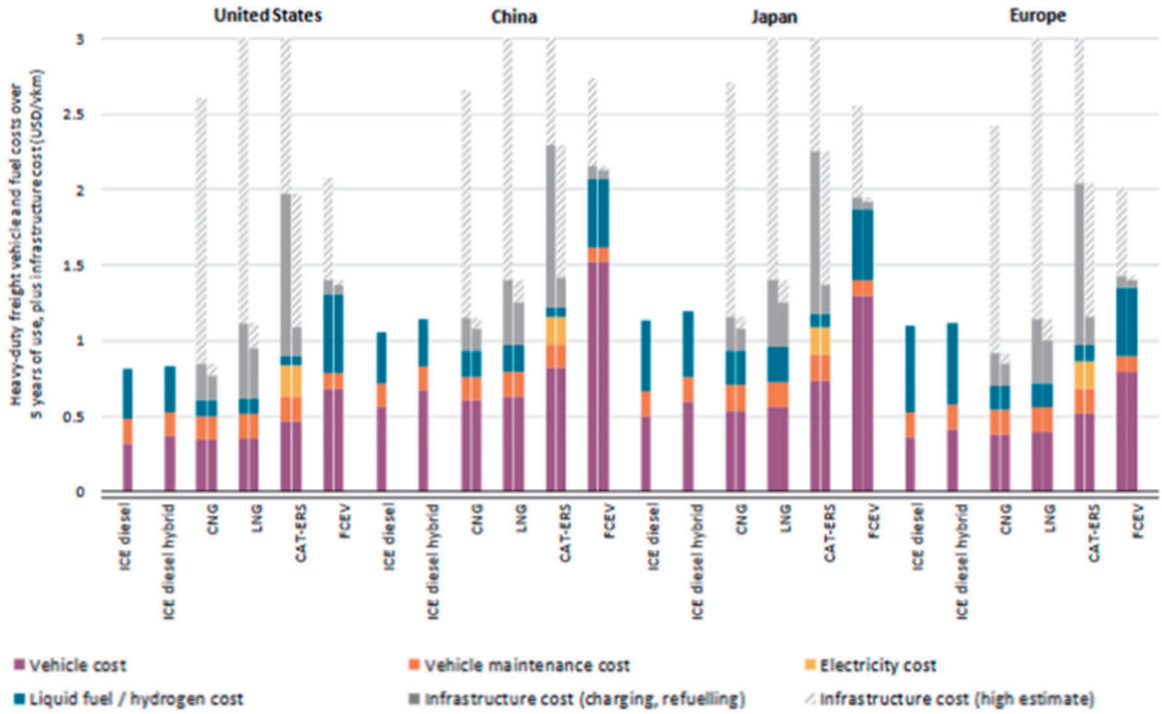
3-6 The economic efficiency of LNG-fuelled vehicles

Since LNG vehicles use a dedicated heat-insulating tank at low temperature, the initial capital outlay is higher than conventional petroleum-fuelled vehicles. As such, LNG-fuelled vehicles are better for long-haul operation in excess of 100,000 km per year. In China and the United States, where LNG vehicles are gaining market share, they are often used as long-haul freight trucks.

The figure below is an IEA compilation of the cost comparison per km of heavy-duty freight vehicles based on various technologies. The calculated costs show the actual cost in 2017 and the estimated cost in 2022. According to the figure, LNG-fuelled vehicles are the alternative fuelled vehicles with the highest economic efficiency. This is especially true in Europe, where high taxes are imposed on petroleum products; even when infrastructure maintenance costs are added, the cost is almost the same as that of diesel-fuelled vehicles.

In regions other than Europe, when the cost of infrastructure maintenance is included, diesel-fuelled vehicles have the lowest cost. However, when infrastructure costs are excluded, LNG vehicles are cheaper in all regions in comparing vehicle price, maintenance costs and fuel prices. Therefore, in these regions, in order to promote the adoption of LNG vehicles, it is necessary to develop further infrastructure or find a scheme in which LNG-fuelled vehicle users jointly bear this infrastructure development cost.

Figure 3-14 Cost of alternative fuelled vehicles in each region



Source: The Future of Trucks 2017, IEA, p. 106-107

Chapter 4 Case Study: China

The following chapters (Chapter 4 to 6) will examine three regional case studies, namely, of Nordic and Northwesternn Europe, China and Southeast Asia, of the use of SSLNG. While there are commonalities across the studies, the case studies highlight the specific will focus on the specific drivers, uses and magnitude that differ across the regions.

4-1 SSLNG in China

The SSLNG supply chain in China encompasses the production, storage and distribution of LNG via varying carriers. Small-scale liquefaction plants are mainly found in the major gas and coal producing areas of the northwestern and central provinces. The number of liquefaction plants exceeds 250.[19] Carriers, such as trucks, trains and tankers, distribute LNG from the inland liquefaction plants and coastal import terminals to rural users outside the reach of pipeline networks. LNG trucking played a crucial role in enabling coal-to-gas switching and meeting regasification constraints during the 2017 winter gas shortage. The expanding market for NGVs and trucks in China is expected to further drive the demand for LNG and SSLNG in the coming decades.

4-1-1 Liquefaction segment

Most small-scale liquefaction plants are concentrated in two regions:

- In proximity to China's major gas and coal production sites in the northern and central provinces of Shaanxi, Shanxi, Inner Mongolia, and Xinjian. Liquefaction plants have also emerged in Sichuan because of the rapid development of shale gas in the province.
- Close to major ports in coastal areas for peak shaving, or backup storage, to meet drastic demand during extreme (cold or hot) weather. Peak shaving facilities can be found in Shandong, Guangdong and Guangxi. While initially popular, the use of SSLNG in these provinces has subsided since 2010 as demand was increasingly met by large-scale tanker imports.

Feedstock

Feedstock gas for small-scale liquefaction is sourced from one or a combination of the following:

- Domestic natural gas and associated gas production (Xinjiang Guanghui LNG, Zhongyuan LNG, Xin'ao Weizhou Island LNG, etc.);[20]
- LNG imports (PetroChina's Fushan LNG, CNOOC's Zhuhai LNG, etc.);
- Imported pipeline gas;

- Coal-bed methane (CBM) and synthetic natural gas (syngas); Shaanxi province holds 90% capacity (PetroChina Yancheng, Shanxi Jincheng Ganghua, etc.).[21]

SSLNG liquefaction plants are also used to liquefy shale gas and CBM and can potentially make unconventional gas projects profitable by offering a low-cost method for accessing demand markets. Unconventional reserves are often found in remote, limited volumes where the construction of pipelines is uneconomical. In contrast to pipelines, small-scale liquefaction plants and LNG trucks offer access at a lower cost with a shorter construction time and thus a faster return on investment. Out of the 23 new SSLNG projects commissioned in China in 2016, 16 used unconventional gas as the feedstock fuel.[22]

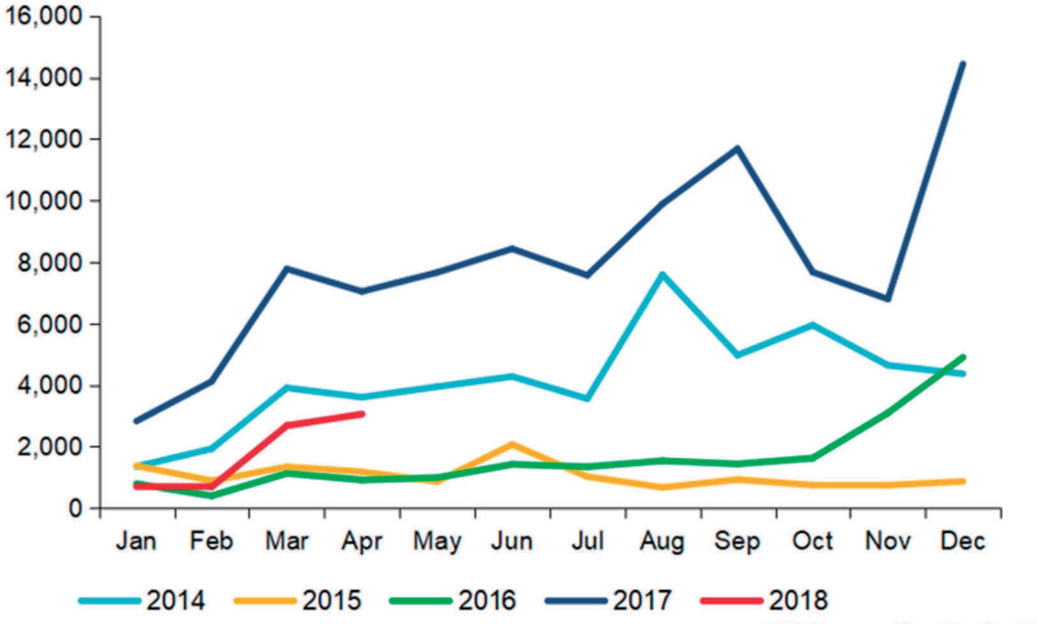
4-1-2 Demand segment

The SSLNG business currently caters to a variety of users in the utility, industrial, transport, commercial and residential sectors without access to pipeline gas. The need for distributed gas became acute when coal-to-gas switching policies were enforced for pollution control in the residential and industrial sectors during the winter of 2017. The eastern and southeastern regions of China have large regasification capacities and can both receive small volumes from inner provinces as well as peak-shaving power stations. LNG also enables flexible supply of gas to power plants during peak times.

In the near future, the transportation sector is expected to become the largest driver of demand for SSLNG. LNG is delivered to gas stations for sale as LNG or as CNG. In China there are approximately 4,700 LNG filling stations and 1,800 CNG stations.23 The sale of LNG as vehicle fuel increased 30% year-on-year in 2017.24 While complex regulations and licensing procedures pose a challenge to the construction and operation of filling stations, their network continues to expand in parallel with the growing market of natural gas-based transport.

With over six million NGVs, China accounts for a fifth of the global market for NGVs.[25] The large fleet of NGV was realised with help from government subsidies and a regulated natural gas price lower than oil products. China also has nearly 200,000 heavy-duty trucks that use LNG as fuel.[26] As seen in the graph below, China has been increasing the production of gas-fuelled trucks in recent years: nearly 96,000 units were produced in 2017, up by 389% from the year earlier. Production peaked in December 2017 at the all-time monthly record of 14,400 trucks (a 195% increase over December 2016).[27] In the first four months of 2018, however, the production of LNG-fuelled trucks was down by two-thirds compared with the previous year, partly due to the uncertainty of demand caused by higher LNG prices.

Figure 4-1 Monthly production of LNG-fuelled trucks, 2014-2018



Source: China's transport industry portal www.cvworld.cn

In 2015, China's first regulations on shipping emissions were imposed in the Shanghai Port area, and the establishment of three ECAs is underway.[28] Marine shippers in China are also gearing up for the IMO's global cap on SO_x emissions that comes into effect in 2020. There are orders for 19 LNG bunkering ships and plans to build another 23.[29]

LNG transportation and bunkering in rivers are still in its early phases in China and is partially constrained by the lack of clear regulations. In April 2018, Hubei Energy Group signed a letter of intent with the city of Zhijiang in the western Hubei province to build one of the first LNG storage and distribution projects on the Yangtze River. The first phase of the RMB 2.5 billion project will consist of two LNG docks, two 40,000 m3 storage tanks and a bunkering station.[30]

4-1-3 Distribution

Trucks play a dominant role in the off-grid distribution of LNG within China. Small marine tankers are also being introduced along the coast and in some rivers.

LNG trucks

The advantage of trucking lies in the high flexibility of distribution and the scalability of new capacity. On the other hand, the lack of clear regulation poses a challenge as many roads and highways simply prohibit their movement because of safety concerns. Nevertheless, by the end of 2016, there were more than 1,300 such LNG delivery trucks,[31] most of which belong to private companies like Xinjiang Guanghui or ENN Xinao Gas. Guanghui retains a fleet for the delivery of LNG from distant Northwestern regions to Fujian and other southern provinces during peak season.[32]

The average wholesale price of LNG in liquefaction plants and import terminals was up by 43% in the winter peaking months of 2018, reducing LNG's discount to diesel to 30% compared with nearly 50% in the same period in 2017.[33] As of September 2018, the transport and environment ministries are reportedly drafting a plan to replace a million heavy duty diesel trucks, almost 20% of the national trucking fleet, with trucks that run on higher-grade diesel, called National Five, electricity, or LNG.[34]

LNG tankers (river and sea)

Small LNG tankers in China deliver LNG from large terminals to nearby, smaller terminals on the coast and along rivers. With a transportation radius of more than 1,000 km, tankers are better suited for long-haul deliveries. Small carriers have the general carrying capacity less than 30,000 m3. Their advantages include a low operating cost and the ability to access offshore basins. On the flip side, much like other carriers, the absence of rules governing river transport of LNG hamper the development of river-going LNG tankers and inland LNG bunkering. As of September 2018, only two SSLNG carriers were operational in China; they are operated by CNOOC and Huaxiang Shipping. The authorities are reluctant to release regulations after a number of high-profile industrial accidents in recent years, and are focusing first on the tightening and better enforcement of the existing rules.[35]

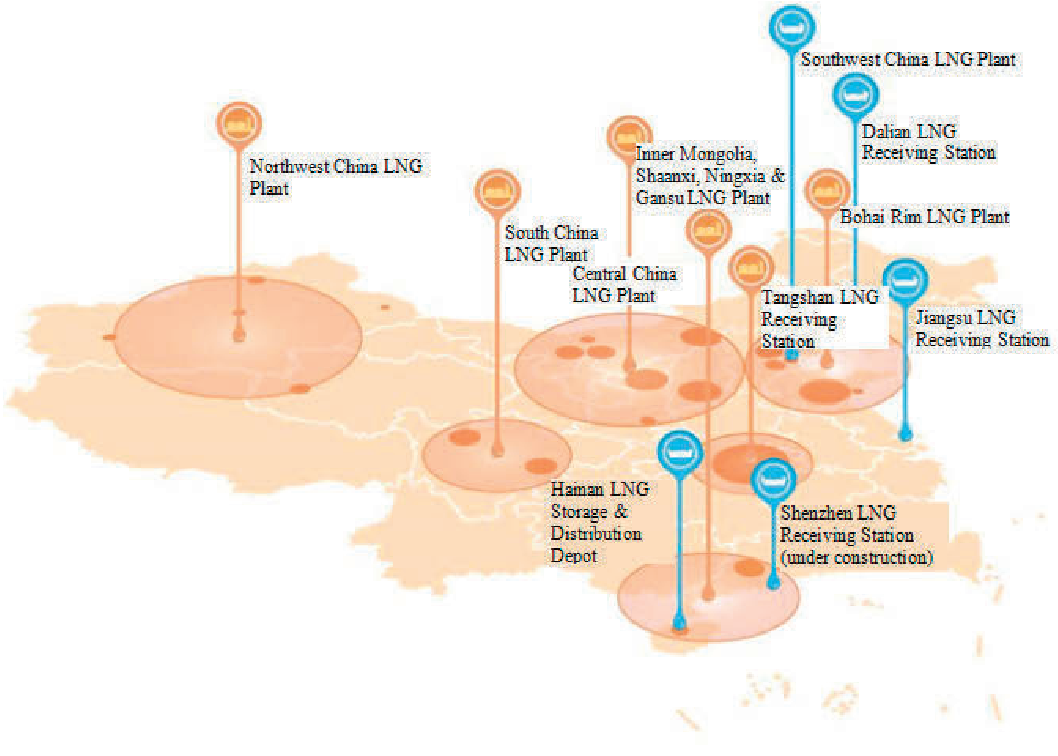
However, more import terminals with specific infrastructure such as LNG storage and wharves enabled to receive small carriers need to be further developed around the coasts and especially along inland rivers. One such terminal is the Shangai Wuhaogou LNG peak-shaving station with 320,000 m3 capacity. It receives LNG via small carriers from the Shanghai LNG terminal or other large terminals.[36] Because such infrastructure has to be jointly developed with demand development, close alliance between gas suppliers and users have to be made. As in China, where publicly-owned entities have a large economic presence, government policy initiatives or coordination plays a significant role.

4-1-4 Market Players

China's first SSLNG liquefaction plant, the Puyang Zhongyuan, was constructed in 2001 in the Henan province by Sinopec. Throughout the early 2000s, the SSLNG market consisted of three large state-owned companies, but today the landscape is more diverse. The majority market share is held by Kunlun Energy, Xinjiang Guanghui and local distributors.[37] In addition, vertically unintegrated midstream companies operate by negotiating purchasing contracts with gas suppliers and sell LNG to distributors at prices regulated by local governments.

The largest SSLNG player is Kunlun Energy, a subsidiary of PetroChina. As of September 2018, Kunlun Energy has 24 LNG plants (both operating and under development) with a combined production capacity of 5.9 mtpa, giving the company a 28% share of China's SSLNG production capacity.[38] The company owns liquefaction capacities in major gas producing regions in the northwestern (Xinjiang), northern (Inner Mongolia, Shaanxi), and central regions (Sichuan, Hubei), as well as in coastal areas close to international LNG import terminals. Kunlun operates three LNG receiving terminals in Hebei, Liaoning, and Jiangsu and has plans to build two more facilities.

Figure 4-2 Kunlun Energy Company's LNG Plants and Terminals



Notes: The covering area is in direct proportion to the production capacity of plants and receiving and unloading capacity of receiving stations.

Source: Kunlun Energy Company

In terms of technology and equipment, facilities with the processing capacity of up to 80 thousand tonnes per annum (ktpa) almost exclusively use domestic technology. Domestic equipment providers are state-owned enterprises, like China Huanqiu Contracting & Engineering Corporation, as well as private companies like CPE-Southwest, HQCEC, Chengdu Cryogenic, Sichuan Air Separation, Lvneng and Harbin Cryogenic.[39] While facilities with a capacity exceeding 80 ktpa were dominantly sourced from international companies, like Black&Veatech, Linde, and Air Products, earlier this decade, today over half of these projects are awarded to local companies.

Foreign companies are also showing signs of interest in the export of SSLNG to China. The first SSLNG shipment from abroad (17 tonnes) was received from Canada's True North Energy in November 2017. Earlier in 2016, Russia's Gazprom announced intentions of constructing a small-scale liquefaction terminal in the Far East for closer access to the Chinese market.

4-2 Market size and potential demand

At the beginning of 2017 China had nearly 250 small-scale liquefaction plants.[40] The current combined capacity of small-scale liquefaction plants is well over 15 mtpa and nearly 21 mtpa capacity is planned for commissioning by 2021.[41] The total installed capacity grew at an average rate of 57% per year between 2000 and 2015. The most intense growth period was between 2010 and 2013, when the total annual capacity grew more than threefold from 2.5 million tonnes to 8.9 million tonnes.[42]

In 2017, 19 mtpa of LNG were transported by trucks, the equivalent of 12% of total gas consumption in China.[43] Inland liquefaction accounts for 60% of LNG transported via trucks, while the remaining 40% are used between coastal import terminals.[44] The economically justifiable transportation radius of trucks is 500 km,[45] but cases where trucks covered over 2,000 km were reported during the gas shortage in winter of 2017/2018.

The demand for SSLNG services in China has high potential. The market potential of the transportation sector is assumed to be the conversion of 10% of the existing diesel demand for road and water transportation (including both passenger and freight vehicles) to LNG engines, which yields a market of 8.6 mtpa. Furthermore, this potential has high prospects for growth given that transportation energy demand is expected to grow by 44% by 2030.[46] While the demand for natural gas in power generation is expected to grow rapidly in China, the application of SSLNG in the power sector will be fairly limited compared with traditional large-scale LNG fired power generation. The market potential in the power sector for SSLNG is assumed to be the replacement of 50% of smaller-sized oil-fired power generation with LNG-fuelled and it is estimated at 0.2 mtpa. Demand for similar replacements in industrial sector is also estimated to be relatively small at 1.5 mtpa.

Figure 4-4 Market potential of SSLNG

Power generation

(Unit: tonnes oil equivalent)

Total	408,010 ktoe
Diesel	298 ktoe
Fuel oil	311 ktoe
Switch %	50%
	0.3 mtoe
	0.3 Bcm
	0.2 million LNG tons

Industry

(Unit: tonnes oil equivalent)

Total	993,954 ktoe
Diesel	16,398
Fuel oil	3,439 ktoe
Switch %	10%
	2.0 mtoe
	2.1 Bcm
	1.5 million LNG tons

Road Transportation

(Unit: tonnes oil equivalent)

Total	243,173 ktoe
Diesel	98,973 ktoe
Fuel oil	0 ktoe
Switch %	10%
	10 mtoe
	10 Bcm
	7 million LNG tons

Domestic Water Transportation

(Unit: tonnes oil equivalent)

Total	21,669 ktoe
Diesel	16,656 ktoe
Fuel oil	5,013 ktoe
Switch %	10%
	2.2 mtoe
	2.3 Bcm
	1.6 million LNG tons

Source: IEEJ analysis, 2019.

The outlook of SSLNG demand trucking and inland liquefaction faces uncertainty and lack of clarity in both the supply availability and price level of the future natural gas market. Users of LNG-fuelled trucks and industry appear cautious following the supply shortage and high price volatility of natural gas last winter. If natural gas demand remains seasonal while regulated retail prices suppress the SSLNG distributors' profit margins, investment in liquefaction and trucking capacity will be limited. The risk of seasonal supply constraints and price increases will erode the operational cost benefits of investing in LNG engines. For example, PetroChina aims to curb winter demand by raising gas supply prices from November to March. Residential prices are benchmarked against the city-gas price of the region.[47] Non-residential users will be divided into two categories: the direct users and city-gas users. Direct users are power plants and industrial companies. Their tariffs will be raised by a flat 22.7% on top of the local city-gate benchmark. Such an increase could price prospective freight haulers out of the LNG freight market.

4-3 Economics of SSLNG for small liquefiers

4-3-1 Domestic price and international price

Natural gas prices were traditionally kept low because they were formulated based on the costs of domestic extraction and transmission and therefore disconnected from higher prices on the international markets. This became problematic when domestic production failed to keep up with surging demand and China grew reliant on foreign gas supply. State-owned importers found themselves subsidising imports that were sold at a loss on the domestic market. PetroChina, for instance, suffered losses of about RMB 41.9 billion in the sale of imported gas in 2012, equal to a third of the company's net profit that year.[48] In response to the looming supply shortage, the National Development and Reform Commission (NDRC) undertook a pricing reform to incentivise the domestic production and import of natural gas.

Prior to the reform, inland LNG plants negotiated their feedstock procurement contracts directly with the gas producers and transmission operators (who were both controlled by the China National Petroleum Corporation [CNPC]). LNG plants were assembled close to the production sites to minimise transmission fees, which were based on the distance from the gas producer. Moreover, since domestic gas was subsidised, SSLNG plants enjoyed low procurement costs and high profit margins of around 150-200 dollars per tonne.[49]

A 2013 reform required any natural gas, whether produced domestically or imported onshore (import LNG was exempt), to enter the transmission grid and to be priced at the city-gate price with predetermined transmission fees. Regulations were lifted on the ex-plant price but not on the retail price. For the LNG producers, this translated to a 33-66% hike in the cost of feedstock gas which could not be passed on to downstream consumers.[50]

Seeing their profit margins squeezed, two months after the reform was enacted, nine LNG plants in Shaanxi formed an opposition group against the higher transmission tariffs and threatened to stop liquefaction if their demands for price revision were unmet by the provincial price bureau. Later in 2014, Xinjiang Guanghui, the second largest LNG producer in the economy, announced that many plants throughout China had been forced into periodic shut down because of the severe constraints that the price changes placed on operations.[51] In 2015, for instance, SSLNG plants operated at an average of 30-40%.[52] The new city-gate price was intended as a ceiling on the price to be negotiated by gas producers and midstream buyers (e.g.: the SSLNG plant operators), as long as it fell within the determined price range. However, the SSLNG producers claimed that CNPC abused its position as the owner of transmission pipelines and supplier to 70% of LNG plants in China to set "the highest city-gate price".[53] This was a transitory period before domestic natural gas prices decreased in 2015, mainly because of lower international crude oil prices. Since then, 23 new liquefaction plants were commissioned in 2016.[54]

While the SSLNG market is growing, there are a number of uncertainties facing SSLNG prices. SSLNG producers are sensitive to international crude oil prices. Profitability dropped when crude prices were low and fuel customers began to switch from LNG to oil. SSLNG producers also compete with imported LNG. Although end-user prices are still largely regulated by the government, LNG sellers can seek profits in the transport sector and in competition with other gas sellers introducing market-based pricing.

4-3-2 City gas pricing mechanism

The city gas category in China includes SSLNG producers. According to the renewed contracts between CNPC, the largest natural gas producer and importer in China, and domestic gas retailers in July 2018, natural gas costs for the distributors will be determined by three conditions – purchased volume, the source of gas (regulated or deregulated), and region.[55]

Purchase volume is priced in three tiers. The first tier, also called base volume, is the equivalent to the same amount of gas as in the winter 2017 plus 8%. The price depends on whether the source of gas is regulated or deregulated. Regulated tariffs include domestic conventional gas production and piped imports, which rose by 20% above the local city-gate price in 2018.[56] Deregulated sources, such as imported LNG, shale gas, CBM and others will cost 27-40% more, depending on the region.[57] The second tier is the peak shaving volume, or the increment from the base volume to 2017 winter's peak volume. Regardless of the source, peak prices are pegged to the Shanghai Petroleum and Gas Exchange rates or raised by 37-40% above the local city-gate price, depending on the region. The third tier encompasses volumes that exceed the winter peak of the second tier; its prices will be entirely market-linked and thus vary by the source of gas and region of purchase.[58]

As of October 2018, it is unclear whether the distributors will be able to pass on the higher prices to end-use consumers, echoing their struggle during the 2013-2015 pricing reform. The regulation of -user prices is a sensitive issue for the government, especially those in the residential and industrial sectors. Since 2017 Beijing has been pushing to cut business expenses, including energy costs, for commercial and industrial firms. Higher costs for natural gas make it harder for end users to comply with the coal-to-gas switching policies and opt for gas over diesel in transport. Nevertheless, a mechanism to safeguard the profit margins of independent liquefaction seems to be necessary to maintain market liquidity and flexibility of distribution.

4-4 Policy incentives

China has been introducing a host of policies to promote gas usage in the industrial and residential areas. More than 10 policies have been issued since 2017 to promote natural gas use and to highlight the government's vision for gas as the major source of energy in China. One notable example is the Clean Heating Plan 2017-2021 released in December 2017 by 10 agencies, including the NDRC and the National Energy Administration (NEA). According to the Plan, half of Northern China is to convert to "clean heating" by 2019; however this concept even includes "highly efficient" coal combustion, leaving the rest to gas and renewables. In this context, the residential gas heating market will be a key target for SSLNG producers.

Pollution reduction is further supported by the Blue Sky policy introduced by the State Council on June 2018. It is a three-year action plan that aims to reduce PM 2.5 by 18% relative to 2015 levels in certain cities and prefectural governments by 2020. Under this policy, each province is required to meet a particular PM 2.5 level target and thus will need to replace coal consumption in various sectors. Industrial coal users or relatively small coal-based power generators also have potential for broader use of SSLNG development.

Policy support is also seen in the transport sector. The 13th Five Year Plan (2016-2020) set out plans to increase the fleet of NGVs to 10.5 million by 2020, with vehicle production expected to increase at roughly 12% per year. Rapid uptake of natural gas in the transport sector is helped by the government's gas-use policy (especially its subsidy for LNG-fuelled trucks), which includes: zero value-added tax (VAT) on transport gas, favourable diesel and gas price differentials, and the expansion of natural gas refuelling stations.[59] A number of provinces have penetration targets for vehicles powered by CNG or LNG and have introduced subsidies for their purchase and retrofitting, sometimes offering up to a third of the vehicle cost.[60]

Policies supporting LNG bunkering have also been introduced. In August 2018, the Ministry of Transport released a draft timetable for developing an LNG bunkering network in China by 2025 and invited feedback from the shipping industry, authorities and national oil companies.[61] According to the draft, operational standards for LNG bunkering and its initial infrastructure are to be developed by 2020. By 2025, at least 15% of new state-owned vessels and 10% of new vessels in the major inland waterways are expected to be powered by LNG. Certain areas, such as Beijing-Tianjin-Hebei (Bohai waters) and the Yangtse River Delta, are encouraged to raise the share of LNG vessels above 50% for new-builds. The plan also mentions the establishment of up to two internationally competitive LNG fuelling hubs. The Ministry of Finance announced tax exemptions for gas powered ships and directed local authorities to reduce transit fees for LNG vessels while granting them priority port access. Lastly, the fourth phase of domestic sulphur restrictions (up to 0.5% of total content) came into effect in three ECAs – the Bohai waters, Yangtse River Delta, and Pearl River Delta – on January 2019.[62]

4-5 Summary findings

China has some uniquely favourable conditions for the market development of SSLNG. First, domestic natural gas reserves in remote and inner parts of its territory without connection to the pipeline grid favoured the development of SSLNG supply chains as a way to commercialise those stranded gas volumes. Its rapidly growing economy also provided a favourable market environment for SSLNG developers. The existence of engineering companies that can construct SSLNG infrastructure at relatively low cost was also helpful as the initial capital outlay is one of the biggest hurdles to SSLNG adoption.

There are two main findings that a prospective SSLNG market can learn from China's experience and both pertain the role of the government. First, government mandated targets can drive fuel switching in the end-use sector. The Chinese government has strongly pursued the adoption of natural gas at the expense of coal, particularly through its targets set out in its 13th Five Year Plan. While this policy does not necessarily advocate or favour SSLNG exclusively, it certainly helped incentivise coal users to examine SSLNG supply as a potential means of increasing natural gas in their end-use demand. The government's policy to reduce oil consumption in the transportation sector has also assisted the demand for SSLNG services.

Second, pricing policy matters. As mentioned above, the pricing system reform in 2013 suppressed the operational margins of SSLNG operators and reduced LNG demand growth in China. Although providing subsidies to a specific energy source is not a sustainable policy option, a certain level of preferable pricing environment may be needed to promote SSLNG in its initial stages.

Chapter 5 Case Study: Southeast Asia

Southeast Asia is a region where significant growth in natural gas demand is expected in the future. According to APEC's 7th edition Demand and Supply Outlook, natural gas supply needs in the south-east Asia region are forecasted to grow by 53% from 2016 to 2050. Due to its unique geographical conditions, SSLNG has an important potential together with conventional LNG uses (mostly power generation and industry). As an example, bunkering in Singapore and the possibility of gas-fired power generation in a remote area in Indonesia are discussed.

5-1 Singapore

5-1-1 SSLNG in Singapore

A promising option for further SSLNG development in Singapore is its use as bunkering fuel. Singapore is one of the world's leading trade ports to which many foreign vessels call and is one of the global leaders in international marine shipping. In addition, the Straits of Malacca and the Singapore Strait, adjacent to Singapore, have become an integral passage for international marine shipments, with many ocean-going ships, which may not directly call at Singapore, still relying on it for resupplies of water and food and crew changes. Because of its strategic location, Singapore is suitably equipped to foster the development of LNG demand as a bunkering fuel.

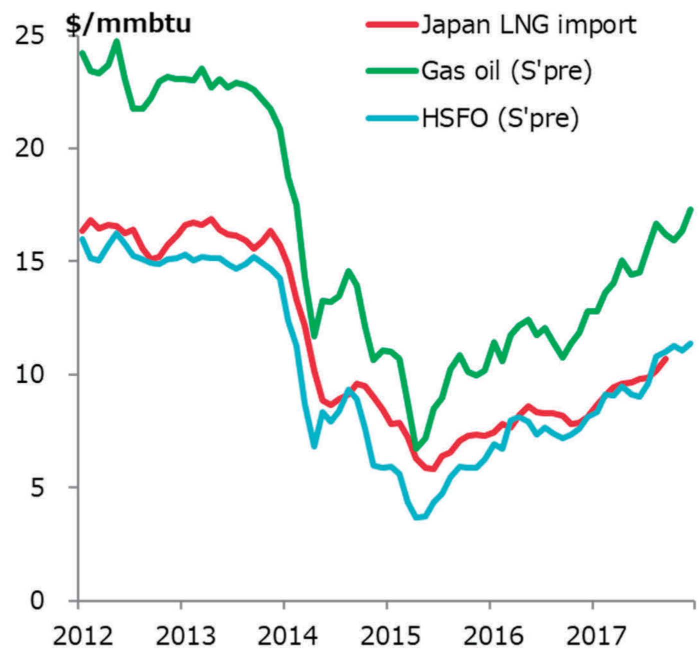
5-1-2 Potential demand size and market environment for LNG as a bunker fuel

According to IEA statistics, Singapore supplied 46.8 million tonnes of oil equivalent (mtoe) in diesel and fuel oil as fuel for maritime transportation in 2016, making it one of the largest bunkering bases east of the Suez Canal. The stricter regulation of sulphur content for marine fuel to less than 0.5% from 2020 by the IMO may boost the long-term demand for LNG as a marine fuel. Shipping companies seem to have three major options in response to the 2020 IMO regulation: switch to low-sulphur petroleum fuels, install flue-gas desulphurisation equipment on ships or switch to LNG.

However, in response to the sulphur regulation, the shipping industry is expected to mainly switch to low-sulphur petroleum fuels and install flue-gas desulphurisation equipment on ships, with few companies considering an immediate conversion to LNG-fuelled ships. Although it is technically possible to convert vessels that currently use heavy fuel oil to run on LNG, such conversions are costly, nearly double that for new builds.[63] Given the uncertainty as to whether such an additional investment can be recovered during its operational life, few shipping operators are expected to use LNG conversions to comply with the fuel regulation. Instead, the conversion to LNG-powered ships is likely to happen with new shipbuilding.

Furthermore, the relative price level of LNG and petroleum products may lead to a shift in the bunkering fuel mix. Figure 5-1 shows Asian LNG prices, fuel oil prices and diesel oil prices. Many ships currently run on heavy fuel oil, but once the IMO regulations are implemented in 2020, it is expected that more shipping companies will switch to diesel (gas oil), putting upward pressure on diesel prices. Under these circumstances, as the relative competitiveness of LNG increases, there is a greater possibility that shippers will consider switching away from petroleum fuels and towards LNG.

Figure 5-1 LNG prices and petroleum products prices in Asia



Source: International Energy Agency, Monthly Oil Market Report, Ministry of Finance of Japan, Trade Statistics

As described above, the market size in the future depends on how many existing ships using fuel oil are converted and how many new LNG-fuelled ships are built. Assuming one quarter of the current international shipping oil demand being supplied in Singapore is converted to LNG it would yield a market size of 8.8 mtpa, an amount that would make Singapore a relevant LNG-bunkering hub. Additionally, as GDP and trade are projected to continue growing in the Asia-Pacific region in the next several years, demand for maritime freight transportation, and thus the market potential of LNG bunkering in the region, will increase accordingly.

Table 5-1 Potential marine LNG demand in Singapore

International Marine Bunker

(Unit: tonnes oil equivalent)

Total	46.8 thousand toe (2016 actual)
Diesel	2.1 thousand toe (2016 actual)
Fuel oil	44.8 thousand toe (2016 actual)
Switch %	25%
	11.7 million toe
	12.3 Bcm
	8.8 million LNG tons

Source: IEEJ estimate based on International Energy Agency, Energy Balances of the World 2018 edition

5-1-3 Economics of LNG bunkering

The relative relationship between the price of petroleum products and LNG is a key determinant to the attractiveness of LNG as a bunkering fuel. The spot price in Northeast Asia in September 2018 for LNG varied between USD 9 per MMBtu and USD 10 per MMBtu, whereas the price of high sulphur fuel oil for ships averaged USD 11 per MMBtu. Whether this price advantage can be secured over the long term depends on the direction of the fundamentals driving the prices of international crude oil and LNG in Asia.

Recently, new liquefaction terminals in the United States have become operational and there are plans in LNG exporters like Qatar to increase large-scale liquefaction capacity. On the supply side, 140 billion cubic meters of liquefaction capacity is expected to be added between 2018 and 2023.[64] However, the supply and demand balance may become tighter by then because of several factors such as demand trends in emerging economies such as China and India, as well as rising LNG demand in Korea and Chinese Taipei due to nuclear power phase-out policies. Therefore, in order to develop a stable demand for LNG bunkering, it may be helpful to have a pricing arrangement such as linking the price of LNG as a bunker fuel to the price of petroleum products. Such a price mechanism could be a short- to medium-term solution to mitigating the impact of LNG and crude oil price volatility on the relative price difference between LNG- and oil-based fuels.

5-1-4 Policy support

Singapore has been exploring the potential of LNG as a fuel for maritime transportation for several years. Since 2015, Singapore's Maritime and Port Authority (MPA) has developed the following policy arrangement to develop Singapore's port as an LNG bunkering hub:[65]

- The MPA is implementing the LNG Bunkering Pilot Supply Program from 2017 to 2020. The purpose of this program is to accumulate knowledge about operational procedures by conducting experimental LNG bunkering to provide a safer and more efficient supply of fuel. In 2016, the MPA licensed Pavilion Gas and FueLNG (a joint venture between Shell and Keppel) as the operators to conduct the LNG Bunkering pilot.
- In September 2015, the MPA announced a program to provide a total of USD 9 million in joint financing, with a subsidy of USD 1.5 million per ship for the construction of ships running on LNG. All of the funding in the program was used by five operators,[66] and in December 2017 the MPA announced it would contribute an additional USD 9 million in financing to promote shipbuilding.[67]
- In addition, the MPA also revealed a five-year exemption in port fees for MPA-registered ships calling to Singapore as LNG-powered ships from 1 October 2017 to 31 December 2019. Finally, in May 2017, Pavilion Energy carried out the first demonstration of this project.[68]

In addition to these domestic measures, the Singapore MPA is cooperating with overseas government agencies in order to promote a broader, global dissemination of LNG bunkering. In June 2010, Japan's Ministry of Land, Infrastructure, Transport and Tourism, the Antwerp Port Authority in Belgium, the Port of Zeebrugge, the Norway Maritime Authority, the Port of Jacksonville in the United States, the Port of Rotterdam Authority in the Netherlands and the Ulsan Port Authority in Korea signed a memorandum of understanding. This was followed by the Port of Ningbo-Zhoushan in China, the Port of Vancouver in Canada and the Port of Marseille in France also signing the memorandum in July 2017. The details of the memorandum are as follows:

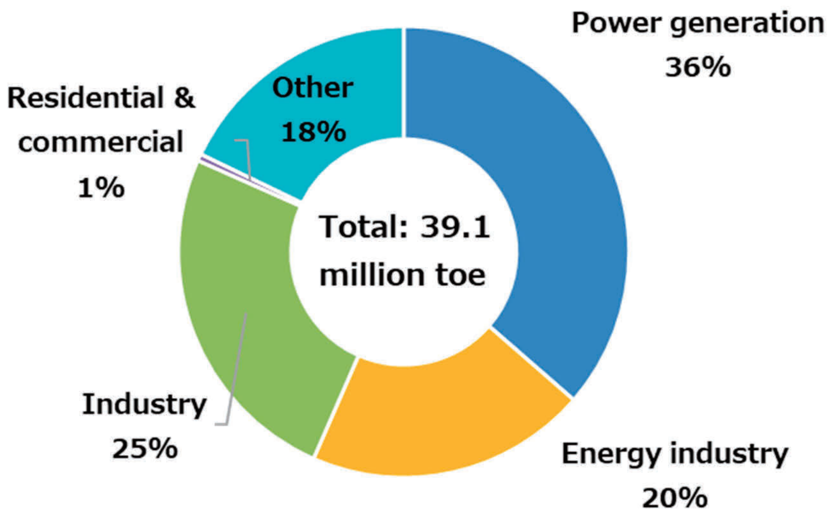
- To encourage shipowners to use of LNG fuel by expanding a global network of LNG bunker-ready ports;
- To deepen the exchange of information relating to LNG bunkering; and,
- To promote the use of LNG as fuel through collaboration with international organisations and private companies.

5-2 Indonesia

5-2-1 SSLNG in Indonesia

Most of the natural gas in Indonesia is used for power generation. Natural gas demand in Indonesia is projected to increase 154% from 2016 to 2050, mainly driven by power generation growth.[69] On islands like Java and Sumatra, where natural gas pipeline networks are already in place, natural gas supply via pipelines is expected to become more widespread. SSLNG could play a relevant role on supplying natural gas to outlying islands, where demand is geographically dispersed and laying pipelines may not be economically feasible. Because demand on outlying islands is rarely high enough to justify the construction of a gas distribution network, SSLNG can be an alternative to supply gas for power generation, especially as an alternative power source for oil-fired generators. The bulk of gas demand, however will likely be limited to power generation and industrial applications, such as for heating.

Figure 5-2 Structure of natural gas demand in Indonesia



Source: International Energy Agency, Energy Balance of the World 2018 edition

5-2-2 Demand size

There are about 4.5 million tonnes of petroleum products (fuel oil and diesel, equivalent to about 3.8 mtpa of LNG) currently used as fuel for power generation in Indonesia domestically and there is latent market for SSLNG within this demand base. In the eastern part of Indonesia, since the demand for energy and electricity is not very large, many islands use small oil-fired power generation. Assuming LNG substitutes for half of the oil products currently in use for power generation and industry, it yields market sizes of 1.4 mtpa and 1.8 mtpa, respectively. Because Indonesia's natural gas demand for power generation and industry will continue to increase by 34% and 61% by 2030, respectively, there is room for SSLNG development.

Table 5-2 SSLNG market potential in Indonesia

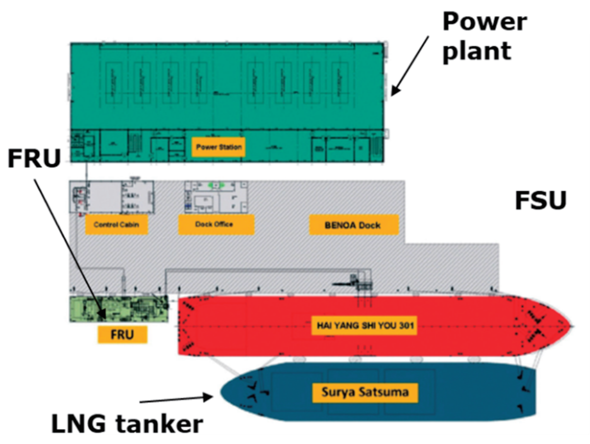
Power generation		Industry	
(Unit: tonnes oil equivalent)		(Unit: tonnes oil equivalent)	
Total	50,919 ktoe	Total	38,830 ktoe
Diesel	2,896 ktoe	Diesel	3,824
Fuel oil	858 ktoe	Fuel oil	945 ktoe
Switch %	50%	Switch %	50%
	1.9 mtoe		2.4 mtoe
	2.0 Bcm		2.5 Bcm
	1.4 million LNG tons		1.8 million LNG tons

Source: IEEJ estimate based on IEA's Energy Balance of the World 2018 edition.

5-2-3 Areas of use

In Indonesia, a SSLNG project already exist in the port of Benoa on the island of Bali. It is comprised of a small floating storage unit (FSU) and a floating regasification unit (FRU), which are used at a gas-fired power plant that receives LNG from a liquefaction facility in Bontang. Although it has a capacity to receive 0.5 mtpa, it normally receives 0.3 mpta to fuel a 200 MW gas plant located 3.7 km from the receiving facility. The FSU and FRU assets have been in operation since 2016. Before this, the power plant generated electricity with fuel-oil and diesel. As such, SSLNG on Bali may be regarded as a model for introducing SSLNG to other outlying islands of Indonesia.

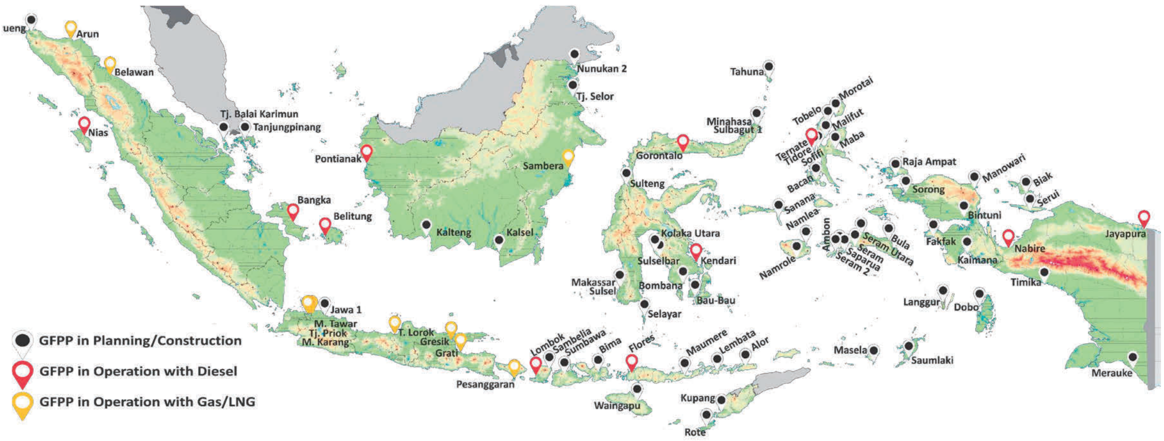
Figure 5-3 Layout of SSLNG assets in Benoa



Source: IEEJ based on China Classification Society

SSLNG has potential to expand on the islands especially in eastern Indonesia. Gas production and most of pipeline infrastructure in Indonesia is located in the West. However, geographic conditions in the east make very challenging to develop a pipeline network. Additionally, given that most power generation in the eastern region is fuelled with diesel, SSLNG offers an economical option of gas supply for power generation and other uses, as noted in Figure 5-4. [70]

Figure 5-4 Natural gas infrastructure in Indonesia



Source: Direktorat Jenderal Ketenagalistrikan, 2018.

As for the actual development trend of new SSLNG assets, current operators include Pavilion Energy of Singapore, who headed an agreement between Indonesia state-owned power company PLN and Keppel Offshore & Marine in September 2017 to explore opportunities to supply SSLNG in western Indonesia. PLN is studying the development of a small gas-fuelled power generation facility in the range of 25 MW-100 MW.[71] With Pavilion Energy pursuing opportunities to supply SSLNG from Singapore's LNG receiving terminals and Keppel using its strengths in shipbuilding, this consortium is expected to be a successful case of SSLNG supply to some of western Indonesia's remote islands.[72]

5-2-4 Policy support

In Indonesia, there is no specific policy focused on promoting the introduction of SSLNG, but the Indonesian government expects that electricity demand will expand at rate of 7%-8.5% per year until 2022.[73] While Indonesia has natural gas resources in the eastern part of Indonesia, the bulk of demand is in the western region, mainly in Java and Sumatra. The development of a cost-effective LNG supply chain that can overcome these logistical hurdles is a big challenge for the future in order to make effective use of domestic natural gas resources.

The use of SSLNG in sectors other than power generation (industry, transportation, residential, etc.) will depend on the successful implementation of Indonesia's Gas Infrastructure Roadmap.[74] Several challenges persist, however, including streamlining the regulatory approval process, attracting the investment needed to achieve the roadmap targets and the formulation of gas prices to stimulate demand for natural gas across the economy.

5-3 Ship-to-ship operations

Recent notable trends on the supply side of the SSLNG value chain are the ship-to-ship (STS) operations, led by Malaysia's state-owned oil company Petronas. Since 2017, Petronas began creating a system for STS LNG transfers from large LNG tankers to smaller LNG tankers as a way to develop SSLNG market in Southeast Asia. Petronas conducted the first STS operation in Brunei Bay in June 2018. The small LNG tanker that was loaded in the operation unloaded at the Dongguan terminal in Guangdong, China. This terminal has the disadvantage of having a shallow draft, which limits the size of ships it can harbour. Many other terminals and ports have shallow drafts; examples are found in Myanmar and Bangladesh, where the construction of new LNG terminals is planned. The use of small LNG tankers by STS has great potential to contribute to developing emerging LNG markets with similar size restrictions and port conditions.

5-4 Summary findings

The Singapore experience shows that the government's initiative and financing greatly contributed to the development of the existing LNG businesses in the economy. Singapore recognises its own unique advantages, such as its geographic location, position as the region's financial and logistic centre, and aims to strategically utilise those assets to promote its SSLNG businesses. Singapore is certainly well positioned to be an Asian SSLNG supply hub, and promote SSLNG market developments in the growing Southeast Asian LNG market.

In Indonesia, there seem to be more challenges for SSLNG development than opportunities at the moment. Indonesia's future natural gas demand, pricing scheme, and natural gas utilisation policy provide an environment of uncertainty. Addressing these uncertainties is critically important to promote SSLNG market development. A strong, consistent and supportive policy from the Indonesian government would be necessary to address these uncertainties. Nevertheless, it is clear that Indonesia has a great potential for SSLNG, and the case of Bali represents a successful example of SSLNG development.

Chapter 6 Case Study: Nordic and Northwestern Europe

6-1 Overview

Nordic and Northwestern Europe are both part of one of the most developed SSLNG markets in the world. There are at least three main reasons why the SSLNG market has developed in this region:

- Conventional LNG terminals facing low utilisation rates see the SSLNG value chain as a means of increasing the utilisation of their facilities.
- Proximity of scattered, small demand centres, which are unconnected to pipeline networks or to natural gas producing regions.
- Environmental reasons: there is a desire to reduce GHG and particulate emissions by switching from refined petroleum products to natural gas in the transport sector and from coal to gas in the electricity sector.

6-1-1 The Netherlands

The Netherlands has been one of the most active countries in promoting SSLNG infrastructure as well as historically one of the largest gas producing countries in Europe. The idea of building LNG receiving terminals emerged in the 2000s in anticipation of a gradual decline in gas production. The Gate LNG project in Rotterdam was sanctioned in 2007, with the original purpose of being a baseload import and regasification terminal to supply gas for use in the Netherlands and for export throughout Northeastern Europe via the existing pipeline network. From the start of operations in 2011, the Gate LNG terminal has the capacity of dealing with the largest LNG ships in the world. Since then, however, global LNG prices lost attractiveness compared with piped gas coming from Russia and Norway, and as a result, LNG import activities in these terminals did not become as active as originally expected.

The changing gas prices in Europe prompted LNG customers with take-or-pay contracts for Gate LNG capacity to look for creative ways to utilise their capacity. Several market areas were identified: fuelling ships with LNG, developing SSLNG receiving terminals in Nordic countries, supplying inland markets not connected to gas pipeline networks, among others. Even if the base-load regasification capacity was underutilised, imported LNG may be utilised if these markets can be developed. As the existing jetty at Gate terminal was originally designed to accommodate large-scale LNG carrier ships including Q-Max ships, it was modified in 2013 to receive ships as small as 5,000 – 65,000 m^3.

With the renewed LNG marketing strategy, the reloaded volumes at the Gate terminal grew. While Spain was the largest LNG reloading country in the world in 2013, growing imports at the redeveloped Gate terminal propelled the Netherlands into top spot in 2015. The terminal is now capable of reloading LNG onto both a small and large ship simultaneously and since 2016, it has also conducted STS transfer of LNG between two large-scale ships taking advantage of multiple jetties without having to use LNG storage tanks at the terminal.

As an example, cargoes coming from the Yamal LNG terminal, located in the Russian arctic region, arrive to Europe for STS transfers, in many cases with service contracts with Montoir, Zeebrugge and Dunkerque terminals. About half of these transfer operations have been carried out at the Gate terminal under one-time arrangements made only a few days prior to arrival.

The Port of Rotterdam was the first port in Europe to offer LNG bunkering at the end of 2013. In typical cases, bunkering vessels are granted rights to load LNG at existing terminals and then deliver LNG to arriving vessels. Such bunker delivery will be either at a berth, from road tankers (truck-to-ship) or STS transfer. In July 2014, Rotterdam's port authority revised regulations to enable sea-going vessels to bunker LNG at the port.

The Gate terminal began truck loading services in 2014, steadily increasing volumes to deliver a record-high at 286 trucks in June 2018.[75] Those trucks have been used all over Europe, including destinations as far as the United Kingdom, Lithuania, and Italy. Although the oldest two jetties have accommodated SSLNG ships, a third jetty dedicated to small-scale ships was installed in August 2016 to reduce congestion.

6-1-2 Belgium

Belgium started to import from 1987 at its Zeebrugge terminal. Zeebrugge was chosen as an LNG import terminal as it is one of the largest natural gas pipeline hubs in Europe. Given the growing awareness of the need to reduce carbon emissions, as well as a means to diversity its natural gas supply sources, the terminal supplied natural gas not only for domestic demand but for a wider Northwestern European users.

In recent years, the market for SSLNG has also been growing in Belgium. At the LNG terminal in Zeebrugge, tanker trucks can load LNG, which they then use to supply fuelling stations and ships directly. Two filling stations for LNG-fuelled trucks are in use, and in 2016, a second jetty at the LNG terminal in Zeebrugge was commissioned to accommodate LNG bunkering vessels.

Five LNG-fuelled inland navigation vessels are currently supplied via tanker trucks that transport LNG from the Zeebrugge terminal and fuel the vessels via truck-to-ship bunkering transfer – a process also referred to as mobile bunkering. It is expected that tanker trucks from Zeebrugge will soon bunker a total of 13 inland navigation vessels.[76]

In the port of Antwerp, truck-to-ship bunkering has been available since 2012, and in 2015, the Antwerp Port Authority issued a request for proposals to build and operate a fixed LNG bunkering facility.[77] In 2016, French company Engie was awarded a 30-year concession agreement for the construction and operation of a joint refuelling station offering shore-to-ship LNG transfers, along with filling stations for CNG and electric vehicles.[78] However, in April 2018, Fluxys took over the concession in the port of Antwerp to make LNG available as an alternative fuel for ships and barges. Fluxys will add a permanent LNG bunkering facility by the end of 2019.[79]

Many ship-owners active in the English Channel and the North Sea are looking into switching to LNG in order to comply with the stringent ECAs sulphur emission standards that came into effect in 2015. Some players have already ordered new ships and some ships are already active: United European Car Carriers (UECC) ordered two bi-fuel pure car and truck carriers (PCTCs) in March 2014. In 2014, Finnish cargo company Containerships ordered four LNG-fuelled container ships to operate in the North Sea and the Baltic Sea. The first ships were delivered in December 2018, and the other three ships will be delivered in the first half of 2019.[80]

Bunkering services in Belgium have begun to be undertaken by energy and shipping companies. The LNG bunkering vessel *ENGIE Zeebrugge,* which is the world's first purpose-built LNG bunkering vessel, performed its first deliveries of LNG as a marine fuel to the two new gas-propelled PCTCs, in Zeebrugge in June 2017.[81]

Fluxys is actively involved in developing LNG refuelling infrastructure for long-haul trucks. Its first filling station opened in Veurne in late 2014. The installation is a cooperative project between Fluxys and haulage company Eric Mattheeuws, which has 26 LNG-powered trucks in its fleet. This is the second LNG filling station in Belgium. The first one opened in Kallo (near Antwerp) a few months earlier. The filling station in Veurne is co-funded by the EU.

Some industrial companies disconnected from Belgium's gas pipeline network already receive LNG via truck coming from the Zeebrugge LNG terminal and use satellite LNG regasification terminals to use this fuel. Such industrial users adopted LNG mainly for the environmental purpose of reducing carbon emissions. Belourthe - a cereal processing company in Ardennnes, Belgium - made the switch to LNG in June 2014.[82]

6-1-3 Nordic Europe

Norway

After Russia, Norway is the largest gas and LNG producer and exporter in Europe. While most of its LNG capacity is utilised for large-scale exports, the existence of two smaller liquefaction facilities, combined with government efforts to reduce NO_x emissions have helped foster demand for LNG as a fuel and develop a domestic SSLNG market.[83][84]The Ministry of Environment signed an agreement with 15 Norwegian business organisations in 2008 to help support investments in projects that reduce NO_x emissions from maritime transportation through the NO_x Fund. The NO_x fund has worked as a strong incentive to adopt LNG as a maritime fuel in Norway.[85] As a result of the fund, there are currently over 50 ships sailing on LNG, accounting to 0.2 - 0.3 mtpa of LNG.

Gasnor is the Norway's leading downstream natural gas company, operating a pipeline network along with some CNG and LNG distribution from three separate production plants (Titania, Karmøy and at Kollsnes). Gasnor opened its first LNG production plant in 2003 and has since built two additional production facilities. Gasnor distributes LNG by 22 tanker trucks and two marine tankers, both operating on LNG.

Another example of SSLNG in Norway is the Skangas liquefaction plant, built in 2010 in Risavika. It has a production capacity of 0.3 mtpa and also has an LNG bunkering facility. Natural gas is brought to the LNG plant by a subsea pipeline system from the Kårstø processing plant.

Finland

Finland's first LNG import terminal was opened in Pori in 2016, but a second one, Tornio LNG, became operational in 2018 and is currently the largest in the Nordic countries.[86] However, due to increases in natural gas taxation in recent years, the use of natural gas has been reduced in Finland's large cities and been replaced by fuels such as coal. Natural gas demand in the residential sector is concentrated in Helsinki, where it is used for cooking in around 20 000 homes and most restaurants. With the exception of Helsinki, natural gas is not the preferred fuel for heating in Finland.

Contrastingly, gas use in the transportation sector has increased recently with help from the increasing availability of CNG refuelling stations. Gasum announced plans to construct around 50 gas filling stations for heavy-duty vehicles in Finland, Sweden and Norway that will be operational by the beginning of the 2020's.[87] LNG has also been used for the maritime transportation sector. In January 2013, the world's first LNG-fuelled large ferry was the Finnish 'Viking Grace.' Viking Line, the operating company, purchases

LNG from Sweden-based AGA Gas, which supplies LNG to Viking Line ships through the bunkering vessel, Seagas.[88] In 2016 Finland began using the world's first LNG-powered icebreaker named "Polaris," which is configured to use either diesel or LNG.

Sweden

Similar to Finland, natural gas is not a large factor in Sweden's energy mix compared with other places in Europe. However, Sweden has two LNG receiving terminals, Nynäshamn (near Stockholm) and Lysekil. In 2014, Skangas started the construction of a new LNG distribution terminal in the harbor of Gävle, while LNG Gothenburg is expected to receive LNG cargoes and mainly use it for vessels bunkering. As for SSLNG, Skangas loaded its first small-scale cargo at the Zeebrugge terminal in Belgium in 2015 for delivery to the Lysekil terminal, where it regularly receives SSLNG cargoes.

6-2 Market size

While there are no official statistics or data to show the size of SSLNG market in Europe. Norway seems to the largest small-scale business in Europe. Although Norway is the second-largest largest gas producer and exporter in Europe, many regions are not connected to the pipeline grid. Sweden has a relatively small domestic market with 0.15 million tonnes of LNG per annum used for industrial, commercial and agricultural purposes and 0.25 million tonnes of LNG per annum for maritime fuel. To supply these users, more than 70 satellite LNG regasification terminals are available to supply industries and local distribution networks in Norway.

6-3 Policy incentives

There are two major policy incentives for SSLNG use in Europe. The first is regulation of emission of the maritime fuels. The Baltic Sea, the North Sea area, the North American area, and the United States Caribbean Sea have been designated as ECAs. Since 2015, sulphur emissions are limited to 0.10% in these areas. As noted above, this regulation has increased SSLNG demand in the maritime fuel sector. From 2020, new IMO regulations will cap sulphur at 0.50% in non-ECAs. While this may result on ship-owners and shipping companies shifting away from heavy fuel oils to LNG as their main fuel, there is significant uncertainty on the extent to which this will happen.

A second incentive is the presence of carbon pricing in the EU through its Emission Trading System (EU ETS). Putting a price on carbon through the EU emissions trading mechanism helps encourage switching from more carbon-intensive fuels, such as coal and RPPs, to less carbon-intensive fuels, like LNG. The EU carbon price was the highest performing commodity in 2018, increasing more than 200% to about EU 25 per tonne.[89]

Strong performance of the EU ETS may encourage further adoption of LNG in the future.

In the Netherlands, the Port of Rotterdam Authority is involved in a project for the design and construction of a dedicated harbor basin for LNG break-bulk operations, and in 2014 introduced new regulations that allow LNG bunkering for inland barges and STS bunkering of seagoing vessels. With this, Rotterdam is playing a leading role on the introduction of SSLNG and the use of LNG as a bunkering fuel. Additionally, in 2013, the "Wadden and Rhine Green Deal", a partnership between government, business and non-government s organisations led to the constitution of the "*Nationaal LNG Platform*" in the Netherlands. It is an operating body where governmental authorities and domestic economic and technical operators meet in order to agree a coordinated policy.[90] Since 2013, the *Nationaal LNG Platform* has been connecting companies and governments to introduce LNG as a fuel for road transport and shipping. To date, this has resulted in the installation of 25 LNG filling stations, 500 LNG trucks and a first inland marine fleet on LNG. The transition has also begun the liquefaction of bio-methane for heavy transport, to bio-based LNG.

In Norway, the use of gas in the industrial and transportations sectors (particularly as a maritime fuel) has increased in recent years.; building up of local experience with LNG technology; and reduction of carbon emission.[91] M/S Glutra, the first LNG-fuelled vessel (excluding LNG carriers), was put into operation in 2000. Norway has a fleet of more than 50 LNG-fuelled ships and the number is growing.[92] The use of LNG as a marine bunker fuel has been supported by the Environmental NO_x-Agreement 2008-2017 between 15 Norwegian business organisations and the Ministry of the Environment.[93]

6-4 Summary findings

There are several implications from these European cases. First, environmental regulations have thus far been effective for incentivising the adoption of LNG as a marine fuel. ECA sulphur emissions regulation, as well as economy-specific regulation, like the Norwegian NO_x Fund, have provided strong incentives to the business sector to choose LNG to meet the regulation. It should also be noted that governments in Europe have the capability to enforce and monitor the regulation to avoid evasions. The experience in Northwestern and Nordic Europe shows that credible regulatory enforcement mechanisms are required to incentivise compliance.

Second, SSLNG can offer a way to increase the utilisation rates of existing liquefaction infrastructure that is underutilised. In some of the LNG terminals such as Gate in the Netherland or Zeebrugge in Belgium, terminal utilisation became unexpectedly low because of market conditions. This provided a strong incentive to terminal operators to offer ancillary services, such as marine bunkering, vessel reloading, LNG truck loading or even infrastructure to fuel LNG-powered freight vehicles. In many cases, SSLNG supply chains can be created using existing liquefaction facilities and do not require the build-out of a new smaller scale liquefaction facility.

Third, besides government's policies, the private sector plays a key role in developing SSLNG. The Europe case studies illustrated that private natural gas suppliers and transportations companies that actually developed SSLNG infrastructure. While incentives and regulations from governments are essential for SSLNG development in early stages, a commercial environment with transparent price mechanisms, as well as clear technical and investment rules, are essential to attract investment from the private sector.

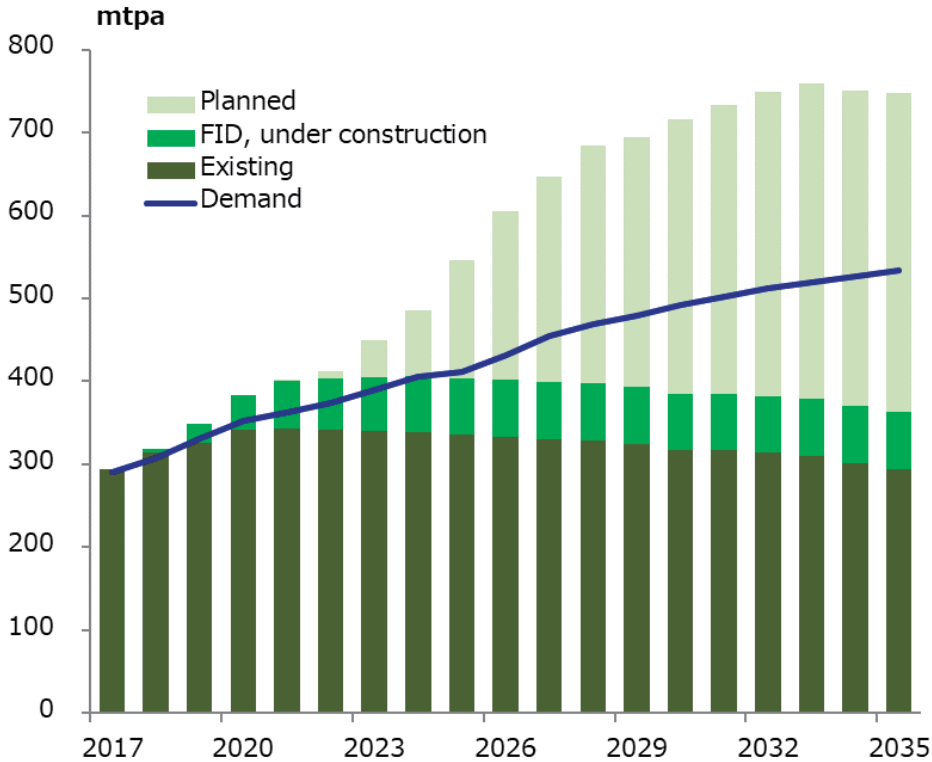
Chapter 7 Conclusions: Issues and challenges

This chapter offers a set of conclusions by summarising the various challenges facing the expansion of the SSLNG market in the future.

7-1 Relative price competitiveness

First, the international price of LNG will have a big influence on SSLNG adoption in the future. The price of SSLNG-sourced LNG depends on the international prices of LNG. For this reason, a sharp rise in international LNG prices will make it difficult to encourage SSLNG adoption as it will become more expensive, particularly in Asia. As observed in the China's case, international imported LNG price affects domestic LNG demand even though there is a policy push toward gas utilisation. Figure 7-1 shows global LNG supply and demand balance. The figure illustrates that while existing liquefaction capacity plus that under construction currently surpasses LNG demand, demand is expected to outstrip this capacity in the mid-2020s. Therefore, if the currently planned projects do not receive positive final investment decisions (FIDs) and move into the construction phase in a timely manner, the excess demand could causes a sharp increase in LNG prices.

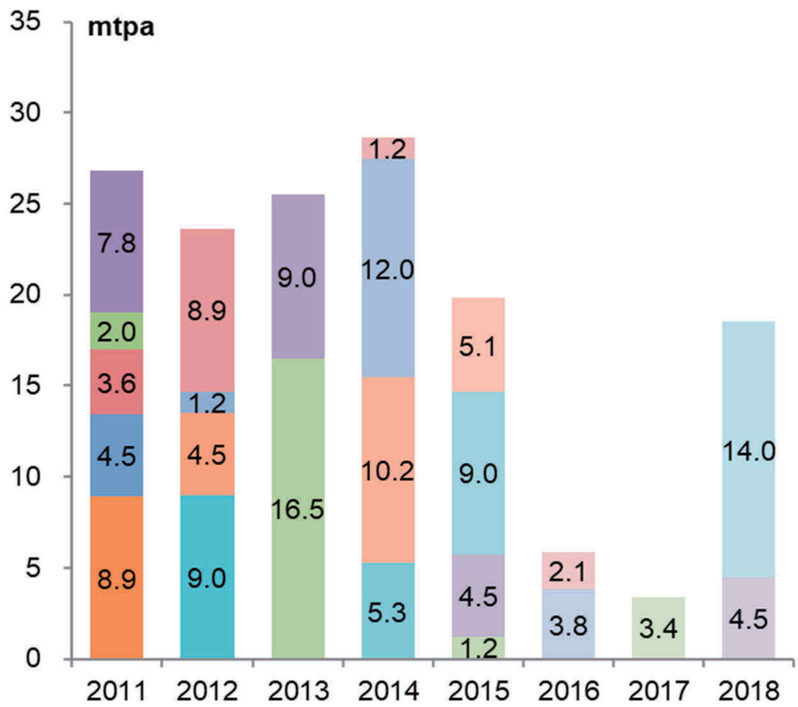
Figure 7-1 Supply and demand balance in the international LNG market



Source: IEEJ estimate

On the other hand, Figure 7-2 shows the final investment decisions (FIDs) made for liquefaction projects after 2011 and their respective capacities. Investment in new projects was stagnant from 2014 to 2017, mostly due to the decline in crude oil prices that began 2014. However, because of the recovery on oil prices in 2016 and the steady growth of LNG demand in emerging LNG importers, such as China, investment momentum for new projects has increased once again. Future liquefaction projects are being considered in the US, Tanzania, Mozambique, Russia, Papua New Guinea and elsewhere. In Qatar, there are plans underway to further expand existing liquefaction capacity by 23 mtpa. While developing liquefaction capacity is a complicated and long process, if these projects are completed as scheduled, they may contribute to keep liquefaction capacity and LNG demand in balance. Consequently, this will affect price stability, creating a favourable environment for investment and further expansion of SSLNG.

Figure 7-2 Liquefaction projects with FIDs and their capacities, 2011-18

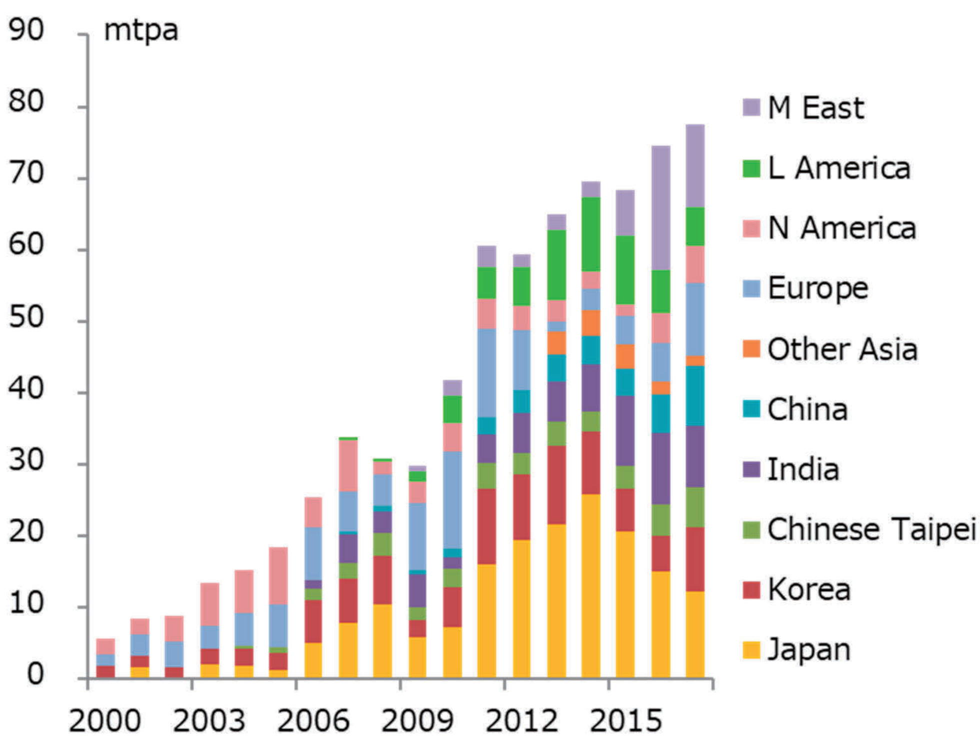


Source: IEEJ based on corporate press releases

The relative price of SSLNG compared with competing fuels is a key factor in determining its demand in the future. As a fuel for remote power generation, it has to compete with coal and petroleum products, such as fuel oil and diesel, which are also the main fuel competitors in the industrial, transportation and buildings sectors. Renewable energies, such as solar and wind power, are also expected to play an increasing role in fuelling electricity and heating demands going forward. These factors represent a challenge for SSLNG competitiveness.

In order to boost SSLNG competitiveness, it is necessary to secure an advantage over competing petroleum product prices in different sectors. In the Asian market, the relative disparity between LNG prices and crude oil prices has been historically small. Recently, however, the discount on the price of LNG versus crude oil has been increasing, reflecting, among other factors, an oversupplied LNG market. Unless these price differentials continue, it is unlikely that significant capital investment will be made on the SSLNG supply chain in Asia.

Figure 7-3 Trends in short-term spot contract volumes, 2000-17



Source: International Group of Liquefied Natural Gas Importers (GIIGNL), 2018.

Short-term trading and spot transactions have been expanding recently in Asia (Figure 7-3), and price benchmarks are trending away from traditional long-term contracts linked to crude oil prices. In this context, US LNG exports to Asia could play a relevant role in changing the current pricing structure by increasingly reflecting the economics of the supply and demand of LNG instead of pricing its contracts via a link to crude oil prices. Additionally, by dissociating crude oil and LNG prices in Asia, SSLNG could increase its competiveness against refined oil products.

This evolving situation may increase uncertainty over future LNG prices. This may have a negative impact on expansion of SSLNG infrastructure, which requires substantial capital investment. A temporary alternative to stabilise competition with refined oil products, could be to link LNG prices with other fuels. Shell and Tokyo Gas recently formalised a deal using a coal-linked formula.[94]

Additionally, gas demand seasonality may further increase volatility. As global demand for LNG peaks from November to February, the winter months in the Northern hemisphere, LNG prices are prone to significantly increases in that period. This seasonality factor affects demand in remote areas for power generation, industry and especially, residential users. However, this seasonality may not apply to the use of LNG as a fuel for marine vessels and heavy-duty vehicles.

Finally, domestic pricing systems play a key role in advancing the introduction of SSLNG. Many of the emerging economies that are expected to see increasing demand for SSLNG are subject to regulated natural gas prices. For this reason, aside from international price levels, domestic regulated prices mechanism for natural gas are a crucial policy instrument to influence gas demand. For example, natural gas demand growth in China in recent years was promoted by the government mainly through low regulated gas prices. Nevertheless, if regulated domestic prices are set too low, there is a possibility that supplying LNG may not be economically viable. However, the experience in China demonstrates that there could be a balance between LNG economic viability and regulated price schemes.

7-2 Cost competitiveness

Saving costs on the supply side is also important for securing the relative economic efficiency of SSLNG. One such cost reduction approach is to modularise the construction of liquefaction units. Construction of facilities for SSLNG, in the case of a remote area, requires the presence of many workers and technicians, which may increase construction costs. In contrast, adopting a modular approach of pre-constructing the relevant facilities at a shipyard, transporting them to the site and assembling them will help reduce construction costs. Modularisation is a process that has already been used in liquefaction and other projects in northwest Australia where it is difficult to secure labour. Although recent experience suggests that it risks escalating costs further unless an experienced and specialised contractor is secured for the modularisation process, its further use is expected for the development of future receiving terminals.[95]

It is also possible to reduce costs by advancing the standardisation of equipment. As the use of SSLNG grows so will the need for constructing the equipment related to its services throughout the SSLNG value chain. From the liquefaction facilities to the receiving facilities and the equipment needed for transporting it, such as small LNG tankers, LNG trucks and LNG-powered ships, costs can be expected to be reduced by the learning effect and as producers gain economies of scale. Governments could also play a role in cost reduction by positively encouraging such standardisation efforts.

7-3 Optimising infrastructure and logistics

Although not limited to SSLNG, in order to successfully penetrate the targeted demand markets it is necessary to optimally prepare infrastructure for its use. For example, when supplying SSLNG from a satellite base, ports (including dredging and the construction of breakwaters) are needed so that small LNG tankers can dock and make transfers. Also, additional pipelines may to connect the receiving terminals to power plants and industrial users may be required. This optimisation process is critically important in Southeast Asia to reduce the delivered cost as much as possible. Also, when using LNG trucks to deliver supplies, it is imperative to develop and maintain roads on which the trucks will circulate. This complex infrastructure development requires joint efforts and coordination between central and local governments, developing companies supplying the SSLNG, and other key local stakeholders.

When establishing an SSLNG supply chain, suppliers must strive to align the development pace to that of the demand for LNG. On the supply side, building out excessive infrastructure could reduce the profitability of the investment and not building enough could result in supply shortages. On the user side, investing in LNG-fuelled end uses, such as LNG-powered vessels, vehicles and natural gas boilers, could prove to be an inefficient use of capital if LNG supply constraints prevent consumers from utilising their investments. This can be accomplished by gauging interest through the issuance of open seasons for SSLNG services in the infant stages of the establishment of the SSLNG supply chain. This will enable suppliers and end-users in the SSLNG supply chain to harmonise their development pace, which would reduce the inefficiency of the supply chain and help the SSLNG industry gain a reputation for being a well-functioning method of supplying natural gas to remote end-users. Additionally, at early stages, pilot and demonstration projects by local governments or companies may help boost demand for LNG by familiarising potential users with the new technology.

Furthermore, an optimal supply route must also be established to distribute LNG to end-users. The high cost per unit of supply is a main drawback of choosing the SSLNG supply chain as a fuel. In order to overcome this challenge, it is necessary to optimise a logistical system with the objective of distributing LNG at the lowest cost possible. In instances where multiple demand sites exist in a decentralised area, it is necessary to pursue the selection of means and routes that can provide the most efficient supply to such demand sites. This may involve incorporating flexibility into supply logistics, including the reduction of costs by using STS operations.

7-4 Capacity building

Finally, because SSLNG is a relatively new way of supplying natural gas, it is also important to develop human resources who are familiar with the natural gas business and natural gas policy in emerging economies who are considering implementing SSLNG supply chains. Developing an SSLNG supply chain was made possible in economies like Norway or China because of the abundant human resources adept at natural gas and LNG handling. On the operational side, SSLNG will require the hire and training of skilled labour resources with advanced knowledge of LNG transactions, infrastructure management and safety aspects that are specific to the supply chain. Furthermore, in making decisions concerning SSLNG-related capital investment, the companies, regulatory authorities, and policymakers must have knowledge of natural gas and the LNG projects themselves.

Specific fields for training such human resources include safety and environmental aspects of the SSLNG industry, knowledge of SSLNG procurement (types of contracts, composition of contract portfolios, studying demand patterns, procurement negotiations, etc.), laws and regulations for promoting the use of SSLNG, knowledge of end-use and power technology that can be adopted to use SSLNG and government gas support policies (tax system advantages, pilot projects, policy incentives, subsidies, etc.).

As for training these human resources, companies that are trying to introduce natural gas in some emerging economies are already implementing their own training programs for the general implementation of LNG. The governments of both China and Japan, for example, actively back up the efforts of these companies, by leading and contributing to the promotion of investment in the natural gas sector. Similar strategies could be adopted to champion the use of SSLNG supply chains throughout the Asia-Pacific region.

7-5 Coordination among stakeholders and government support policies

Coordination among stakeholders in SSLNG becomes more important since its supply chain is more complex than conventional LNG projects and involves more stakeholders. This multiplicity of actors, including all companies involved in the procurement, regasification, transport and supply of LNG, regulators, governments, utilities and end-users, requires clear and effective communication and rules. This could be facilitated by a stakeholder (normally the central government) taking leadership of the project. However, this could vary depending on the nature of the SSLNG project. For example, in developing SSLNG for power generation in a remote area, the electric utility may be in a good position to coordinate the project, as it will be the main off taker, absorbing most of the risk in the project.

Finally, governments could play a key in expanding the demand for natural gas by SSLNG. Local governments' inclusion and proactive participation on policies, regulations, and permits that promote infrastructure development is necessary. There must be clear domestic gas usage policies that reduces any future policy and market risks. Economic evaluations in Chapter 3 suggest that recovering the initial capital outlay is the biggest challenge of SSLNG infrastructure development. Reducing the capital outlays (through subsidies or tax breaks) in LNG investments could therefore help spread LNG adoption on the demand side, as shown by the cost analysis case studies of industrial boilers and natural gas-fired generators in this report. Moreover, establishing the relevant international standards for safety and environmental regulations are still a pending issue. Therefore, it is also important to establish an effective regulatory system by closely exchanging information with businesses and other governments that have also introduced SSLNG.

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