Fuelling Maritime Shipping with Liquefied Natural Gas

The Case of Japan

Case-Specific Policy Analysis

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Case-Specific Policy Analysis Reports

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Executive summary

What we did

This report assesses Japan's ambition to become an international bunkering hub for Liquefied Natural Gas (LNG). The Japanese government expects LNG to emerge as a significant fuel for shipping and is positioning Japan as a hub for ships to bunker LNG. This strategy would make Japan one of the key places in Asia where natural gas fuelled or co-fuelled ships would be able to take on board LNG. The study is based on desk research and focuses specifically on bunkering facilities in the Tokyo Bay area, notably the Port of Yokohama.

What we found

Japan is the world's largest importer of LNG by a large margin and has developed marine bunkering facilities to provide LNG to ships, alongside the fuel's main use in electricity production. Japan is also a major trading nation and the volume of its maritime trade provides the basis for LNG bunkering hub strategy. The success of this strategy will depend on four conditions:

Uptake of LNG as ship fuel. There are currently 118 LNG fuelled vessels in the world; a marginal share of the world fleet. However, the number is growing and will almost double by 2020, based on ship order data. The recent order by container line CMA CGM of nine LNG-enabled mega-container ships is likely to be followed by similar orders from other lines. This would increase the prospects for bunkering of LNG-fuelled ships on main East-West trade lanes. Competitive LNG prices can further incentivise alternative fuel investment strategies by firms.

Availability of LNG bunkering facilities worldwide. Ship-owners and operators will need a network of ports where they can take on board LNG. These facilities are becoming increasingly available in Europe, and to a lesser extent in North America and Asia.

Recent and future emissions regulations. Regulations to reduce SO_x and NO_x emissions from ships have increased demand for alternative propulsion options, including LNG. In particular, the stricter requirements in Emission Control Areas as of 2015 have boosted LNG-fuelled coastal shipping in Northern Europe and North America. The global sulphur cap from 2020 will likely drive the use of LNG fuelled ships in other parts of the world as well.

Strategic location close to trade routes. Major Japanese ports could benefit from increased LNG-fuelled container ship traffic because of their geographic situation. The Port of Keihin (Yokohama, Tokyo and Kawasaki), which has developed the technical and infrastructure requirements for LNG bunkering, is located at one end of the North Pacific trade route as a first port for loading and unloading. This gives it a locational advantage to become a major LNG bunkering hub.

Japan has the potential to become a major LNG bunkering hub. At the same time some uncertainties exist. Emission regulations have so far focused on reducing SO_x and NO_x emissions from ships, but will soon target maritime greenhouse gas emissions as well. In that context, LNG has advantages over conventional fuels but is not the ideal solution to reduce CO_2 emissions from ships. It can cut them by around 20%, but there is "methane slip" (releases of methane from unburnt gas in engine exhaust). Also, handling LNG at each stage of the supply chain leads to fugitive emissions. Global standards on the safe handling of LNG on the shore side will also be required.

The analysis confirms the strategic importance for Japan to invest in LNG bunkering facilities in anticipation of the 0.5% global sulphur cap. The sulphur regulations in the Emission Control Areas in Northern Europe have generated orders and deliveries for LNG-fuelled ships operating in coastal trades. With the sulphur cap imminent, this might also happen in Japan. Given its current level of infrastructure, experience and geographical position, Japan will most likely secure a competitive advantage vis-à-vis other Asian ports that are developing similar bunkering facilities for LNG. With these in place, the ports in the Tokyo Bay area in particular will strengthen their current position as key regional and international ports and enable the emerging East-West traffic by LNG-fuelled ships traffic to trade in Japan.

What we recommend

Involve stakeholders in the development of policies governing LNG bunkering

Japan has a range of players with a stake in the development of LNG bunkering. These include LNG importers, global and coastal shipping companies, as well as firms with a high degree of expertise in storage and handling of LNG. Japan's LNG bunkering strategy can be successful if it builds on the experience of these stakeholders while stimulating competition in the Japanese LNG market.

Plan LNG infrastructure in a flexible manner

The uptake of LNG propulsion by the shipping sector is increasing, but its perspectives are far from certain. In order to avoid over-investment, the LNG bunkering strategy should be flexible and able to scale up when demand grows. New storage facilities and gas infrastructure should thus be able to accommodate a range of gases, such as bio-methane once they become a viable option.

Stimulate international cooperation in LNG bunkering services

Increasing the number of LNG-propelled vessels significantly requires a world-wide network of LNG bunkering facilities. Japan has been active in international coordination efforts, for instance via a Japan-Singapore Summit Meeting in 2016 and a Japan-Singapore Joint Study on LNG Bunkering in 2017. These efforts need to be sustained. Japan could bring together the relevant world ports for LNG bunkering and facilitate the harmonisation of technical standards in LNG bunkering. It could also promote transparent global LNG markets, building on its experience and expertise in handling LNG.

Mitigate negative environmental side-effects of LNG-fuelled shipping

LNG can reduce the overall greenhouse gas emissions of maritime transport. It could increase its contribution to more sustainable maritime transport if operators of LNG supply facilities build on their extensive experience in LNG handling to further minimise the remaining negative impacts, such as fugitive methane emissions and hence the overall greenhouse gas impact of LNG use.

Introduction

Until recently, almost all ships were propelled by heavy fuel oil or marine diesel oil. Regulations to reduce SO_x and NO_x emissions from ships have changed this situation. In this context, liquefied natural gas (LNG) has become one of the emerging fuels for maritime and coastal shipping. LNG is formed when natural gas is cooled to -162ºC, which shrinks the volume of the gas 600 times. This makes it easier and safer to store: in its liquid state, LNG is not explosive and does not ignite. Its environmental advantages are considered to be a major argument for using LNG as a ship fuel. Using a gas-only engine can reduce NO_x emissions by 85% or 90% and SO_x and particulate matter by almost 100% compared to conventional fuel oil (IMO, 2016).

Japan has, in line with its recent energy strategy, formulated the ambition to become an international LNG bunkering hub. This report provides an assessment of this ambition. It covers the drivers of global LNG uptake as a ship fuel, assesses current demand and supply forecasts for LNG, and highlights the current opportunities and challenges for Japan in becoming a major international LNG bunkering hub.

Demand and supply of LNG bunkering facilities

Historically, technological change in shipping has been slow, especially change in propulsion technology. The paradigm change from sail to steam propulsion took approximately one century. The gradual change in uptake of new propulsion technologies can be explained by the relatively large investment that a ship represents and the long lifetime of ships, which for a modern vessel is 25-30 years. The adoption of LNG for ship propulsion is likely to be incremental, although faster than with earlier technologies. The drivers for change and technological options in this case are different. First, the technological change with LNG is not as radical as sail to steam or steam to internal combustion, because retrofitting of existing marine engines is an option. Compared to earlier examples of changes in propulsion technology, investments are smaller and returns on investment faster. Second, the regulatory environment has created an incentive for the use of LNG as a bunker fuel, setting emission limits in specific sailing areas that can be met cost-effectively by conversion to LNG.

Conceptually, we assume the uptake of LNG propulsion to be determined by three main drivers: operational, market and regulatory (Table 1). Operational drivers cover the technological push and eventual cost savings. The technological push stems from the availability of specialised engines from equipment manufacturers and ship builders who are able to install them on new-built or retrofitted ships. Cost savings arise from differences in energy prices. High oil prices push ship owners to consider alternative fuels to save on bunker costs in comparison with conventional fuels. Since the introduction of market-based prices, e.g. for LNG coming from North America, LNG prices have become increasingly de-linked from oil prices. Accordingly, long-run price competitiveness and regional price advantages can favour alternative fuel investment strategies of carriers. The second driver type are market factors that include the preferences of shippers or clients who may choose cleaner or greener shipping options or request specific ship bunker fuels. Currently however, we see fairly limited evidence for shippers being ready to pay higher prices for cleaner fuels to be used for freight transport. Therefore we consider that

the market drivers influence the uptake of LNG propulsion only to a limited extent at the moment. The third driver type is regulatory change. This category involves the regulations that governments apply, for example, in terms of reducing emissions of air pollutants at sea, with emission control areas in the North Sea and Baltic Sea. We assume that the rise of LNG as ship fuel will depend mainly on its attractiveness to ship operators for meeting environmental regulations.

Table 1. **Drivers of eco-innovation activities**

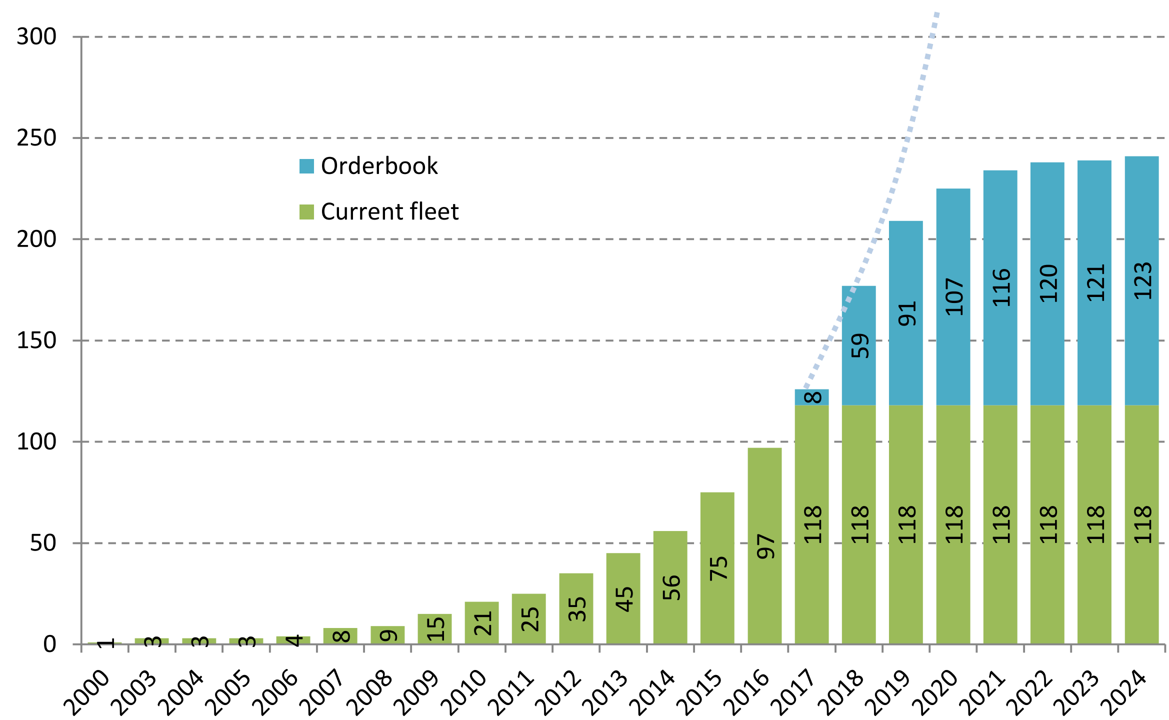
Operational drivers or supply side factors	Technology push	• Technological and management capabilities • Collaboration with research institutes, agencies and universities • Access to external information and knowledge • Size
	Cost-saving	• Material prices • Energy prices
Market drivers or demand side factors	Market pull	• Market share • Market demand for green products
Regulatory drivers or environmental policy influences	Regulatory pull/push	• Existing regulation • Expected future regulation • Access to existing subsidies and fiscal incentives

Source: Aronietis et al. (2016) based on Erzurumlu and Erzurumlu (2013), Triguero, Moreno-Mondéjar and Davia (2013) and Horbach (2008)

There are currently 118 LNG fuelled vessels in the world[1], excluding LNG carriers and inland waterway vessels (full list in Annex 1). Despite the relatively small number of LNG-fuelled ships, less than 0.01%[2] of the world fleet has grown exponentially since the early 2000s and currently available data on the ships on order indicates that the trend is unlikely to stop (Figure 1). This growth pattern is typical with innovations in their early adoption stages, as their adoption usually follows an S curve with an exponential growth in the early stages.

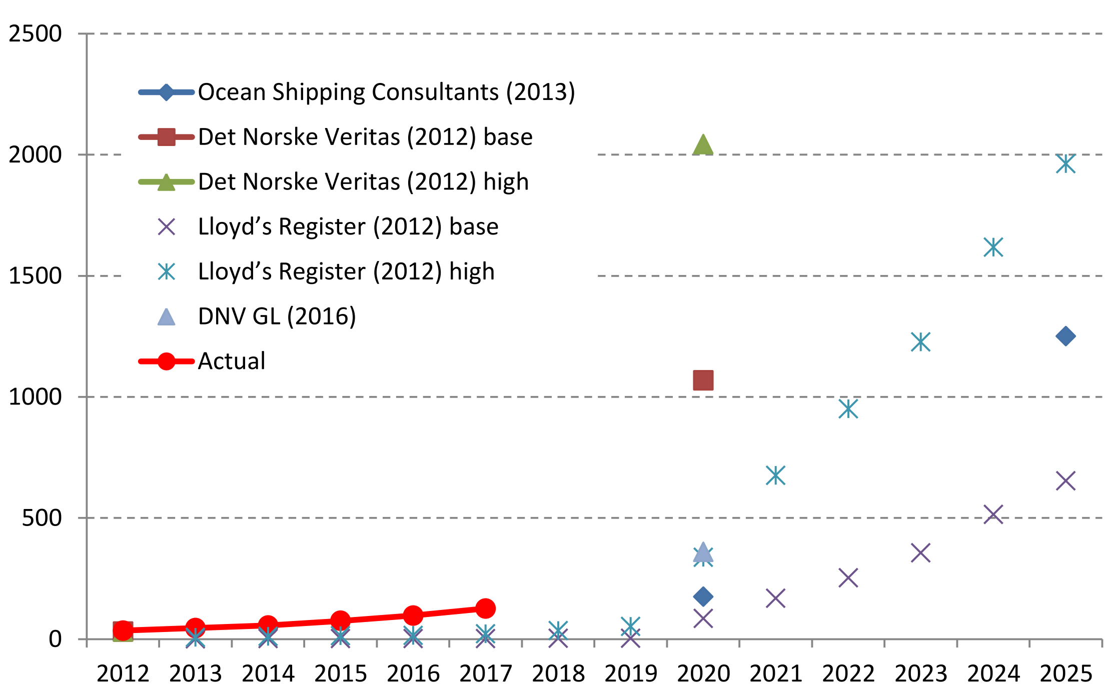
In the near future, based on confirmed orders, the fleet is expected to double and grow by another 123 vessels in the next years (see Annex 2). When interpreting Figure 1 it must be taken into account that growth is not expected to level off and complete the S cycle, because the data on the ordered ships in the next years only shows currently available information. The available longer-term LNG-fuelled fleet forecasts from different sources are summarised in Figure 2. The forecasts agree on the exponential growth of the number of LNG-fuelled ships and currently available data confirm this. As shown in Figure 2, the forecasts have slightly underestimated the development between 2012 and 2017. It remains to be seen whether the trend will continue according to forecasts.

Figure 1. **LNG-fuelled fleet and orderbook, cumulated number of ships**



Source: Data from DNV GL (2017), on 01.12.2017

Figure 2. **Long-term forecast of LNG-fuelled fleet, number of ships**

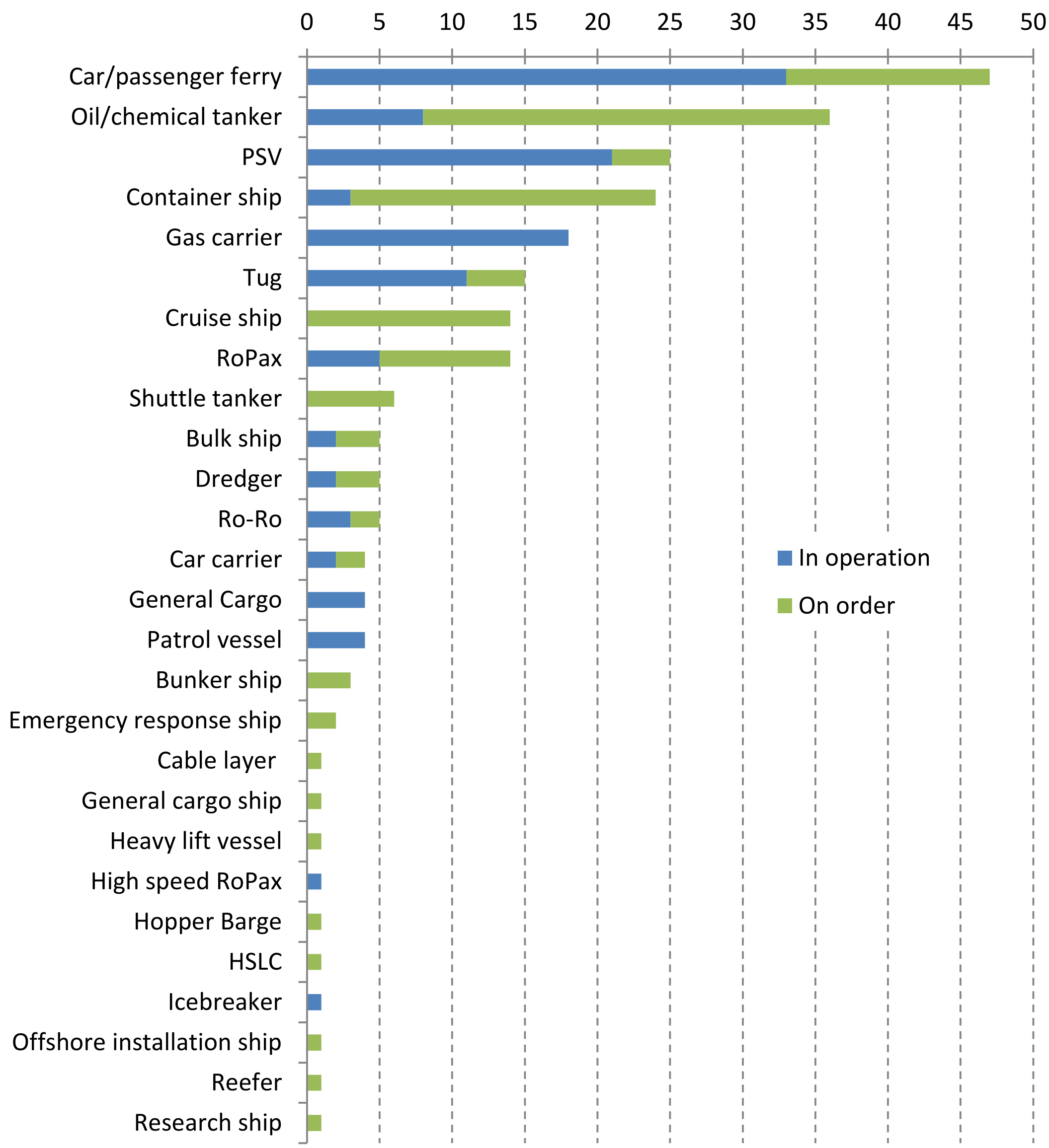


Source: Own composition based on DNV GL (2017), Aronietis et al. (2016) and DNV GL (2016b)

Data shows that the adoption of LNG as bunker fuel is not uniform in all market segments (Figure 3). The adoption rates seem to be higher in some segments either due to the availability of the fuel, as with gas carriers and platform supply vessels (PSVs), or due to the regulatory restrictions in the areas in which they sail. Tugs are probably amongst the top LNG-fuelled ship types due to political and environmental reasons, as they are usually owned by public bodies and operate in urban areas that suffer air pollution.

Currently the advantages of using LNG for ship propulsion for an individual ship seem to depend on its sailing pattern and whether the regulatory environment sets an emission limit in areas in which it operates. Fundamentally the LNG advantage depends on what presents the most cost-efficient means of achieving regulatory emissions targets. Since LNG has virtually no sulphur content, the decision of the International Maritime Organization’s (IMO) Marine Environment Protection Committee (MEPC 70) in October 2016 that, from 1 January 2020, the sulphur content of any fuel used should be limited to 0.50%, is very likely to accelerate the use of LNG globally across all ship types. The current distribution of LNG fuelled ships across different segments can be expected to change greatly.

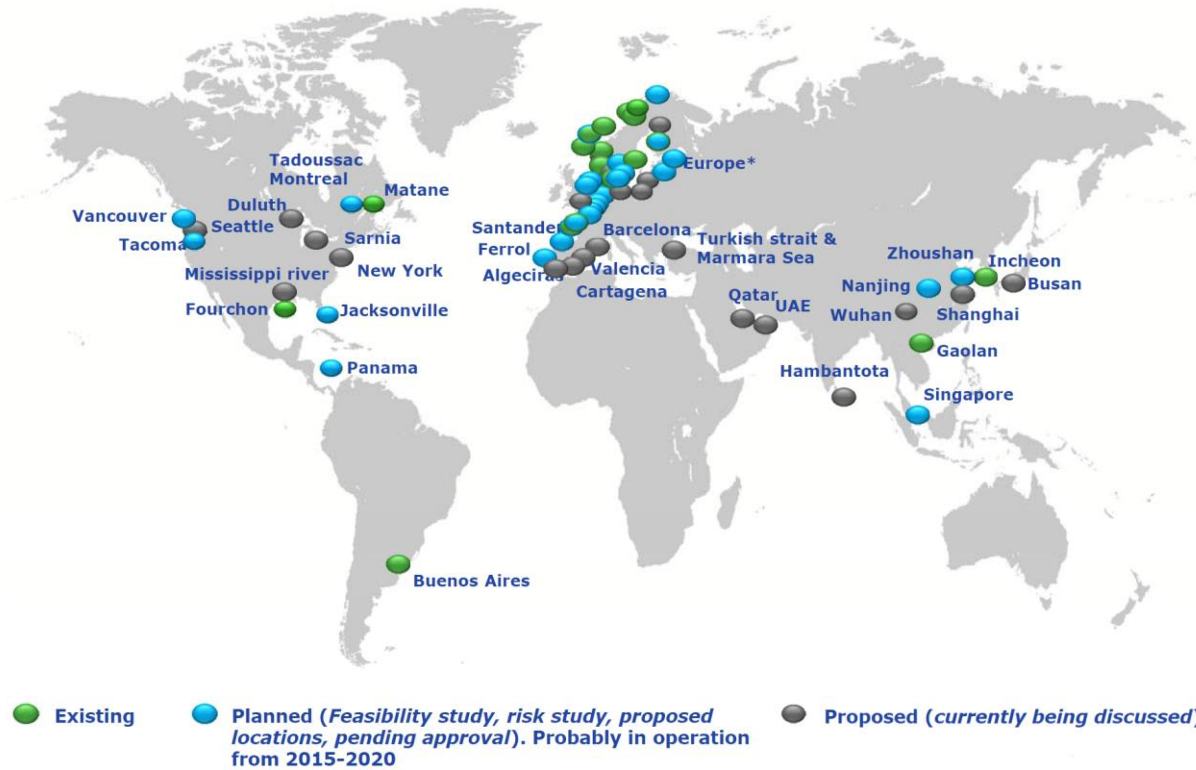
Figure 3. **LNG-fuelled ships by ship type, number of ships**



Source: Data from DNV GL (2017), on 01.12.2017

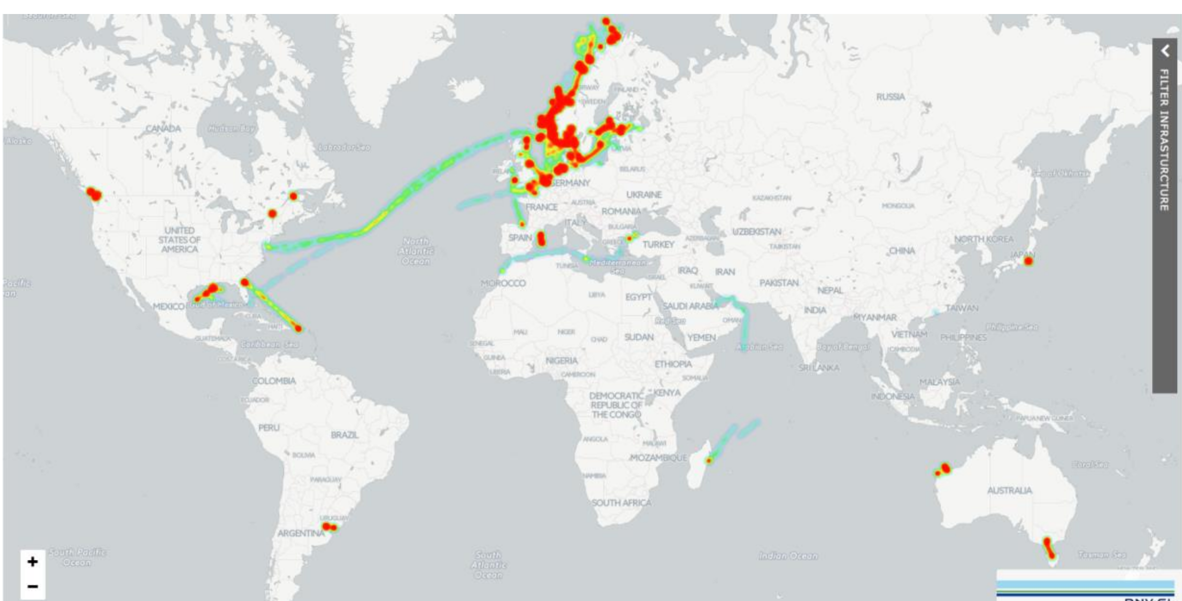
The development of a global LNG bunker infrastructure is a prerequisite for ocean going ships to use LNG for propulsion. Currently a range of ports have such infrastructure. The largest bunkering infrastructure concentration is in the north of Europe, see green dots (Figure 4). Some bunkering facilities are available also in other parts of the world. A range of other LNG bunkering facilities is in the planning stage, blue dots in Figure 4, mostly in Europe, North America and the Far East. Ensuring global availability of LNG bunker fuel across a wide geographical area should ensure that big ocean going ships can transition to LNG. As shown in the heat map of LNG-fuelled ship operation in Figure 5, the vast majority of the ships currently in operation are sailing in the northern part of Europe and on specific routes in a few other specific locations around the world.

Figure 4. **Overview of LNG bunkering facilities in ports**



Source: DNV GL (2016a)

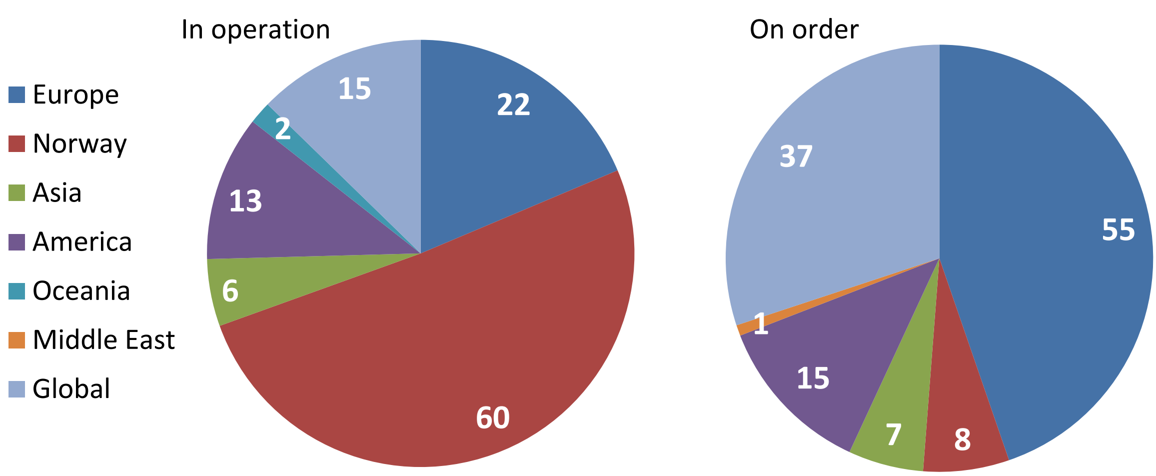
Figure 5. **Heatmap of LNG-fuelled ship positions**



Source: DNV GL (2017), on 15.05.2017-25.05.2017

The order book shows that the current geographical concentration of LNG-fuelled vessel operations will likely shift towards a higher number of ships involved in global trade (Figure 6). Although the biggest part of the new ships will extend the fleet that operates in Europe, approximately a third of the ships are expected to work on global routes with the others starting operations in America and Asia. The expected expanding geographical scope of the sailing patterns requires bunkering infrastructure to follow and support this trend due to the relatively low energy density of LNG compared to conventional bunker fuels, which means more frequent bunkering needs and – hence – need for denser global bunkering infrastructure.

Figure 6. **Areas of operation of LNG-fuelled vessels**



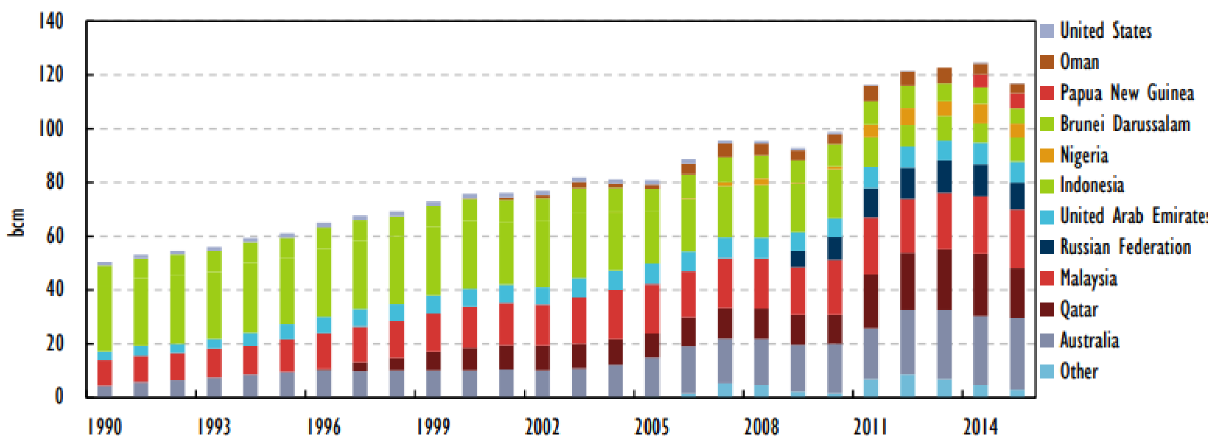
Source: Data from DNV GL (2017), on 01.12.2017

Currently there are only three LNG-fuelled container ships in operation, one of which is a recent retrofit. IMO (2016) expects to see significant growth in the number of LNG-fuelled ships in the segment of container ships. In the near future another 21 container ships are expected to become operational as new-builds by 2021, see Annex 1 and 2 for details. However, container ships usually operate on longer voyages, which means that a relatively large cargo carrying capacity needs to be sacrificed to be used for LNG storage tanks to satisfy the range requirements of these ships. At the same time, the operational patterns of container ships also represent an opportunity for LNG uptake. The long fixed routes of some container ships make them a favourable segment for LNG adoption, because the availability of LNG bunkering facilities needs to be ensured in only the small number of ports that are called at. In comparison, for a ship engaged in the tramp trade without fixed schedules[3], far wider availability of LNG at ports around the world would be required.

Opportunities and challenges of Japan as LNG bunkering hub

Japan is the world's largest LNG import market, both by capacity and by import volumes. Its dominant import position is not expected to change. The rapid global oil price decline since late 2014 has greatly benefited large Japanese LNG importers and LNG markets are expected to remain in oversupply for several years (IEA, 2016). However, domestic consumption of LNG might drop in the years to come, as the share of renewable and nuclear power grows. This has prompted moves to diversify and liberalise the LNG market stimulating interest in LNG for shipping. Japan has limited domestic energy resources that have met less than 10% of the country's total primary energy use each year since 2012 (U.S. Energy Information Administration, 2017). Japan relies on LNG imports for 98% of its natural gas demand. Its LNG imports are relatively diversified and originate from Australia (22.9%), Malaysia (18.7%), Qatar (15.8%), Russia (8.5%), the United Arab Emirates (6.7%) and others (IEA, 2016).

Figure7. **Japan's natural gas imports by origin (1990-2015)**



Source: IEA (2016).

Japan's policies

In recent years, Japan's energy policy was focused on mitigating the impact from the 2011 Great East Japan earthquake and the subsequent Fukushima Daiichi nuclear accident, which led to the gradual shutdown of Japan's entire nuclear power capacity after March 2011, leaving a gap of around 30% in electricity supply. At the time, this energy gap was compensated primarily by LNG, which has led to rapidly growing LNG demand. The nuclear shutdown also led to replacement by oil and coal, provoking a massive increase in annual CO_2 emissions from power generation by more than 110 million tonnes, or by one-quarter in 2013 (IEA, 2016).

In 2014, the government reconsidered its energy policy and adopted the fourth Strategic Energy Plan (SEP) introducing safety among the key objectives of energy policy, alongside the three "Es" of energy security, economic efficiency and environmental protection. The SEP includes four goals for the gas market reform:

- "Secure the stable supply of natural gas, including the reinforcement of supply during disasters, through increasing gas pipeline networks, maintenance and interconnection;

- Lower gas prices to the maximum extent possible by promoting market competition among natural gas procurement and retail services and improve the lifestyle of citizens;

- Expand gas choice for consumers and bring about innovation by means of market entry of other industries and expansion of gas companies to other areas, by offering them greater diversity of retail choices and pricing plans for gas consumers;

- Expand natural gas use by promoting the participation of businesses that can build new gas pipelines, develop new markets for gas, and propose new utilisation methods for natural gas such as fuel cells and co-generation" (Japanese Agency for Natural Resources and Energy, 2015).

Based on the SEP, the Ministry of Economy, Trade and Industry (METI) adopted the "Long-Term Energy Supply and Demand Outlook" in July 2015. In line with Japan's climate objectives, the Outlook forecast a new electricity supply mix for 2030, projecting declines in the share for natural gas, coal and oil, a comeback of nuclear energy and a strong increase in renewable energy. Depending on the pace of nuclear restart, LNG imports are expected to slowly decline in the coming years (Rogers, 2016). In the long run, Japan's focus is shifting from securing long-term stability and sufficient quantity, to more flexibility, resilience and better market utilisation.

In a process involving major consumers and suppliers of LNG, METI developed a new Strategy for LNG Market Development which was adopted in May 2016. This strategy puts an emphasis on the importance of creating a flexible international LNG market, further promotion of LNG bunkering and speeding up berthing assessment of LNG vessels to ports, and sets out plans to develop an LNG trading hub in Japan. Conventional LNG contracts usually contain a destination clause that restricts the destination of LNG cargo, a practice that has hindered free resale of LNG outside of designated geographic markets (usually, the national domestic market). The Strategy insists on achieving a more flexible LNG market: easing or the elimination of destination clauses, which would help LNG importers avoid risks arising from volume commitments by enabling them to sell to additional markets. The Japanese Ministry of Economy, Trade and Industry (METI) hosted the LNG Producer-Consumer Conference in October 2017, where several Japanese initiatives were presented, matching the general awareness for the importance of improved LNG bunkering bases. METI announced joint public and private finance of around USD 10 billion to support Asian LNG demand and pledged to provide human resources and skills development for at least 500 people working or aiming to work in the LNG sector. Furthermore, commitments were made towards three initiatives: strengthening the flexibility, transparency and liquidity of Asian LNG markets; supporting port capacities to launch LNG bunkering; and working towards international consensus on a wider use of LNG via inter-governmental dialogue.

While Japan is the largest LNG importer worldwide, it pays some of the highest gas prices in the global LNG market, with most of the long-term contracts based on oil-indexed formulas, not necessarily reflecting the actual supply and demand on the LNG market (IEA, 2014). In this context, the Strategy mentions the need for price indices reflecting supply and demand of LNG and that METI is engaging in dialogue with domestic and international market players, including international LNG price reporting agencies, such as Platts, Argus, or RIM Intelligence. METI also attempts to work with LNG producers to remove destination clauses, create a price discovery mechanism, and liberalise domestic access to LNG infrastructure.

As part of the Gas Business Act of April 2017 partly liberalising the Japanese gas sector, the LNG terminal third-party use regime now enables third parties to utilise unused capacity of an LNG receiving terminal (LNG storage tanks), which is owned by either a city gas provider or an electric power utility

company. The revised Gas Business Act now prohibits owners of primary LNG receiving terminals with certain criteria from rejecting third parties that intend to use such terminals. The natural gas infrastructure in Japan is an important factor in the development of the LNG supply chain. Japan currently does not have any cross-border gas pipelines and has a relatively fragmented domestic pipeline network with a geographic coverage of 5.7% (IEA, 2016). The Strategy aims to promptly secure wide-area pipelines connecting major points of demand and underground gas storage facilities of sufficient capacity.

In June 2016, MLIT set up a Steering Committee to build a network of stakeholders to promote LNG bunkering comprising Tokyo Gas, Nippon Yusen Kabushiki Kaisha, Yokohama Kawasaki International Port, and the country’s administrative agencies. In December 2016, MLIT and the Steering Committee for LNG bunkering at the Port of Yokohama published a Feasibility Study to develop a bunkering hub at the Port of Yokohama. The Committee suggested a road map for the development of the LNG bunkering hub at the Port of Yokohama in three phases. The first phase will focus on the optimization of truck to ship bunkering operations, which is currently carried out at the port’s Shinko Pier. The second phase of the project envisages the start of ship-to-ship bunkering from 2020, while the third phase will include strengthening ship-to-ship bunkering when demand reaches a certain scale.

According to the Feasibility Study, developing an LNG bunkering hub required more collaboration between private enterprises, the national government and port management bodies. Possible incentive schemes could include a reduction in port fees to attract LNG fuelled ships calling the port of Yokohama. Along these lines, Yokohama Port and Harbour Bureau has taken direct support measures such as a subsidy system including assistance for selling LNG at the initial operational stage to reduce the cost of LNG fuel. The Bureau also considers making adjustments for their participation in the Environmental Ship Index (ESI) managed by the International Association of Ports and Harbours (IAPH) and Green Award operated by Green Award Foundation, which incentivise port calls of environmentally friendly ships. Ports are also encouraged to put in place LNG-fuelled service vessels to boost domestic demand for LNG propulsion. In Yokohama and Kawasaki, a government subsidised LNG-fuelled tugboat “Sakigake” has been in operation since August 2015. Another LNG-fuelled tugboat is expected to operate in Osaka Bay from April, 2019 along with an LNG fuel supply system at Sakai-Senboku Port (Mitsui O.S.K. Lines, 2018). In addition, four companies, Kawasaki Kisen Kaisha, Chubu Electric Power, Toyota Tsusho and NYK, began studying commercialisation of LNG fuel supply for ships in Chubu district (Nagoya and its surrounding region).

The Feasibility Study also suggests several operational solutions to remaining challenges to LNG bunkering at the Port of Yokohama. For example, one ongoing issue is the lack of separation of legal competencies between ship and shore operations. The Study suggests that the Ship Safety Law should be applied to the use of ship equipment and the use of LNG equipment between ships, such as a Ship to Ship bunkering, and the High Pressure Gas Safety Act should be applied to the use of terminal facilities for Shore to Ship bunkering. Regarding safety measures for bunkering operations, it is suggested that bunkering companies formulate specific safety measures in cooperation with the Japan Coast Guards and related parties.

In order to widen the network of LNG bunker-ready ports in Europe, the U.S. and Asia, MLIT joined an international network to develop common LNG bunkering standards in October 2016. In October 2016, the Port authorities of eight representatives from seven countries, including the Ports and Harbours Bureau of the Ministry of Land, Infrastructure, Transport and Tourism, concluded the “Memorandum of Understanding on Cooperation on the Development of LNG as a Marine Fuel (MoU)” as one of the approaches to form an LNG supply base network. The purpose of this MoU is to form a network among LNG bunkering bases and promote the uptake of LNG as a ship fuel by harmonising standards and specifications related to LNG bunkering. With growing interest to supply LNG as a marine fuel to meet future demands of the shipping industry, the network was further expanded to include the

Port of Ningbo-Zhoushan, Port of Marseille Fos and Port of Vancouver in July 2017. In this context, Japan promotes cooperation with other countries, especially with Singapore, which is the world's largest bunkering country. For instance in September 2016, the Japanese government attended the Japan-Singapore Summit Meeting and it was agreed that there is a need for strong cooperation in the development of LNG's fuel supply base as a ship fuel. In August 2017, the countries announced a joint study on the feasibility of LNG bunkering for car carriers between Japan and Singapore (LNG World News, 2017). The study is conducted by a working group including MLIT, MPA (Maritime and Port Authority of Singapore), K-Line, NYK and MOL.

Locational features and infrastructure

The location of ship bunkering hubs for heavy fuel oil (HFO) is generally dependent on their centrality along maritime routes and the proximity of refineries. The centrality guarantees that ships avoid too much deviation from their intended voyage, and therefore avoid time and financial losses when bunkering. The proximity of refineries minimises the price for heavy fuel oil, one of the residual products of the refinery process. As the energy content of HFO is very high, ships operating on HFO do not need to bunker very often. For this reason, bunkering facilities are concentrated in a handful bunkering hubs around the world, of which the biggest ones by bunker sales volumes are Singapore (48.6 million metric tons), Fujairah (24 million mt), Rotterdam (10.1 million mt), Hong Kong (7.4 million mt) and Antwerp (6.5 million mt).[4]

Former locational dynamics in ship bunkering are likely to change with the uptake of LNG. LNG takes up much more volume, so requires more frequent bunkering. In the case of cargo ships, LNG tanks are limited in size in order not to consume too much of the space dedicated to cargo. It is estimated for instance that the newest LNG hybrid container ship ordered by CMA CGM in November 2017 theoretically loses at least 1 500 TEU of capacity due to the space needed for LNG tanks, as compared to a similar container ship without LNG technology ordered by MSC.[5] The increased bunkering frequency expected with the uptake of LNG as a container ship propellant is changing locational dynamics in a way that a more decentralised worldwide bunkering infrastructure will be required.

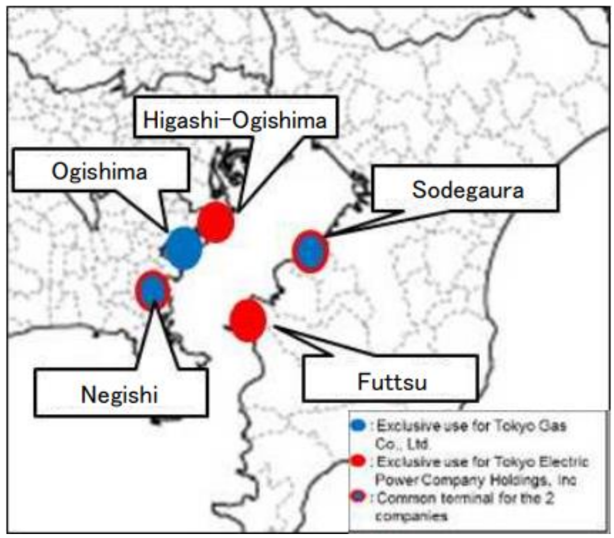
Japan generates substantial trade flows and thus maritime traffic, but scores fairly low on centrality in shipping networks, as it is not at the core of the largest maritime trade flows. While this limits its role as a transhipment hub, this is not relevant to its potential role as an LNG bunkering hub considering the more decentralised network of facilities needed for LNG bunkering.

The geographic location of Japan and more specifically the port of Keihin (which comprises Yokohama, Tokyo and Kawasaki) is nonetheless important. On the North Pacific route between Asia and North America, Keihin is the first port of the inbound trip (first discharging port) and the last port of the outbound trip (last loading port). Keihin has direct services to ports in North America. Furthermore, meteorological conditions throughout the year could allow for a relatively safe and stable harbour management.

As the world's largest LNG import market, Japan disposes of a dense network of primary terminals, which are listed in Annex 3. There are currently 40 LNG terminals on Japan's coasts of which four are under construction. Japan has eight secondary LNG terminals dedicated to domestic vessels. According to a feasibility study developed by the Steering Committee for LNG bunkering at the port of Yokohama[6], further advantages of the location of the port of Yokohama include the presence of nearby LNG infrastructures, such as the LNG terminals Negishi and Ogijima. Another three important LNG terminals, Higashi-Ogishima, Sodegaura and Futtsu, are located in the Tokyo bay area (Figure 8). In setting up an LNG hub in this area, the supply cost can be reduced by using the existing facilities. In developing

bunkering facilities, Japan bases itself on existing technology, knowledge and experience in handling LNG. Japanese ports already count on a staff base familiar with LNG safety regulations. Currently, LNG transported by large carriers from overseas is unloaded at primary LNG bases to Japanese domestic LNG carriers, in a process similar to ship-to-ship bunkering. Japan's experience and expertise related to LNG handling would suggest fast adaptation of all the upstream steps needed to make natural gas available for bunkering in different ports.

Figure 8. **Existing LNG terminal infrastructure in the Tokyo bay**



Source: MLIT (2016).

Table 2. **Capacities of LNG terminals in the Tokyo bay area**

LNG terminal name	Location	Owner	Total volume (cubic meter)	No. of tanks	Year
Sodegaura LNG terminal	Chiba	Tokyo Gas, Tokyo Electric Power	2 660 000	35	1973
Negishi LNG terminal	Kanagawa	Tokyo Gas, Tokyo Electric Power	1 180 000	14	1969
Futtsu terminal	Chiba	Tokyo Electric Power	1 110 000	10	1985
Ogishima LNG terminal	Kanagawa	Tokyo Gas	850 000	4	1998
East Ogishima terminal	Kanagawa	Tokyo Electric Power	540 000	9	1984

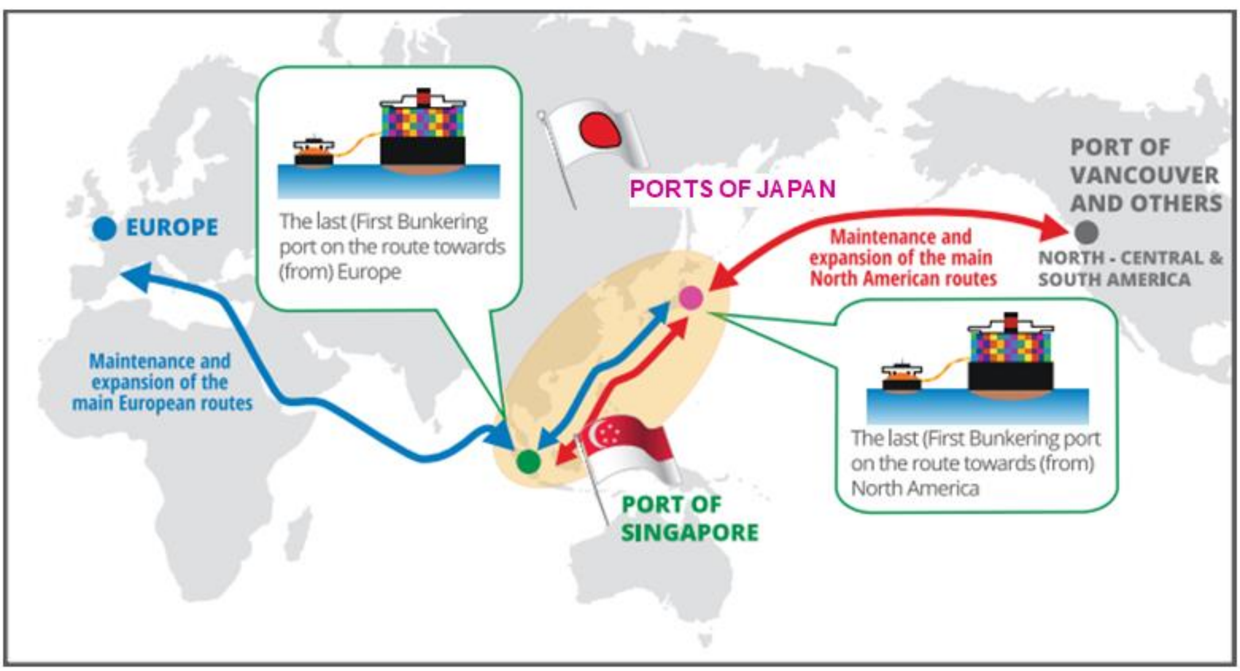
Source: METI, MLIT, IEA.

Currently, a pier to reload LNG exists at the Sodegaura Terminal although the Feasibility Study expects that demand for LNG would exceed available supply from this terminal, supporting investment in additional capacity at Yokohama's Negishi LNG terminal. The report also suggests that once ship-to-

ship bunkering will be introduced in 2020 as part of the second phase, the Sodegaura Terminal will need to upgrade its infrastructure to support an LNG bunker-supply ship exceeding tank capacity of 500 m^3.

Considering future scenarios, Asia could develop one dominant trading hub acting as a reference for the whole region. It would also be possible for several trading hubs to coexist in Asia, given the expected future size of the Asian market, which was estimated at over 1 trillion cubic metres by 2035 (IEA, 2014). MLIT collaborates in a focus group together with other ports and administrative entities that are striving to become major LNG bunkering locations, and cooperates directly with the Maritime and Ports Authority of Singapore. According to the vision of this collaboration, Singapore would become a bunkering hub for Southeast Asia or Europe-bound trade, and Japan would a hub for East Asia and North America-bound trade. By engaging in strategic cooperation, the countries aim to streamline equipment standards, qualifications required for seafarers and safety measures, which facilitate the operation of LNG-fuelled ships. While there are no harmonised standards yet, the countries involved expect to simplify the uptake of LNG as a ship fuel and contribute in developing a global market by further harmonising their standards.

Figure 9. **Collaboration between Japan and the Port of Singapore to establish two major Asian bunkering hubs**



Source: MLIT (2016).

There is an opportunity for Japan's ports to leverage the operational pattern of container ships by offering LNG bunkering facilities to the liner shipping companies. Specifically focusing on liner shipping, which has the advantage of fixed routes, should be done in collaboration with other ports on the traditional liner shipping routes. This will ensure that the ports "on the other end" have a similar LNG offering so that the fuel tank size could be minimised on traditional liner routes for higher profitability. Such an approach may be the easiest way for overcoming the "chicken and egg" problem that assumes that LNG demand also depends on the availability of bunkering infrastructure.

The bunkering frequency for LNG fuelled ship is dependent on ship type and ship size. For example, the bunkering frequency of small and mid-size tankers operating in coastal trade in Northern Europe is around twice a month, which is approximately the same bunkering frequency for a similar ship fuelled by HFO. The bunkering time for these ships can amount to up to 20 hours if it is truck-to-ship bunkering and 6-12 hours for ship-to-ship bunkering, depending on bunkering procedures and pumping capacity. Considering the substantial time that bunkering operations take – which represent a monetary value for the ship operator – most operators would prefer bunkering to take place at the same time as the loading/unloading of the ship. This is starting to happen in Northern European ports. There are concerns about simultaneous LNG bunkering and handling operations of cargoes with a sensitive flashpoint, but it is happening for less risky cargoes. One example is at the port of Gothenburg (Sweden) where simultaneous LNG bunkering and loading of diesel/gasoil has taken place.

The port of Yokohama is a large diversified port, which acts as a hub for Japan, in particular the east of Japan. This national hub function is well illustrated by the large amount of feeder connections from Yokohama to Eastern Japan and a relatively large share of domestic ship calls: 25 828 out of 35 131 total calls in 2016 (74%). Almost all of these domestic ships are smaller than 10 000 dwt; the largest domestic ship categories are tankers and carriers for building materials (sand, gravel and stones). Around half of the calls from ocean going vessels are from container ships; smaller ship categories include general cargo ships, pure car carriers and tankers.

This reflects a broader point to be made on Japan: its locational advantage along main maritime trade lanes. Its developed consumer and producer market has turned Japan into a crucial node along East-West maritime trade lanes. This is reflected in the significant maritime flows touching Japanese ports, from ships as diverse as container carriers, tankers, car carriers and grain carriers. Japan has also emerged as a cruise destination and seen an increasing number of calls from cruise ships. Japan is well-positioned to become an international LNG bunkering hubs for these types of ships if they were to be LNG-fuelled in the future.

Policy and regulatory aspects

The prospect for the uptake of LNG as a ship propellant is helped by recent policy decisions, both at the global level and regional level, including important trade partners of Japan. The Marine Environment Protection Committee (MEPC) of the International Maritime Organisation (IMO) decided in October 2016 to set a global cap for the sulphur content of marine fuels from 3.5% to 0.5% by 2020 (revised MARPOL Annex VI). Consequently, ship operators will need to switch either to cleaner, more expensive bunker fuels, such as low sulphur fuel oil, diesel, LPG or LNG, or invest in exhaust gas cleaning systems (scrubbers). In this context, endorsements for LNG by major operators such as CMA CGM could serve as catalyst for broader uptake.

Stringent rules on sulphur emissions already exist on a regional level, including in the legislations of Japan’s key trade partners. Both North Europe and North America have emission control areas (ECAs) in which stricter controls were established to minimize airborne emissions from ships. Since 1 January, 2015, only 0.1% sulphur content is allowed in these areas. Existing ECAs include the Baltic Sea, the North Sea, the North American ECA including most of U.S. and Canadian coats, and the U.S. Caribbean ECA including Puerto Rico and the Virgin Islands since 2014. China has installed its own emission control areas, where a 0.5% limit will be effective from 2018.

Table 3. **Special areas under MARPOL Annex VI**

MARPOL Annex VI: Prevention of air pollution by ships (Emission Control Areas)			
Special Areas	**Adopted**	**Date of Entry into Force**	**In Effect From**
Baltic Sea (SO_x)	26 Sept 1997	19 May 2005	19 May 2006
North Sea (SO_x)	22 Jul 2005	22 Nov 2006	22 Nov 2007
North American ECA (SO_x & PM)	26 Mar 2010	1 Aug 2011	1 Aug 2012
(NO_x)	26 Mar 2010	1 Aug 2011	***
US Caribbean Sea ECA (SO_x & PM)	26 Jul 2011	1 Jan 2013	1 Jan 2014
(NO_x)	26 Jul 2011	1 Jan 2013	***

*** A ship constructed on or after 1 January 2016 and is operating in these emission control areas shall comply with NOx Tier III standards set forth in regulation 13.5 of MARPOL Annex VI.
Source: IMO

In 2014, demand of LNG for transport was still negligible, representing only 0.1% of total Japanese gas consumption (IEA, 2016). In this context, public incentives and investments are considered an appropriate means to support the uptake of LNG, as a meta-review of existing studies suggests (Wang, 2013). National incentives in the form of financial support such as environmental incentives and ports and national funds such as the NO_x fund (Norway) can significantly impact the way stakeholders comply with environmental regulation (OECD/ITF, forthcoming). Ship builders in Japan can apply for government subsidies under a scheme that promotes green ship building, including LNG compatible ships. In order to incentivize the construction of LNG bunkering vessels and facilities, from FY 2018, another subsidy system has been introduced for business operators who will establish bunkering bases at the Japanese ports. In addition, the Japanese government has implemented a R&D scheme "Improving Productivity in Ship Building and Operation" that supports research and naval design targeted at the reduction of CO2 emissions.

Some European port authorities, like Rotterdam and Antwerp, have established port-specific emission regulations that give a discount in port fees to ship owners who use clean fuels for their vessels (i.e. based on different indices such as the Environmental Ship Index (ESI)). Table 4 provides an overview of diverse approaches which directly or indirectly support the uptake of alternative ship fuels.

Table 4. **Selected emission reduction incentives**

Port, country or other administrative entity	**Policy measure, incentive or funding**
28 out of the 100 largest ports worldwide (in terms of volume handled), including 4 Japanese ports: **Tokyo, Yokohama, Nagoya, Kitakyushu**	Environmental port fees. Example Rotterdam: Differentiated port dues and discounts to vessels with a high Environmental Ship Index (ESI) score or a Green Award certificate. Further discounts are granted based on low NOx emissions (individual NOx score).
Ports of Antwerp, Bremerhaven, Gothenburg, Hamburg, Panama Canal Authority, Rotterdam, Singapore	Deduction of port fees for LNG-powered vessels.

Ports of Los Angeles, Long Beach	Incentives for the use of IMO Tier III engines.
China, Turkey, Norway	Scrap and build subsidies.
Denmark	Blue INNOship: funding for innovation projects in collaboration with academia.
Finland	Investment aid programme targeted at SO_x emissions, project duration: 2010-2014. The fund supported mainly scrubber retrofitting, one LNG newbuild and one LNG conversion, as well as 4 LNG terminal projects.
Japan	Grant by MLIT for shipbuilding and ship machinery companies (started in 2009) which carry out R&D for CO_2 emissions reduction in international shipping. Subsidies for LNG-compatible ship building Subsidies for ports for LNG bunkering facilities. R&D scheme “Improving Productivity in Ship Building and Operation”, supporting research and naval design targeted at the reduction of CO_2 emissions.
Norway	NO_x Fund: All ships operating in Norway pay a fee into the fund. Shipping companies can then apply for a subsidy from the same fund to finance projects that would help to reduce NO_x emissions from their ships. The project was introduced in 2007 and involves a budget of NOK 700 million/year (€71 million/year).
Romania	Blue growth projects: i.e. support for LNG hybrid solutions, as well as R&D grants.
Singapore	25% reduction in port dues for ocean-going ships using scrubbers or cleaner fuels (max. 0.5% sulphur content). Vessel registration: Tax deduction (up to 75%) and Initial Registration fees (up to 50%). Funds to promote LNG bunkering vessels and LNG-fuelled vessels
City of Shanghai	Emission trading scheme, compulsory emission reports, financial sanctions for fraudulent information or non-compliance with sector-specific threshold of 10,000t CO_2/year.
EU/EIB	Loan guarantees to ship owners for greener vessel purchases.

Source: Based on OECD/ITF (forthcoming) and OECD (2016).

In addition, ports have established networks to discuss about common challenges and approaches towards LNG bunkering. An international focus group was formed in 2014 to cooperate on harmonising LNG bunkering standards, which initially consisted of the ports of Singapore, Rotterdam, Antwerp and Zeebrugge. Other ports and public authorities joined in October 2016: the Port of Jacksonville Florida; the Norwegian Maritime Authority; the Japanese Ministry of Land, Infrastructure, Transport and Tourism, and Ulsan Port Authority (South Korea). This focus group based on a MoU attempts to facilitate information sharing and alignment of key aspects of the LNG bunkering process across participating ports (MPA Singapore, 2016).

Several policy measures are underway to back the development of supply infrastructure and LNG bunkering facilities. The United Arab Emirates is reportedly planning to install LNG storage facilities at the Port of Fujairah, which is currently the world’s second-largest bunkering hub (OPEC, 2017). Additionally, the EU approved the Commission’s Trans-European Transport Network (TEN-T) proposal to fund an LNG pipeline from Italy to Malta to speed up the deployment of alternative marine fuels (European Commission, 2017).

EU directive 94/2014 on the deployment of alternative fuels infrastructure stipulates that all TEN-T core ports (list established by Regulation (EU) No 1315/2013, TEN-T Core Network) need to be

equipped either with LNG bunkering facilities or shore power facilities. According to Article 6, §1 of the directive, Member States shall ensure, by means of their national policy frameworks, that an appropriate number of refuelling points for LNG are put in place at maritime ports, to enable LNG inland waterway vessels or seagoing ships to circulate throughout the TEN-T Core Network by 31 December, 2025.

In Singapore, the Maritime and Ports Authority of Singapore (MPA) has in 2017 invested SGD 12 million (Singapore dollar) to boost LNG bunkering in the Port of Singapore. Half of this investment has been reserved to co-fund the building of new LNG bunkering vessels to facilitate the development of ship-to-ship bunkering. The remaining half will be used to top up MPA's existing co-funding programme to support the building of LNG-fuelled vessels. Applications to this new fund are open to companies incorporated in Singapore and the funded vessels must be registered under the Singaporean flag and licensed for bunkering activity in the port of Singapore for a period of at least five years.

This set of regulations in place gives a good indication of the likelihood of uptake of LNG-propelled ships worldwide. Furthermore, IMO's decision on a global sulphur cap has added a degree of clarity and predictability to ship owners considering switching to LNG and other alternative fuels. Whereas these developments strongly benefit Japan's strategy to develop into an LNG bunkering hub, some risks and challenges remain.

Potential risks and uncertainties

Compared to the use of diesel fuel, use of LNG will reduce NO_x emissions by about 90% on a lean burn gas fuelled engine, and SO_x emissions are negligible without any need for abatement technology on the ship. CO_2 emissions from ships are about 20% lower compared to diesel fuel (IMO, 2016). However, the overall GHG emissions of LNG need to be studied further, especially emissions of methane and thus the overall impact on the climate compared to conventional fuels (Anderson, 2015). In order to retain the climate benefits of LNG, it is important to address fugitive methane emissions and exhaust emissions of unburnt methane. While currently regulations are focused on SO_x and NO_x emissions from ships content of fuel, it cannot be excluded that future regulation will cover methane gas emissions, which might make LNG a less attractive option as ship fuel.

It is likely that only with regulatory clarity and established international standards for safe handling will LNG become a mainstream option for ship propulsion. The Feasibility Study Report on the LNG bunkering hub development plan at the Port of Yokohama notices e.g. the lack of global standards for LNG quality as a ship fuel, the calibre of LNG hoses, emergency withdrawal devices and the weighing method for LNG bunkering (MLIT, 2016).

The choice of LNG strategies and bunkering methods will depend on the vessel type, as well as applicable legislation and guidelines. The IGF Code, International Code of Safety for Ships using Gases or other low Flashpoint Fuels, entered into force on January 1, 2017. Amendments to the International Convention for the Safety of Life at Sea (SOLAS) include the IGF code as a mandatory instrument applicable to all ships using gases and other low flashpoint fuels, built or converted after January 2017. IMO is also in the process of developing a standard for bunkering systems and equipment for supplying LNG as fuel to ships (ISO 20519 "Ships and marine technology – Specification for bunkering of gas fuelled ships"). A draft has been published in June 2013, ISO/DTS 18683: Guidelines for Systems and Installations for Supply of LNG as Fuel to Ships (IMO, 2016). While the standards are in place for ships, safety measures of shore-side activities often still depend on mutual agreements and cooperation between major players (MPA Singapore, 2016). The IGF code covers only the ship side of the bunkering operation (including the flange on the ship side). Covering new training requirements for seafarers, these

provisions also highlight the need for qualified and adequately trained personnel on the ship as well as on the shore.

Despite a gradually rising demand, global uptake of LNG as a ship fuel is still in the initial phase, and that a broad uptake remains an open-ended question. Due to the high costs of investing in a new fleet, ship owners might prefer to change only the type of fuel or invest in scrubbers to be installed on the ship, i.e. when the construction costs are much more important than the difference in fuel costs. Uptake will also depend on the presence of an inexpensive and efficient supply system, as well as competitive LNG prices. Competitive LNG prices can further incentivise alternative fuel investment strategies by firms.

Global discussions are now focusing on reduction of GHG emission from ships. IMO member states are preparing an Initial GHG Strategy for Shipping that would need to be approved in April 2018. This Initial Strategy will likely contain targets for GHG reductions and possible measures to achieve these. As mentioned above, the use of LNG allows for CO_2 reductions of ships of about 20%. However, with the prospect that international or local regulations could become more stringent, it is possible that some industry actors explore alternative other options to reduce CO_2 emissions. Several observers have already warned that massive investment in LNG ships and LNG bunkering facilities might present a risk of creating “stranded assets” in case of a strong push for decarbonisation of maritime transport (UMAS, 2016). Although there is a gradual increase in the use of LNG, long-term strategies for GHG emission reductions from shipping should bear in mind other possible mitigation scenarios.

Conclusion

This analysis confirms the strategic importance for Japan of investing in LNG bunkering facilities in anticipation of the 0.5% global sulphur cap in 2020. The sulphur regulations in the emission control areas in Northern Europe have generated orders and deliveries for LNG fuelled ships operating in coastal trades. This might also happen in Japan in anticipation or following the 2020 sulphur cap. Given its current level of infrastructure, experience and geographical position, Japan will most likely be able to secure a competitive advantage vis-à-vis other Asian ports that are developing similar LNG bunkering facilities. With LNG bunkering facilities in place, particularly the ports in the Tokyo Bay area will strengthen their current position as key regional and international ports and enable the emerging East-West LNG fuelled ship traffic to trade in Japan.

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Annex 1: LNG-fuelled fleet on 1 December 2017

Year	Type of vessel	Owner	Class
2000	Car/passenger ferry	Fjord1	DNV GL
2003	PSV	Simon Møkster	DNV GL
2003	PSV	Eidesvik	DNV GL
2006	Car/passenger ferry	Fjord1	DNV GL
2007	Car/passenger ferry	Fjord1	DNV GL
2007	Car/passenger ferry	Fjord1	DNV GL
2007	Car/passenger ferry	Fjord1	DNV GL
2007	Car/passenger ferry	Fjord1	DNV GL
2008	PSV	Eidesvik Shipping	DNV GL
2009	PSV	Eidesvik Shipping	DNV GL
2009	Car/passenger ferry	Tide Sjø	DNV GL
2009	Car/passenger ferry	Tide Sjø	DNV GL
2009	Car/passenger ferry	Tide Sjø	DNV GL
2009	Patrol vessel	Remøy Management	DNV GL
2009	Car/passenger ferry	Fjord1	DNV GL
2010	Patrol vessel	Remøy Management	DNV GL
2010	Car/passenger ferry	Fjord1	DNV GL
2010	Patrol vessel	Remøy Management	DNV GL
2010	Car/passenger ferry	Fjord1	DNV GL
2010	Car/passenger ferry	Fjord1	DNV GL
2010	Car/passenger ferry	Fosen Namsos Sjø	DNV GL
2011	PSV	DOF	DNV GL
2011*	Oil/chemical tanker	Tarbit Shipping	DNV GL
2011	Car/passenger ferry	Fjord1	DNV GL
2011	PSV	Solstad Rederi	DNV GL
2012*	Car/passenger ferry	Fjord1	DNV GL
2012	PSV	Eidesvik	DNV GL
2012	PSV	Olympic Shipping	DNV GL
2012	PSV	Island Offshore	DNV GL
2012	General Cargo	Nordnorsk Shipping	DNV GL
2012	PSV	Eidesvik Shipping	DNV GL
2012	PSV	Island Offshore	DNV GL
2012	Car/passenger ferry	Torghatten Nord	DNV GL
2012	Car/passenger ferry	Torghatten Nord	DNV GL
2012	Car/passenger ferry	Torghatten Nord	DNV GL
2013	PSV	REM	DNV GL
2013	RoPax	Viking Line	LR
2013	Car/passenger ferry	Torghatten Nord	DNV GL
2013	Tug	Incheon Port Authority	KR
2013	General Cargo	Eidsvaag	DNV GL
2013	RoPax	Fjordline	DNV GL

Year	Type of vessel	Owner	Class
2013	High speed RoPax	Buquebus	DNV GL
2013	Tug	CNOOC	CCS
2013	Tug	CNOOC	CCS
2013	Car/passenger ferry	Norled	DNV GL
2014	Car/passenger ferry	Norled	DNV GL
2014	Tug	Buksér & Berging	DNV GL
2014	RoPax	Fjordline	DNV GL
2014	Patrol vessel	Finish Border Guard	DNV GL
2014	Tug	Buksér & Berging	DNV GL
2014	Gas carrier	Anthony Veder	BV
2014	Gas carrier	Anthony Veder	BV
2014	PSV	Remøy Shipping	DNV GL
2014	General Cargo	Egil Ulvan Rederi	DNV GL
2014	General Cargo	Egil Ulvan Rederi	DNV GL
2014	PSV	Siem Offshore	DNV GL
2015	PSV	Harvey Gulf Int.	ABS
2015	Ro-Ro	Norlines	DNV GL
2015	Car/passenger ferry	Samsoe municipality	DNV GL
2015	PSV	Simon Møkster Shipping	DNV GL
2015	PSV	Siem Offshore	DNV GL
2015	Ro-Ro	Norlines	DNV GL
2015*	Oil/chemical tanker	Bergen Tankers	LR
2015	Car/passenger ferry	Society of Quebec ferries	LR
2015	Gas carrier	Evergas	BV
2015	Gas carrier	Evergas	BV
2015	Tug	CNOOC	CCS
2015*	Car/passenger ferry	AG Ems	DNV GL
2015	Tug	NYK	NK
2015	Gas carrier	Chemgas Shipping	BV
2015	Gas carrier	Evergas	BV
2015	PSV	Harvey Gulf Int.	ABS
2015	Container ship	TOTE Shipholdings	ABS
2015	Car/passenger ferry	AG EMS	DNV GL
2015	Bulk ship	Erik Thun	LR
2016	Container ship	TOTE Shipholdings	ABS
2016	Gas carrier	Evergas	BV
2016	PSV	Harvey Gulf Int.	ABS
2016	Bulk ship	Erik Thun	LR
2016	Oil/chemical tanker	Terntank	BV
2016	Gas carrier	Navigator Gas	ABS
2016*	Oil/chemical tanker	Furetank Rederi	BV
2016	Icebreaker	Arctica Shipping	LR
2016	Car/passenger ferry	Boreal Transport Nord	DNV GL
2016	Car/passenger ferry	Boreal Transport Nord	DNV GL
2016	Tug	CNOOC	CCS

Year	Type of vessel	Owner	Class
2016	Gas carrier	Chemgas Shipping	BV
2016	Car carrier	UECC	DNV GL
2016	Oil/chemical tanker	Terntank	BV
2016	Oil/chemical tanker	Terntank	BV
2016	Car/passenger ferry	BC Ferries	LR
2016	Gas carrier	Evergas	BV
2016	PSV	Siem Offshore	DNV GL
2016	Car/passenger ferry	Seaspan Ferries Corp.	BV
2016	Gas carrier	Navigator Gas	ABS
2016	Ro-Ro	Searoad Holdings	DNV GL
2016	Car carrier	UECC	DNV GL
2017	Gas carrier	Navigator Gas	ABS
2017	Car/passenger ferry	Seaspan Ferries Corp.	BV
2017*	RoPax	Baleària	BV
2017	RoPax	Tallink	BV
2017	Gas carrier	Ocean Yield	DNV GL
2017	PSV	Harvey Gulf Int.	ABS
2017	Tug	Østensjø Rederi	BV
2017	Oil/chemical tanker	Groupe Desgagnés	BV
2017	Oil/chemical tanker	Terntank	BV
2017	Car/passenger ferry	BC Ferries	LR
2017	Gas carrier	Ocean Yield	DNV GL
2017	Gas carrier	Evergas	BV
2017	Gas carrier	Evergas	BV
2017	Gas carrier	Evergas	BV
2017	Tug	Østensjø Rederi	BV
2017	Tug	Østensjø Rederi	BV
2017	Dredger	DEME	BV
2017*	Container ship	Wessels Reederei	BV
2017	Car/passenger ferry	BC Ferries	LR
2017	Dredger	DEME	BV
2017	Gas carrier	Navigator Gas	ABS

The list excludes LNG carriers and inland waterway vessels. * - conversion project.

Source: DNV GL (2017)

Annex 2: Orderbook of LNG-fuelled vessels on 1 December 2017

Year	Type of vessel	Owner	Class
2017	Tug	Drydocks World	Tasneef
2017	Hopper Barge	Bremenports	DNV GL
2017	PSV	Harvey Gulf Int.	ABS
2017	Cable layer	DEME Tideway	DNV GL
2017	RoPax	Rederi AB Gotland	DNV GL
2017	Oil/chemical tanker	Groupe Desgagnés	BV
2017	Container ship	Crowley Maritime Corp.	DNV GL
2017	Bulk ship	POSCO	KR
2018	Container ship	Brodosplit	DNV GL
2018	Container ship	Brodosplit	DNV GL
2018	Bulk ship	ESL Shipping	DNV GL
2018	Bulk ship	ESL Shipping	DNV GL
2018	Car/passenger ferry	Society of Quebec ferries	LR
2018	Car/passenger ferry	Society of Quebec ferries	LR
2018	PSV	Siem Offshore	DNV GL
2018	PSV	Siem Offshore	DNV GL
2018*	Ro-Ro	TOTE Shipholdings	ABS
2018*	HSLC	Fred. Olsen	DNV GL
2018*	Car/passenger ferry	BC ferries	ABS
2018	Car/passenger ferry	Caronte & Tourist	RINA
2018	Oil/chemical tanker	Groupe Desgagnés	BV
2018	Oil/chemical tanker	Groupe Desgagnés	BV
2018	Container ship	Crowley Maritime Corp.	DNV GL
2018	Tug	Keppel Smit Towage	ABS
2018	Tug	Maju Maritime	ABS
2018*	Car/passenger ferry	BC ferries	ABS
2018	PSV	Harvey Gulf Int.	ABS
2018	Container ship	Brodosplit	DNV GL
2018	Container ship	Brodosplit	DNV GL
2018	Car/passenger ferry	Royal Doeksen	LR
2018	Car/passenger ferry	Royal Doeksen	LR
2018	Car/passenger ferry	CHFS	LR
2018	Car/passenger ferry	CHFS	LR
2018*	Ro-Ro	TOTE Shipholdings	ABS
2018	RoPax	Rederi AB Gotland	DNV GL
2018	General cargo ship	Nordnorsk Shipping	DNV GL
2018	Container ship	Container ships	ABS
2018	Container ship	Container ships	ABS
2018	Container ship	GNS Shipping	ABS
2018	Container ship	GNS Shipping	ABS
2018	Heavy lift vessel	Heerema Offshore	LR

Year	Type of vessel	Owner	Class
2018	Oil/chemical tanker	Furetank Rederi	BV
2018	Oil/chemical tanker	Furetank Rederi	BV
2018	Oil/chemical tanker	Furetank Rederi	BV
2018	Dredger	DEME	BV
2018	Dredger	van der Kamp	DNV GL
2018	Oil/chemical tanker	Thun Tankers	
2018	Oil/chemical tanker	SCF	DNV GL
2018	Oil/chemical tanker	SCF	DNV GL
2018	Oil/chemical tanker	AET	ABS
2018	Oil/chemical tanker	AET	ABS
2018	Car/passenger ferry	Torghatten	DNV GL
2018	Bunker ship	Harley Marine Services	
2018	Bunker ship	Harley Marine Services	
2018	Bunker ship	Sinanju Tankers	
2018	Reefer	SeOil Agency/Gas Entec	
2018	Car/passenger ferry	Torghatten	DNV GL
2018	Car/passenger ferry	Torghatten	DNV GL
2018	Car/passenger ferry	Torghatten	DNV GL
2019	Car/passenger ferry	Torghatten	DNV GL
2019	Oil/chemical tanker	Thun Tankers	BV
2019	Oil/chemical tanker	Thun Tankers	BV
2019	Oil/chemical tanker	Thun Tankers	BV
2019	Oil/chemical tanker	SCF	DNV GL
2019	Oil/chemical tanker	SCF	DNV GL
2019	Oil/chemical tanker	SCF	DNV GL
2019	Oil/chemical tanker	SCF	DNV GL
2019	Oil/chemical tanker	AET	ABS
2019	Oil/chemical tanker	AET	ABS
2019	Tug	Mitsui O.S.K. Lines	
2019	Cruise ship	Carnival Corporation	RINA
2019	Cruise ship	Carnival Corporation	RINA
2019	Oil/chemical tanker	Thun Tankers	BV
2019	Offshore installation ship	DEME	DNV GL
2019	Dredger	DEME	BV
2019	RoPax	Baleària	BV
2019	Car carrier	Siem Car Carriers	ABS
2019	Car carrier	Siem Car Carriers	ABS
2019	Emergency response ship	German Transport Ministry	
2019	Emergency response ship	German Transport Ministry	
2019	RoPax	Brittany Ferries	BV
2019	RoPax	Baleària	
2019	RoPax	Baleària	
2019	Shuttle tanker	AET	DNV GL
2019	Shuttle tanker	AET	DNV GL
2019	RoPax	Polish Baltic Shipping Co	

Year	Type of vessel	Owner	Class
2019	RoPax	Polish Baltic Shipping Co	
2019	Shuttle tanker	Teekay Offshore	DNV GL
2019	Container Ship	CMA CGM	BV
2019	Oil/chemical tanker	Älvtank	BV
2019	Oil/chemical tanker	Älvtank	BV
2020	Container Ship	CMA CGM	BV
2020	Container Ship	CMA CGM	BV
2020	Container Ship	CMA CGM	BV
2020	Container Ship	CMA CGM	BV
2020	Container Ship	CMA CGM	BV
2020	Container Ship	CMA CGM	BV
2020	Container Ship	CMA CGM	BV
2020	Shuttle tanker	Teekay Offshore	DNV GL
2020	Shuttle tanker	Teekay Offshore	DNV GL
2020	Shuttle tanker	Teekay Offshore	DNV GL
2020	Container ship	Pasha Hawaii	
2020	Container ship	Pasha Hawaii	
2020	Research ship	German Transport Ministry	
2020	RoPax	Viking Line	DNV GL
2020	Cruise ship	Carnival Corporation	RINA
2020	Cruise ship	Carnival Corporation	RINA
2021	Container Ship	CMA CGM	BV
2021	Oil/chemical tanker	Rosneft	RR
2021	Oil/chemical tanker	Rosneft	RR
2021	Oil/chemical tanker	Rosneft	RR
2021	Oil/chemical tanker	Rosneft	RR
2021	Oil/chemical tanker	Rosneft	RR
2021	Cruise ship	Carnival Corporation	RINA
2021	Cruise ship	Carnival Corporation	
2021	Cruise ship	Disney Cruise Lines	
2022	Cruise ship	Carnival Corporation	RINA
2022	Cruise ship	MSC Cruises	
2022	Cruise ship	RCCL	
2022	Cruise ship	Disney Cruise Lines	
2023	Cruise ship	Disney Cruise Lines	
2024	Cruise ship	MSC Cruises	
2024	Cruise ship	RCCL	

The list excludes LNG carriers and inland waterway vessels.

Source: DNV GL (2017)

Annex 3: LNG Primary LNG Terminals in Japan

Name	Owner	Total capacity (thousand cm^3)	Operations start year
Soma LNG Terminal	JAPEX	n/a	2018
Sodegaura LNG Terminal	TEPCO, Tokyo Gas	2 660	1973
Senboku II Terminal	Osaka Gas	1 585	1977
South Yokohama Thermal Power Plant Negishi LNG Terminal	TEPCO, Tokyo Gas	1 180	1969
Futtsu Thermal Power Plant	TEPCO	1 110	1986
Wakayama LNG Terminal	The Kansai Electric Power	840	2022
Himeji Terminal	Osaka Gas	740	1984
Nihonkai LNG Niigata Terminal	Nihonkai LNG (Tohoku Electric Power, Development Bank of Japan, Niigata Prefecture, etc.)	720	1984
Chita LNG Terminal	Chita LNG (Chubu Electric Power, Toho Gas)	640	1983
Ohgishima LNG Terminal	Tokyo Gas	600	1998
Joetsu Thermal Power Plant	Chubu Electric Power	540	2012
Higashi Ohgishima Thermal Power Plant	TEPCO	540	1984
Himeji LNG Terminal	The Kansai Electric Power	520	1979
Tobata LNG Terminal	Kitakyusyu Liquefied Natural Gas (Kyushu Electric Power, Nippon Steel and Sumitomo Metal)	480	1977
Yanai Thermal Power Plant	The Chugoku Electric Power	480	1990
Kawagoe Thermal Power Plant LNG Facilities	Chubu Electric Power	480	1997
Oita LNG Terminal	Oita Liquefied Natural Gas (Kyushu Electric Power, Oita Gas)	460	1990
Sakai LNG Center	Sakai LNG (The Kansai Electric Power, Iwatani, Cosmo Oil, Ube Industries)	420	2006
Chita Midorihama LNG Terminal	Toho Gas	400	2001

Hibiki LNG Terminal	Hibiki LNG (Saibu Gas, Kyushu Electric Power)	360	2014
Naoetsu LNG Terminal	INPEX	360	2014
Shimizu LNG Sodeshi Terminal	Shimizu LNG (Shizuoka Gas, TonenGeneral Sekiyu)	337.2	1996
Shinsendai Thermal Power Plant	Tohoku Electric Power	320	2016
Mizushima LNG Terminal	Mizushima-LNG-Group (The Chugoku Electric Power, JX Nippon Oil & Energy)	320	2006
Yokkaichi LNG Center	Chubu Electric Power	320	1988
Chita LNG Joint Terminal	Chubu Electric Power, Toho Gas	300	1978
Hachinohe LNG Terminal	JX Nippon Oil & Energy	280	2015
Yoshinoura Thermal Power Plant	Okinawa Electric Power	280	2012
Joetsu Thermal Power Plant	Chubu Electric Power	240	2023
Hitachi LNG Terminal	The Kansai Electric Power	230	2015
Yokkaichi LNG Terminal	Toho Gas	230	1991
Toyama Shinminato Thermal Power Plant	Hokuriku Electric Power	180	2018
Ishikari LNG Terminal	Hokkaido LNG	180	2012
Sakaide LNG Terminal	Sakaide LNG (Shikoku Electric Power, Cosmo Oil, Shikoku-Gas)	180	2010
Hatsukaichi LNG Terminal	Hiroshima Gas	170	1996
Senboku I Terminal	Osaka Gas	90	1972
Kagoshima LNG Terminal	Nihon Gas	86	1996
Gas Bureau City of Sendai LNG Terminal	Sendai City	80	1997
Fukuoka LNG Terminal	Saibu Gas	70	1993
Nagasaki LNG Terminal	Saibu Gas	35	2003

Total: 19 043.2

Note: Terminals are listed in the order of total capacity. Rows in grey include terminals with an operations start date later than 2017.

Source: MLIT.

Notes

1 At the time of writing, based on DNV GL (2017) data on 01.12.2017.

2 Calculated based on UNCTADstat (2017) and DNV GL (2017).

3 Without a fixed schedule or ports of call.

4 Numbers are from 2015, except for Singapore and Rotterdam (2016). Source: www.shipandbunker.com

5 Industry observers believe that both CMA CGM and MSC have chosen MGX24 technology vessels with nominal intakes of 22,000 TEU (CMA CGM) and 23,500 TEU (MSC). Both companies have reached a different conclusion on the propulsion of the vessels. The difference of nominal capacity would therefore be due to the size of the LNG tanks on CMA CGM vessels. See King, M./Lloyd's Loading List (2017).

6 The Ports and Harbours Bureau of the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) of Japan has established a Steering Committee on the development of LNG bunkering hub at the Port of Yokohama in June 2016. Members are TOKYO GAS CO., LTD., NYK Line, Yokohama Kawasaki International Port Co., Ltd., the City of Yokohama, the Japanese Agency for Natural Resources and Energy of the Ministry of Economy, Trade and Industry, the Maritime Bureau of MLIT, the Ports and Harbours Bureau of MLIT, and the Japan Coast Guard. Observers are the Ministry of Economy, Trade and Industry (METI) and the Kanto Regional Development Unit of MLIT.

International Transport Forum

Fuelling Maritime Shipping with Liquefied Natural Gas

The Case of Japan

The use of Liquefied Natural Gas (LNG) as a ship fuel is expected to increase significantly from its current marginal share in the coming years. This will require new facilities where ships can take on board the LNG. Japan is positioning itself as a potential hub in Asia for LNG refuelling. This study assesses the factors that will influence the realisation of that ambition.

This report is part of the International Transport Forum's Case-Specific Policy Analysis series. These are topical studies on specific issues carried out by the ITF in agreement with local institutions.

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