Feasibility Study Report

on

the LNG bunkering hub development plan

at the Port of Yokohama

December 2016

The Steering committee

for LNG bunkering at the port of Yokohama

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Introduction

Due to the tightening of international regulations on emissions from shipping, the conversion of ship fuel from heavy oil to LNG with cleaner emissions is expected to proceed and LNG fuelled ships have already launched in a part of North America and Europe where emission control is advanced.

Furthermore, at the general meeting of the 70th Maritime Environment Protection Committee (MEPC70) of the International Maritime Organization (IMO) in October 2016, it was decided that the global sulfur cap will be tightened from the current "3.5% or less" to "0.5% or less" in 2020.

Considering that it is required to build a global network of LNG bunkering bases in order to further promote LNG fuelled ships, we are promoting international coordination such as the statement of the leaders of two countries about LNG bunkering at the Japan-Singapore Summit held in September 2016 and the conclusion of "Memorandum of Understanding on Cooperation on the Development of LNG as a Marine Fuel (MOU)" by eight representatives from seven countries in October 2016.

Under these circumstances, to build LNG bunkering bases in Japan and enhance the competitiveness of our ports, we held a "The Steering committee for LNG bunkering at the port of Yokohama" in June 2016 and compiled a development plan to build LNG bunkering hubs in Japan, using the Port of Yokohama as a model case with the participation of related administrative agencies (Agency for Natural Resources and Energy, Ministry of Land Infrastructure, Transport and Tourism Maritime Bureau and Ports and Harbours Bureau, Japan Coast Guard Headquarters, City of Yokohama) and related private business operators (Tokyo Gas co., Ltd., Nippon Yusen Kabushiki Kaisha, Yokohama Kawasaki International Port co., Ltd.).

When reviewing the plan, firstly, we studied the trends surrounding LNG fuelled ships. Next, we confirmed the advantages of the Port of Yokohama as an LNG bunkering hub. In addition, we estimated the demand for LNG fuel in the future, and based on the estimation, we created a roadmap consisting of three phases, and compiled the contents of improvement required for each phase. Finally, we also complied issues to be addressed to realize the roadmap.

I hope that the information in this report will be useful and persons concerned will strive as one. I also hope that the reinforcement of the competitiveness of our ports will contribute to the growth of the Japanese economy and a new LNG fuel supply market will be developed through the rapid development of LNG bunkering hub by the coordination with Singapore, which is the world's largest port of bunkering. Finally, I greatly expect the future efforts of persons concerned.

The chairman of the Steering committee for LNG bunkering at the port of Yokohama

1. Trends in environmental regulations and possible conversion to LNG fuel

1-1. Overview of environmental regulations

Concerning emissions from vessels, the regulations on sulfur oxides (SOx), nitrogen oxides (NOx) and carbon dioxide (CO2) have been gradually tightened in accordance with Annex VI of the "International Convention for the Prevention of Pollution from Ships" (MARPOL Convention) for the purpose of reducing greenhouse gas emissions and preventing air pollution.

Since sulfur oxide (SOx) is originated from sulfur contained in fuel oil, it is regulated based on the sulfur concentration in fuel oil. The current upper limit for sulfur concentration is 0.1% in the Emission Control Area (ECA) where emission control is strict, such as North Sea & Baltic Sea, the coast of North America and US Caribbean Sea.

Meanwhile, it is set to 3.5% in all other sea areas (general sea areas), however, it was agreed to regulate the upper limit of sulfur concentration in fuel oil to 0.5% from 2020 at the Maritime Environment Protection Committee (MEPC70) of International Maritime Organization (IMO) held in October this year.

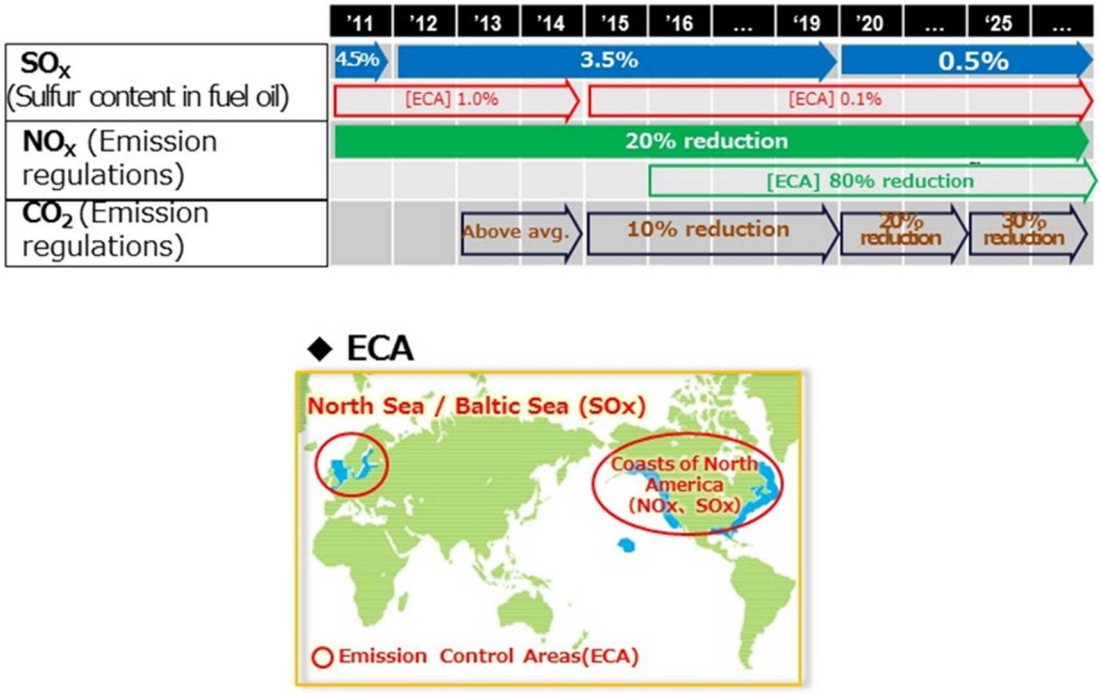


Figure 1. Trends in environmental regulations

1-2. Approaches to environmental regulations

The following three methods can be mainly considered as approaches to comply with the regulations on sulfur oxides (SOx). In particular, when LNG is used as an alternative fuel (Ⅲ), they will lead not

only to the reduction of sulfur oxide (SOx) but also that of nitrogen oxides (NOx) and carbon dioxide (CO2) concerning emissions from vessels. They are corresponding methods with environmental advantages.

As for the installation of exhaust gas scrubber (scrubber) (Ⅱ), since it is unnecessary for the port to deal with it, it is not considered in this feasibility study.

Ⅰ. Utilization of low sulfur fuel oil that is suitable for environmental regulations

Use fuel oil that meets environmental regulations, such as light oil (light oil or A heavy oil) or compatible oil made by blending light oil with residual oil. The fuel prices are higher than high sulfur C heavy oil currently used in many vessels, and requires small investment to install additional facilities to meet regulations.

Ⅱ. Installation of exhaust gas scrubber (scrubber)

Install a scrubber on a ship newly to reduce SOx emissions. Although it requires an initial cost to install a scrubber, it is possible to continue using high sulfur C heavy oil and it can suppress the increase of fuel cost.

Ⅲ. Utilization of alternative fuels such as LNG

Use alternative fuel without sulfur content such as LNG. Although it requires to install a LNG fuel tank and LNG fuel engine equipment and the initial cost is higher than a normal diesel engine, emissions of NOx and CO_2 can be suppressed by using LNG fuel.

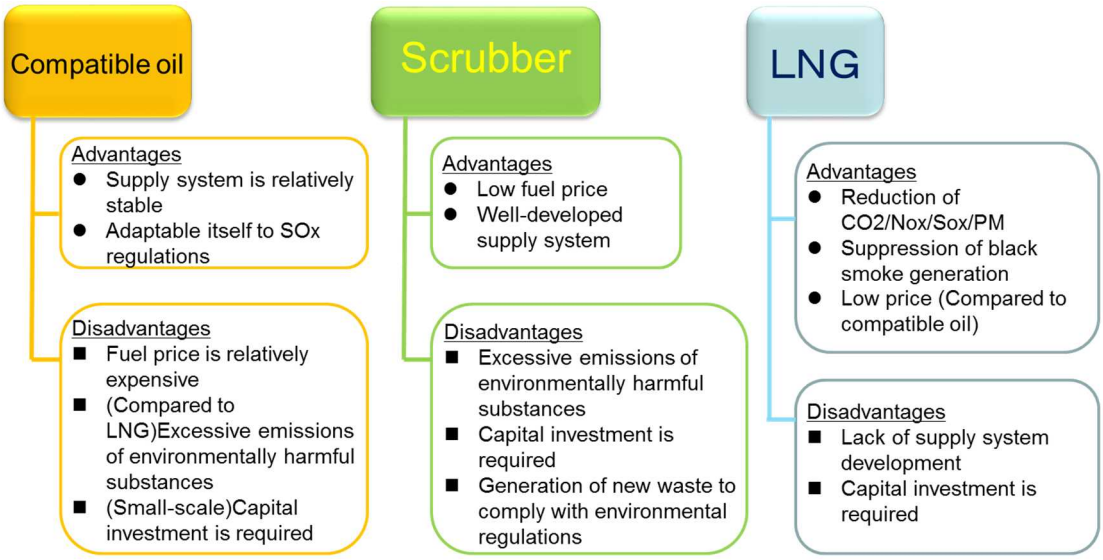
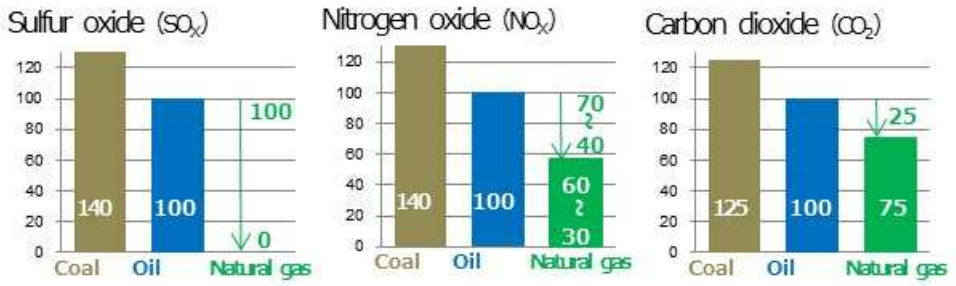


Figure 2. Advantages and disadvantages of each methods



*Relative values when oil is set to 100

Figure 3. Environmental advantages of natural gas

The introduction of LNG fuelled ships has been started with ferries, car carriers and cruise ships in the ECA where the environmental regulations have been tightened in advance. It is conceivable that the introduction of LNG fuelled ships will further expand if the global sulfur cap is tightened in the future.

Figure 4. LNG fuelled ships in-service

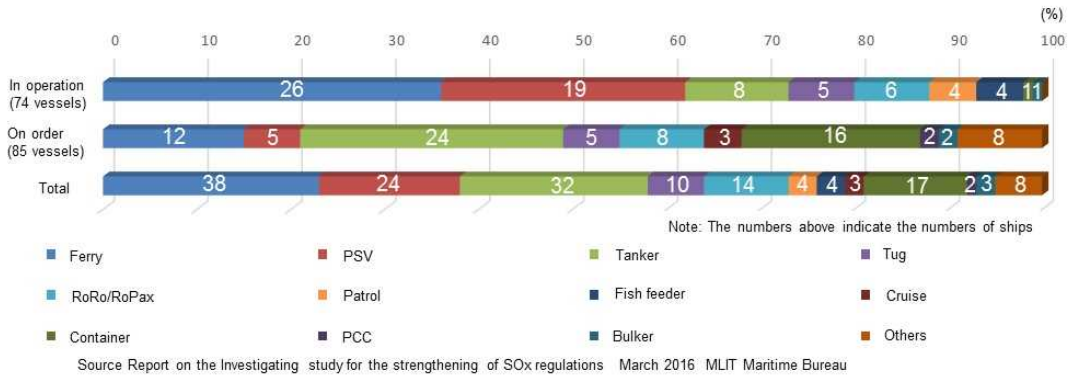


Figure 5. Number of LNG fuelled ships, which have been ordered and in active service

1-3. LNG bunkering methods

When LNG is used as an alternative fuel, the following three types can be listed as bunkering methods for supplying LNG to ships.

【Truck to Ship bunkering】

Supplying LNG from a LNG lorry parked on a quay to an LNG fuelled ship moored on a quay. The initial investment cost is low and it is suitable for small ships.

【Shore to Ship bunkering】

Supplying LNG from a LNG shore terminal or an LNG satellite terminal to an LNG fuelled ship moored on a quay or a pier. Fuel can be supplied to large vessels.

【Ship to Ship bunkering】

Bring an LNG bunkering ship along an LNG fuelled ship moored on a quay or a pier and supply LNG. Fuel can be supplied to large vessels.

Figure 6. Bunkering methods

The Maritime Bureau of the Ministry of Land Infrastructure, Transport and Tourism has established the "Committee for Comprehensive Measures toward Disseminating/Promoting LNG Fuelled Ships" in 2012, in order to improve the environment for the dissemination of natural gas fuel ships and support the approaches of related business operators. They prepared an operation manual and an operation guideline for each of the above 3 types of bunkering and announced them in June 2013.

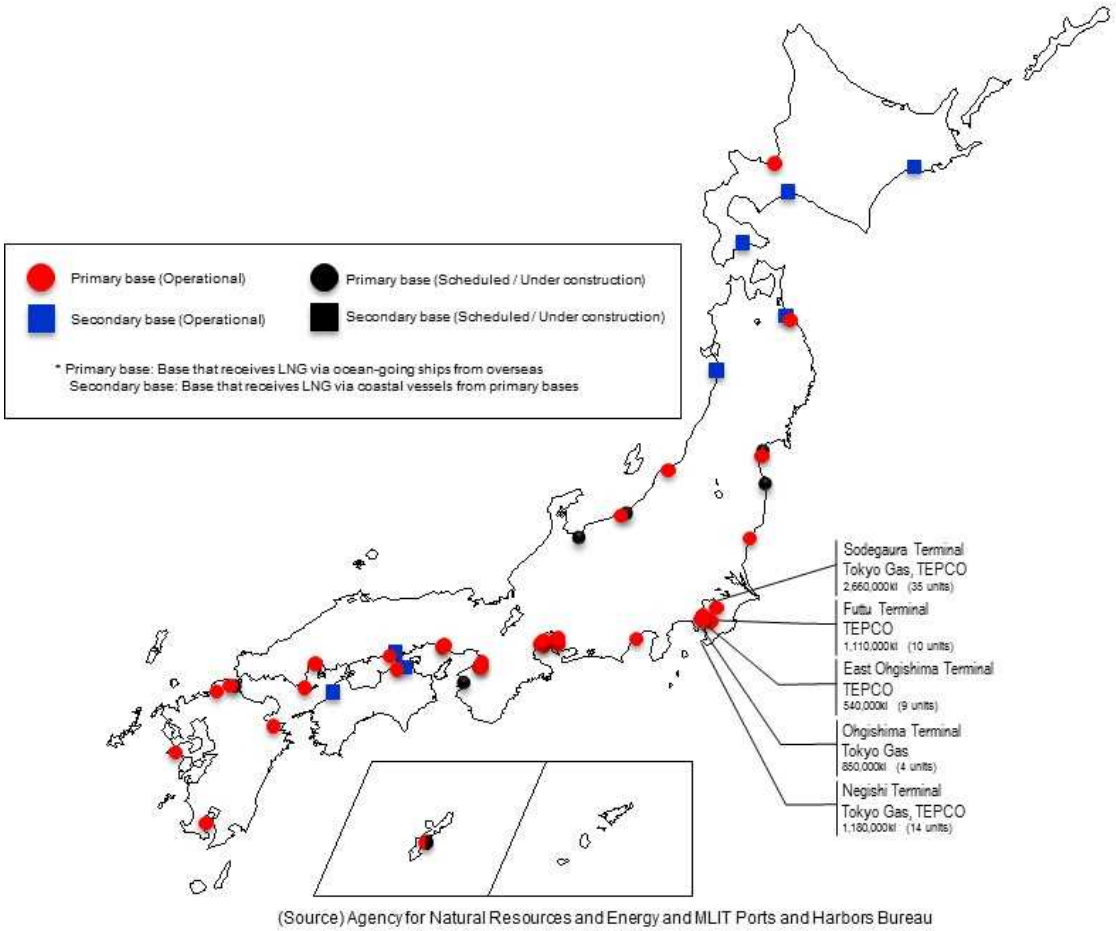
2. Advantages of the Port of Yokohama as a LNG bunkering hub

2-1. Advanced existing infrastructure

Japan is the world's largest LNG importing country (1/3 of the whole world), and have an advanced existing infrastructure, such as operations of the world's largest LNG carrier fleets and the large number of LNG terminals close to ports.

Especially, it is not realistic to improve an LNG terminal exclusively for a bunkering project as it requires great costs, for this reason, it is necessary to have an existing LNG terminal to develop a LNG bunkering hub.

The Port of Yokohama has 2 terminals, Negishi and Ogijima, and in Tokyo Bay area, there are a total of 5 terminals, Higashi-ogishima, Sodegaura, Futtsu in addition to the above 2 terminals. Moreover, Hitachi terminal is located in the Kanto district. Negishi, Sodegaura, Futtsu and Hitachi terminals already have LNG lorry shipping facilities, and Sodegaura and Hitachi terminals already have facilities such as shipping piers which are necessary for paying out LNG.



(Source) Agency for Natural Resources and Energy and MLIT Ports and Harbors Bureau

Figure 7. Main LNG terminals in Japan

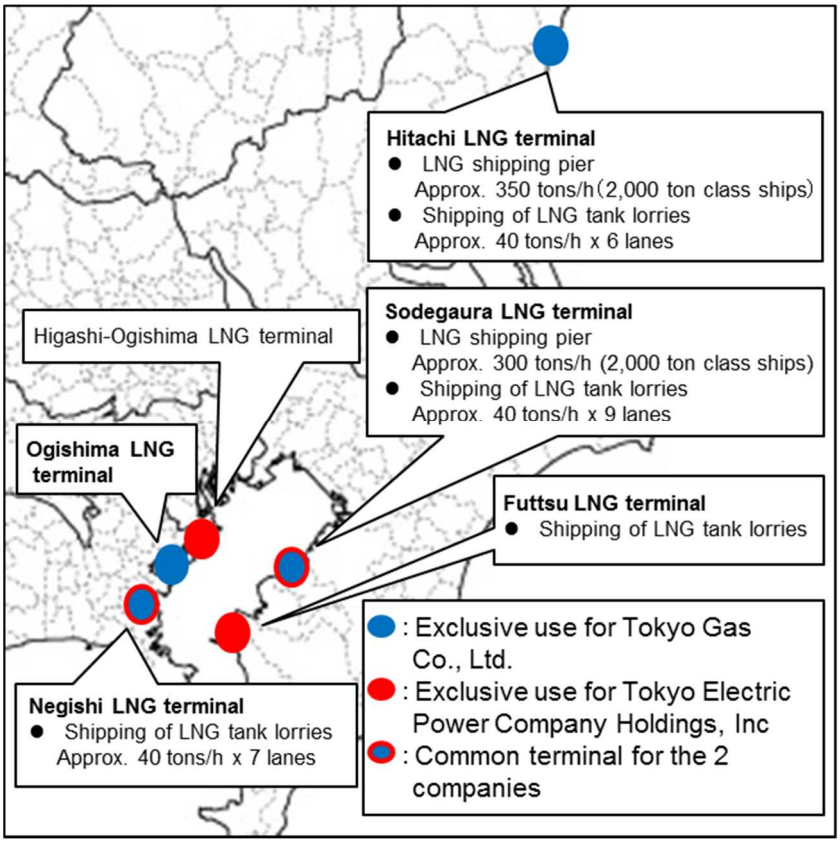


Figure 8. LNG terminals at the Port of Yokohama and in the surrounding area

2-2. Operation of a LNG fuelled tugboat "Sakigake"

At the Port of Yokohama, the operation of a tugboat "Sakigake", which is the first LNG fuelled ship in Japan among ocean-going vessels and domestic vessels - except for LNG carriers, started in August 2015. Sakigake is equipped with a dual fuel engine that can use both heavy oil and LNG as fuel. For the engine development and the construction, the Ministry of Land, Infrastructure, Transport and Tourism and the Ministry of Economy, Trade and Industry assisted a part of the expenses.

Sakigake's LNG bunkering is conducted by "Truck to Ship" method on fortnightly basis at Shinko Pier of the Port of Yokohama and about 7 tons of LNG is supplied from a tank lorry at one time. It is also an advantage of the Port of Yokohama that related business operators and administrative agencies aiming at accumulate know-how of LNG bunkering after more than one year since Sakigake's first operation.

Figure 9. Photo of Sakigake

Table 1. Main specifications of Sakigake

Shipowner	Nippon Yusen Kabushiki Kaisha	Total length	37.2m
Completion	August 2015	Total width	10.2m
Propulsion engine	Dual fuel (LNG + heavy oil)	Molded depth	4.4m
Operating place	The Ports of Yokohama and Kawasaki	Gross tonnage	272t

Figure 10. Fuel supply

2-3. Geographical characteristics – Position as International Container Hub

LNG tanks of LNG fuelled ships have a larger structure than that of heavy oil tanks, however, LNG tanks can not be considerably enlarged as it is necessary to save places for cargo holds. For this reason, it is important that the network of bunkering bases is properly formed to promote the spread of LNG fuelled ships. Since the Port of Yokohama is located on the Pacific side and it serves as the first or last bunkering hub in the Asian side of the North American route, the Port of Yokohama has advantages as a LNG bunkering hub, mainly for ships navigating the Pacific Ocean.

In addition, the Port of Yokohama, which is a part of the Port of Keihin, is positioned as an International Container Hub Ports along with the Port of Hanshin. Various measures, which consists of hard and soft aspects, from International Container Hub Ports Policy are intensively taken and function enhancement is promoted for the Port of Yokohama as a national policy by promoting the collection of containers from inside and outside of Japan.

Moreover, since many ships such as container ships, pure car carriers and cruise ships call at the Port of Yokohama, it has a high potential as an LNG bunkering hub.

3. Roadmap for the development of LNG bunkering hub and tasks

3-1. Demand forecast

Although the introduction of LNG fuelled ships depends on the trends of environmental regulations, some LNG fuelled ships have already launched in the ECA where environmental regulations are tightened in advance. Various investigation institutions forecast the demand for LNG as marine fuel and the following table shows a demand forecast conducted by THE BOSTON CONSULTING GROUP, Lloyd 's Register, DNV-GL and iHS. Although there is a difference between each percentage, it is expected that, 5 to 27% of heavy oil will be replaced by LNG. Since the world annual bunkering amount of heavy oil is about 240 million tons (2013)[1], the annual LNG demand is forecasted at about 12 million to 64.8 million tons.

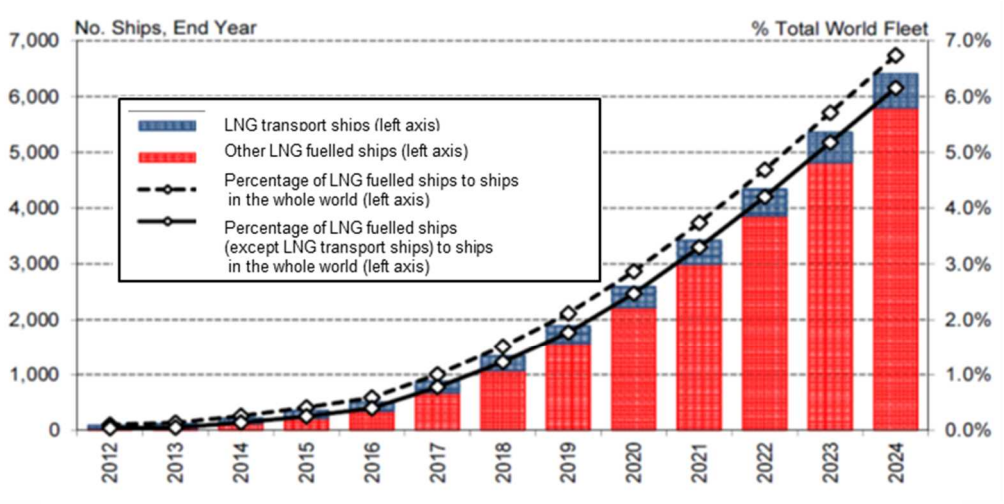
Table 2. Demand forecast of LNG fuel

Research organization	Period	Percentage of the replacement from heavy oil to LNG
THE BOSTON CONSULTING GROUP	2025	5～27%
Lloyd's Register	2030	11%
DNV-GL	2025	6～11%
iHS	2030	8%

- DNV-GL obtained the percentage considering the heat difference between LNG and heavy oil based on the global annual amount of heavy oil bunkering set as 240 million tons.

About 200 LNG fuelled ships were confirmed as of August 2016 (including those planned), and about 70 LNG-ready ships, which are planned to be remodeled to be LNG fuelled, were also confirmed (including those planned). Since a tightening of global sulfur cap will be introduced in 2020, the number of LNG fuelled ships is expected to increase significantly in the future.

1 Based on documents of Japan Petroleum Energy Center



(Source) "Forecast of construction demand for LNG fuel ships (2012-2014) research" Japan Ship Exporters' Association
*If LNG fuel compliant options become widespread as market standards and the fuel price difference increases in important areas, which will be designated as ECA especially Far East (Japan, etc.) and Australia, in the near future or in the medium term future.

Figure 11. Estimation of the increasing number of LNG fuelled ships

Regarding the demand for LNG bunkering at Keihin's main ports, the Steering Committee forecasted (1) the demand when the constant rate switches to LNG based on the amount of heavy oil bunkering at the Port of Keihin, (2) the demand when the constant rate switches to LNG based on the amount of heavy oil bunkering if the competitive fuel price is realized, according to the port call record of Keihin's main ports. The Steering Committee referred to IEA "Oil Information 2014" and statistics from domestic oil companies for the estimation.

Table 3. Demand forecast of LNG

Percentage of the replacement from heavy oil to LNG	①Amount of demand when the constant rate switches to LNG based on the currently amount of heavy oil bunkering at the main Ports of Keihin	②Amount of demand when the constant rate switches to LNG based on the amount of heavy oil bunkering estimated when a competitive fuel price is realized, according to the port call record of main ports of Keihin.
5%	Approx. 90,000 tons/year	Approx. 250,000 tons/year
10%	Approx. 180,000 tons/year	Approx. 500,000 tons/year
20%	Approx. 360,000 tons/year	Approx. 1,000,000 tons/year

3-2. Roadmap for the development of LNG bunkering hub

As mentioned above, although the demand forecast is conducted by various agencies, there is a difference between each value and nothing is certain at the present time. However, it shows a common

point among them that the demand for LNG fuel is increasing with the passage of years.
In addition, it seems that it will take time until the demand rises as it is expected that the number of LNG fuelled ships will gradually increase by being replaced from existing ships, rather than a great number of newly built LNG fuelled ships will go in service, due to the start of the regulations in 2020.
In this feasibility study, the Steering Committee formulated the road map below and decided to advance the development of the LNG bunkering hub at the Port of Yokohama according to the trends of demand under the policy to use the existing infrastructure as much as possible to reduce the initial delivery cost[2].

Phase Ⅰ　Truck to Ship bunkering optimization (from today)
Phase Ⅱ　Introduction of Ship to Ship bunkering (from 2020)
PhaseⅢ　Strengthen of Ship to Ship bunkering (After the demand reaches a certain scale)

Phase Ⅰ　Truck to Ship bunkering optimization (from today)
Regarding Truck to Ship bunkering currently carried out at Shinko Pier at the Port of Yokohama, it will be more smooth and efficient, such as carry out bunkering operations with a LNG tank lorry close to a LNG fuelled ship.

Phase Ⅱ　Introduction of Ship to Ship bunkering (from 2020)
Introduce LNG bunkering ships towards 2020 and start a Ship to Ship bunkering with higher convenience than Shore to Ship bunkering in order to meet the large LNG fuelled ships in 2020 when the tightening of ship emission regulations starts.
Use the terminal in Tokyo Bay (Sodegaura terminal) where required facilities are already in place for supplying LNG to bunkering ships, in terms of the optimization of existing stock.

PhaseⅢ　Strengthen of Ship to Ship bunkering (After the demand reaches a certain scale)
Aiming at a further strengthen of the bunkering system by developing required facilities for the LNG terminal at the Port of Yokohama and use the terminals in Tokyo Bay in order to optimize Ship to Ship bunkering after the demand for LNG bunkering reaches a certain scale.

2 Supply costs, such as the cost for the terminal added to the price of LNG liquid and the cost of shipping for the sale of LNG fuel

Table 4. Commencing time and expenses related to facility maintenance for each phase

	From today	From 2020	After the annual demand reaches 300 – 400 thousand tons	Cost of facility improvement
Phase Ⅰ	→	→	→	
Phase Ⅱ	- - →	→	→	6 billion yen
Phase Ⅲ		- - →	→	10 billion yen

3-3. Required improvement of facilities for each phase and the tasks

1) Phase Ⅰ Optimization of "Truck to Ship" bunkering

A LNG tank lorry and a ship, which were about 20m away from each other, had been connected with a flexible hose at each bunkering since the first operation of a LNG fuel tug boat "Sakigake" in August 2015. However, according to the result of a detailed structure examination of the quay of Shinko pier, it became possible to bring a LNG tank lorry close to a LNG fuelled ship and the optimization of the bunkering has been realized since November 2016.

Afterwards, some effects are observed such as shortening of preparation work time by 50 %, reduction of the number of workers by 30% and a safety improvement due to a reduction of a hazardous materials handling area.

Shinko Pier, where the bunkering is currently conducted to Sakigake, remains as a temporary use and City of Yokohama, which is a port authority of a tugboat allocation plan, is considering permanent supply places and the fixation of some facilities.

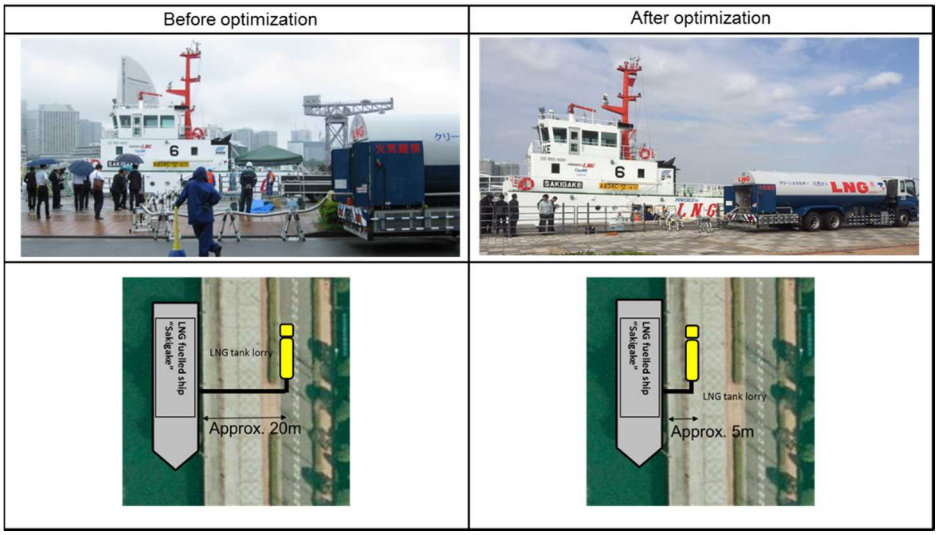


Figure 12. Optimization of Truck to Ship bunkering

Table 5. Result of the optimization

Work preparation time	reduced by 50%
Number of workers	reduced by 30%
Hazardous materials handling area	reduced by 75%

2) Phase II Introduction of "Ship to Ship" Bunkering

① Required facilities

It will be required to introduce an LNG bunkering ship that supplies fuel to LNG fuelled ships for "Ship to Ship" bunkering operations.

For reference, the following table is the specifications of an LNG bunkering ship to be launched by an European LNG bunkering company invested by Nippon Yusen Kabushiki Kaisha and other companies.

Figure 13. Image of the LNG bunkering ship

Table 6. Specification of the LNG bunkering ship

Total length(m)	Total width(m)	Draft(m)	Gross tonnage (ton)	Tank capacity(m3)
100	18	4.7	6,000	5,000

Regarding LNG terminals, if a LNG bunkering ship has the above specifications, it will not be necessary to refurbish the shipping pier at the LNG terminal (Sodegaura terminal) in Tokyo Bay, which already has a shipping pier for coastal transportations. However, it will be required to repair the shipping arm due to the height difference between the receiving port of the LNG bunkering ship and the shipping arm. Since it will take a certain period of time to build such an LNG bunkering ship, it is necessary to deal with it as soon as possible in order to start the Phase II promptly in 2020.

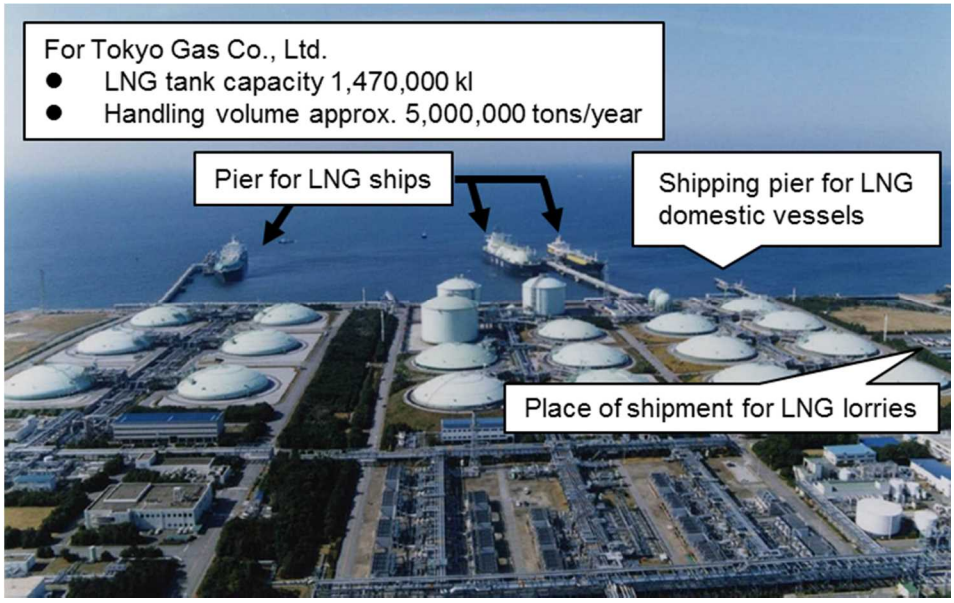


Figure 14. Sodegaura LNG terminal

Figure 15. Shipping arm

② Business profitability

A selling price of LNG fuel is roughly divided into a "price of LNG itself" and a "delivery cost", and the latter consists of the cost of an LNG terminal and LNG bunkering ships, a BOG cost (LNG cost which decreases by natural vaporization), general administrative expenses of LNG suppliers.

Since a fixed cost is included in the delivery cost, the price per unit can be suppressed as the bunkering amount increases. Figure 17. shows the relation between annual bunkering amount and indexed delivery costs.

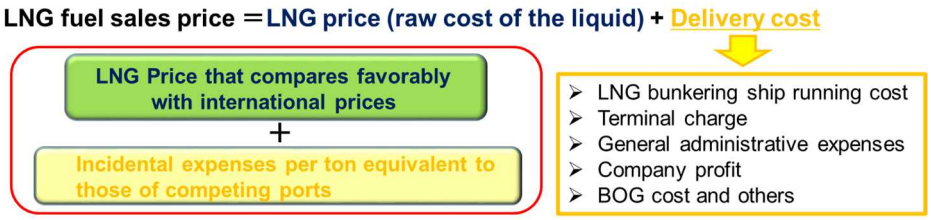
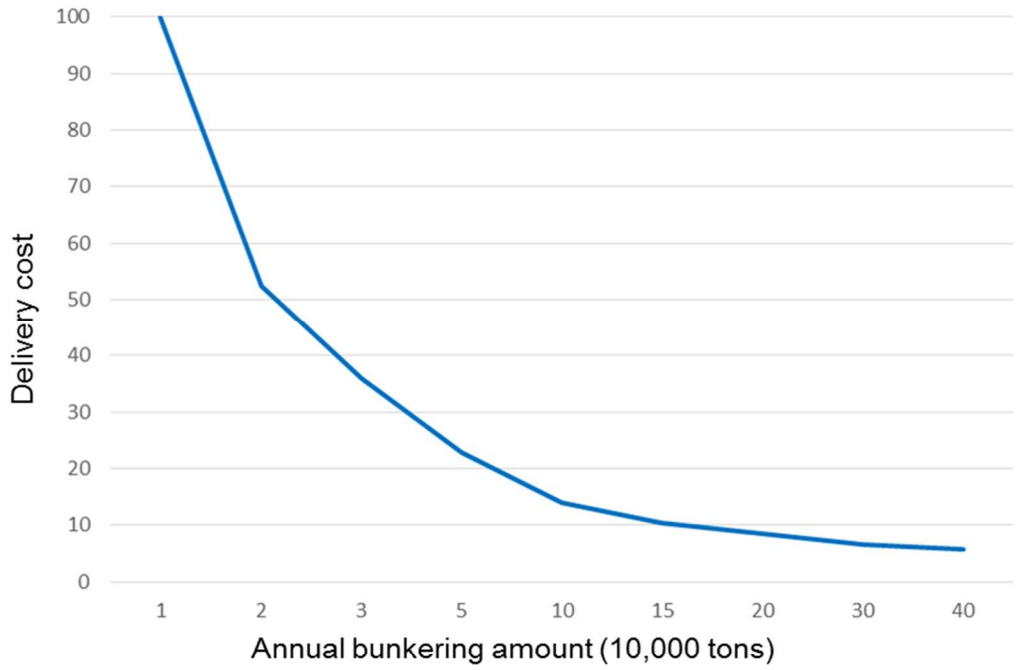


Figure 16. Cost concept



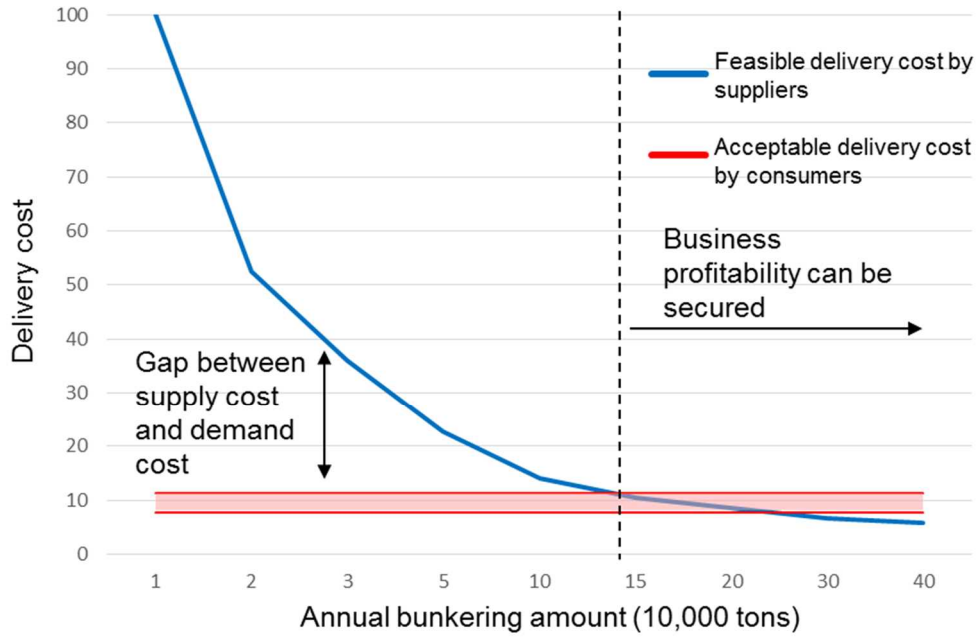
- The delivery cost is set to 100 when the annual bunkering amount is 10,000 tons.
- Terminal shipping cost is taken into account as LNG terminal expenses, charter base, general and administrative expenses and BOG costs are taken into account as LNG bunkering ship running cost, and they are set based on hearings.
- The fixed costs (ex. office rent) included in general administrative expenses for LNG bunkering ships are added from over 100,000 tons of annual bunkering when the demand becomes important.
- Last spot prices (as of the end of September 2016) are adopted for fuel (LNG, LSDO) prices (dollar/ton).

Figure 17. Relation between annual bunkering amount and delivery costs

On the other hand, when a ship owner chooses a method to comply with environmental regulations, he will choose an option with the cheapest total amount of the ship building costs and operating costs of the shipping. There is no major difference in the cost of seafarers between the options, the ship building cost and the fuel cost will have a significant influence on the owner's choice.

Currently, LNG fuelled ships are more expensive to construct than vessels fuelled by heavy oil, however, the former is cheaper compared to LNG and LSDO (low sulfur fuel oil corresponding to environmental regulations). In other words, if the difference in fuel cost exceeds the difference in construction cost of the ship, it may become an incentive for the owner to build an LNG fuelled ship.

Figure 18. shows the highest and lowest figures of the preliminary calculation of the delivery cost index added on top of Figure 17. with the calculation, the owner can select a construction of a LNG fuelled ship for each type of ship and hull form. Although it is a preliminary calculation based on a presupposed index, if the delivery cost can be reduced to the level of the red band on the graph due to the increase in demand, it is expected that the owner will be able to choose the option of an LNG fuelled ship as a method to comply with environmental regulations.



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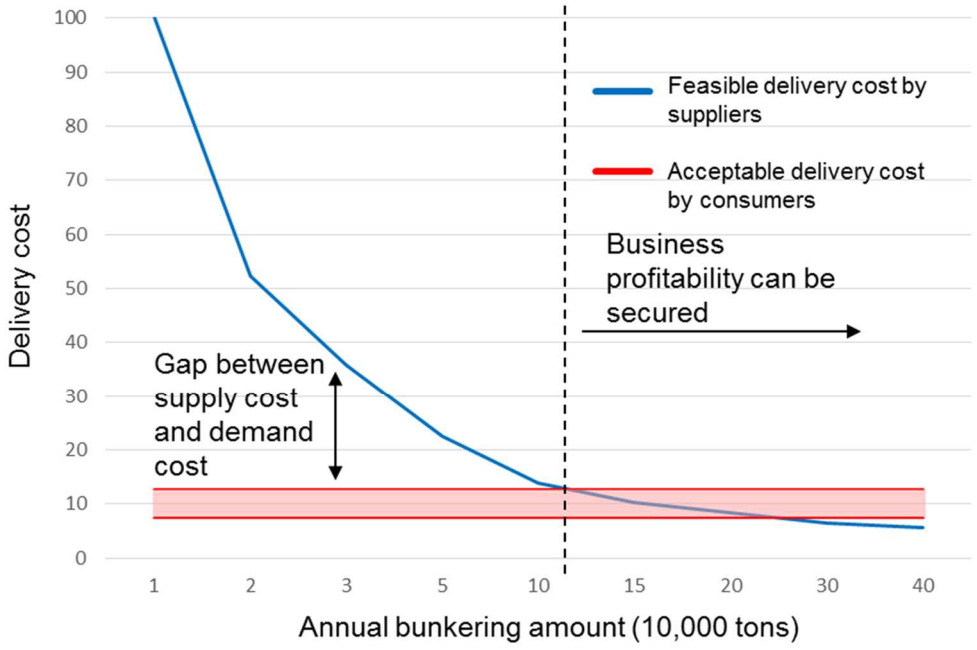
- The fixed costs (ex. office rent) included in general administrative expenses for LNG bunkering ships are added from over 100,000 tons of annual bunkering when the demand becomes important.
- Last spot prices (as of the end of September 2016) are adopted for fuel (LNG, LSDO) prices (dollar/ton).
- The following 6 kinds of ship types and full forms are set ; 5,000 TEU ocean container ship, 6000 unit ocean PCC, 100,000 GT class ocean cruise ship, 500 TEU coastal container ship, 10,000 GT coastal ferry, 15,000 dwt coastal tanker
- The construction cost for each ship type and full form were set based on hearings, and the construction cost for a LNG fuel ship is set 1.3 times as much as that of a heavy oil fuel ship. However, only the ocean cruise ship was separately set considering the proportion of the interior decoration to the construction cost. The construction costs is to be collected over 15 years.
- Fuel consumption for each ship type and full form is set based on IMO "Third Greenhouse Gas Study 2014".

Figure 18. Relation between feasible delivery costs by bunkering companies and acceptable delivery costs by owners (in case of last spot prices)

The following graph shows the reference value of owners' acceptable delivery cost with the fuel price set as the average price since January 2003, under the same conditions.



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- The fixed costs (ex. office rent) included in general administrative expenses for LNG bunkering ships are added from over 100,000 tons of annual bunkering when the demand becomes important.
- Average prices (after January 2003) are adopted for fuel (LNG, LSDO) prices (dollar/ton).
- The following 6 kinds of ship types and full forms are set ; 5,000 TEU ocean container ship, 6000 unit ocean PCC, 100,000 GT class ocean cruise ship, 500 TEU coastal container ship, 10,000 GT coastal ferry, 15,000 dwt coastal tanker
- The construction cost for each ship type and full form were set based on hearings, and the construction cost for a LNG fuel ship is set 1.3 times as much as that of a heavy oil fuel ship. However, only the ocean cruise ship was separately set considering the proportion of the interior decoration to the construction cost. The construction costs is to be collected over 15 years.
- Fuel consumption for each ship type and full form is set based on IMO "Third Greenhouse Gas Study 2014".

Figure 19. Relation between feasible delivery costs by bunkering companies and acceptable delivery costs by owners (in case of average prices)

According to the above preliminary calculation, if an annual demand for bunkering reaches around 100 thousand to 150 thousand tons, it can be profitable for both the bunkering company (supply side) and the owner (demand side). On the other hand, it became clear that there is a large gap between the feasible delivery costs by the bunkering company and the acceptable delivery costs by the owner at the stage of low demand.

3) Phase III Improvement of "Ship to Ship" bunkering

① Required facilities

At the bunkering using the existing base in Tokyo Bay (Sodegaura terminal) , which has an existing shipping pier mentioned earlier, the limit value of supply will be about 300 thousand to 400 thousand tons per year due to the limitation of the mooring capacity of the LNG terminal.

In this case, if an annual demand reaches 300 thousand to 400 thousand tons, it is necessary to use the LNG terminal at the Port of Yokohama to improve the bunkering function by the use of a closer LNG terminal to the supply point.

Since none of the LNG terminals at the Port of Yokohama has shipping facilities, some improvement will be necessary such as building a shipping pier, installing piping facilities and improving the discharging pumps.

Regarding bunkering ships, as the amount of bunkering that can be handled by one ship will be about 400,000 tons per year at maximum, depending on the enroute configurations, it will be required to provide a second bunkering ship at the same time as the addition of an LNG terminal.

In case of LNG bunkering at the Port of Yokohama, the sailing time from the terminal to the bunkering place will be shortened, which will enable faster operations, and a reduction of fuel cost of the bunkering ship is also expected by using the LNG terminal at the Port of Yokohama. In this feasibility study, the Steering Committee discussed the improvement of bunkering facilities of Negishi LNG terminal, which is close to a demand area of Minami Honmoku Pier at the Port of Yokohama (Figure 20.).

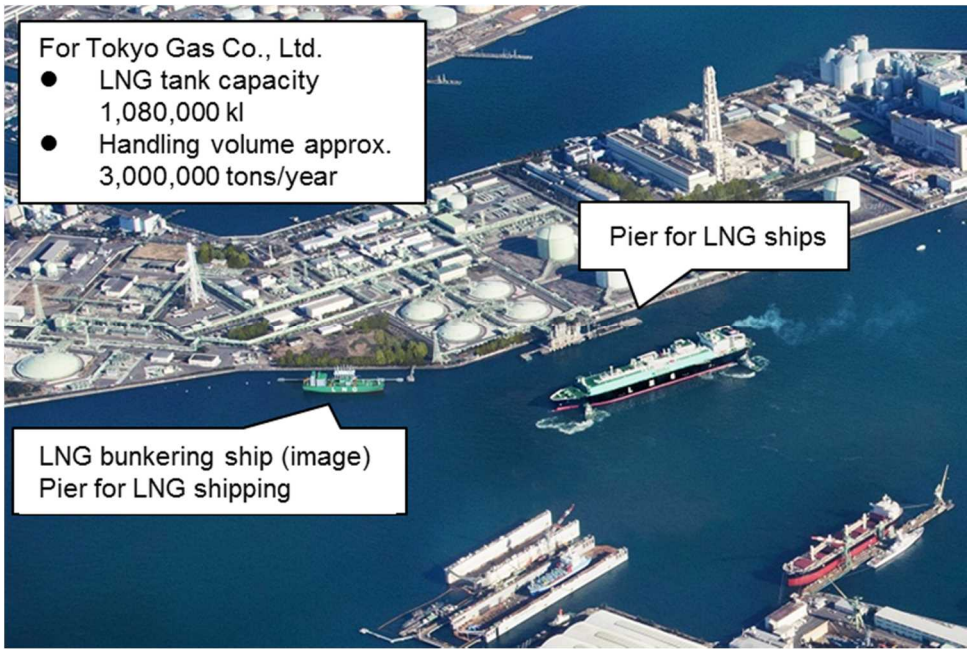
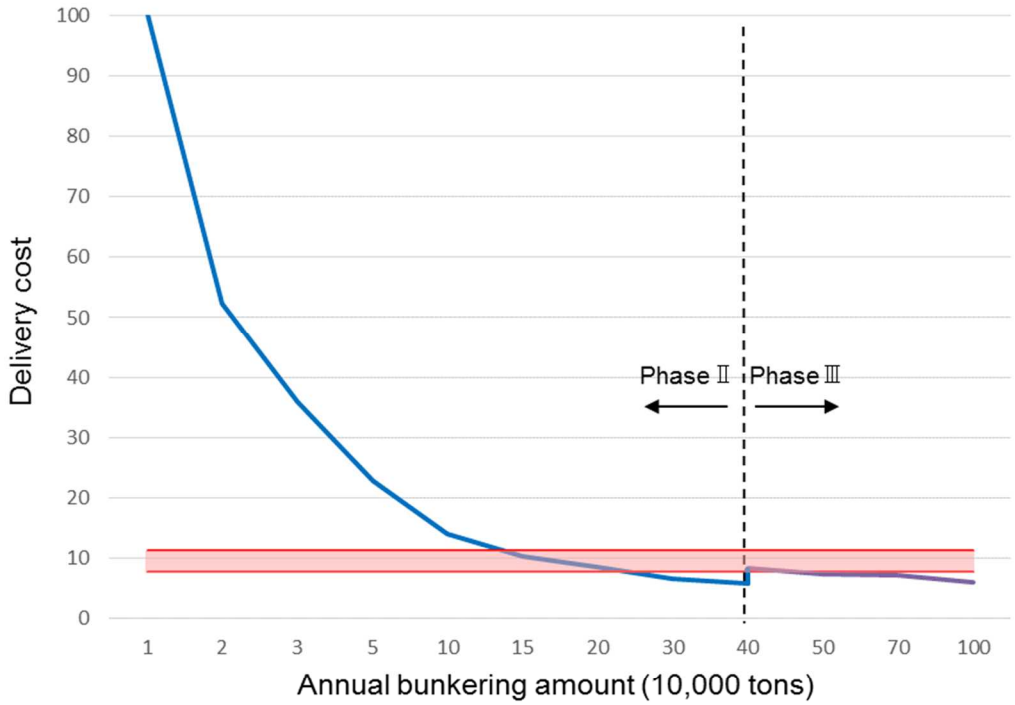


Figure 20. Image of a shipping from Negishi LNG terminal

② Business profitability

The following figure shows "Annual bunkering amount (ten thousand tons)", which is

the horizontal axis of Figure 18. , displayed up to one million tons.



- The delivery cost is set to 100 when the annual bunkering amount is 10,000 tons.
- Terminal shipping cost is taken into account as LNG terminal expenses and charter base, general and administrative expenses and BOG cost are taken into account as LNG bunkering ship running costs, and they are set based on hearings.
- The fixed costs (ex. office rent) included in general administrative expenses for LNG bunkering ships are added from over 100,000 tons of annual bunkering when the demand becomes important.
- Last spot prices (as of the end of September 2016) are adopted for fuel (LNG, LSDO) prices (dollar/ton).
- A terminal and a bunkering ship are added when the annual bunkering amount reaches 400,000 tons.
- The following 6 kinds of ship types and full forms are set ; 5,000 TEU ocean container ship, 6,000 unit ocean PCC, 100,000 GT class ocean cruise ship, 500 TEU coastal container ship, 10,000 GT coastal ferry, 15,000 dwt coastal tanker
- The construction cost for each ship type and full form were set based on hearings, and the construction cost for a LNG fuel ship is set 1.3 times as much as that of a heavy oil fuel ship. However, only the ocean cruise ship was separately set considering the proportion of the interior decoration to the construction cost. The construction costs is to be collected over 15 years.
- Fuel consumption for each ship type and full form is set based on IMO "Third Greenhouse Gas Study 2014".

Figure 21. Relation between annual bunkering amount and delivery costs

According to this figure, it became clear that business profitability can be secured for both the bunkering companies (supply side) and the owners (demand side). It seems that the feasible delivery costs will be less than the acceptable delivery costs of the owners if an annual bunkering amount increases to about 300 thousand to 400 thousand tons, even though the delivery cost rises at the timing of an additional investment of a terminal and a bunkering ship.

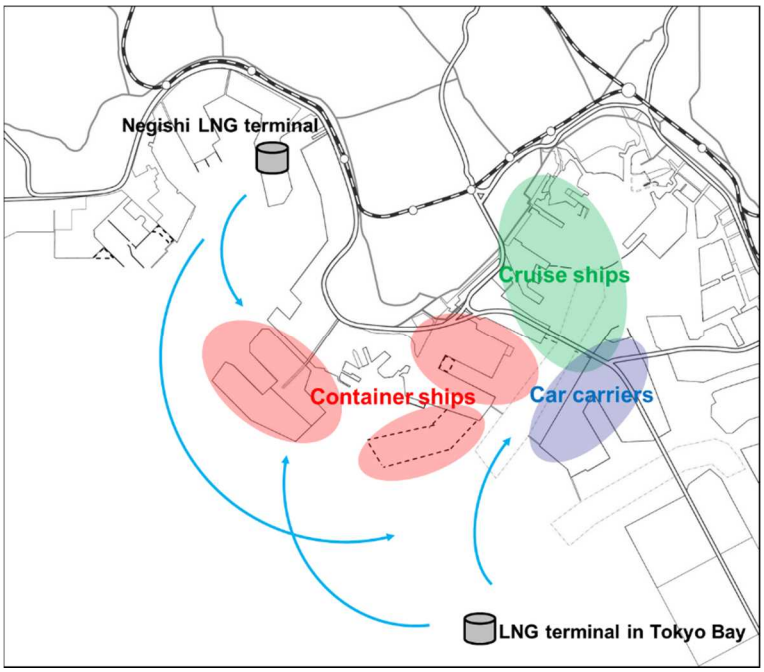


Figure 22. Ship types for LNG bunkering and an area at the Port of Yokohama

Figure23. Image of the LNG bunkering ship in the Port of Yokohama

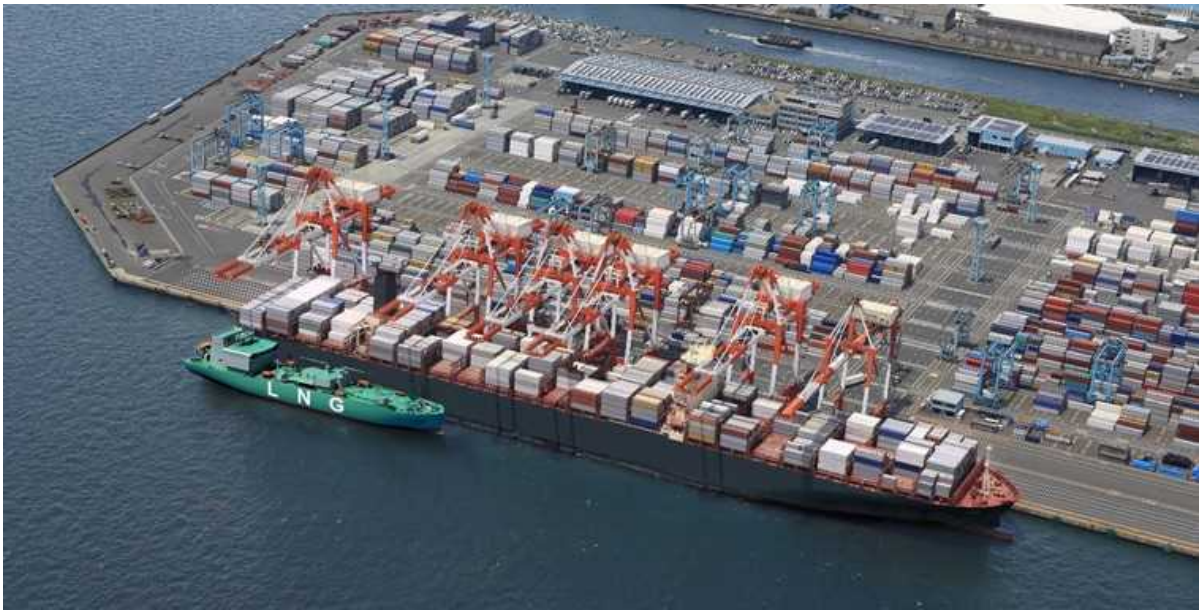


Figure 24. Image of "Ship to Ship" bunkering to a container ship

Figure 25. Image of “Ship to Ship” bunkering to a cruise ship

Figure 26. Image of “Ship to Ship” bunkering to a car carrier

4. Towards the realization

Developing an LNG bunkering hub requires approaches of private enterprises, the national government and port management bodies. Possible measures include cost reductions, a promotion of the introduction of LNG fuelled ships by forming an LNG supply network and a realization of competitive LNG prices and so on. Each section of this chapter will introduce you the approaches of these each entities.

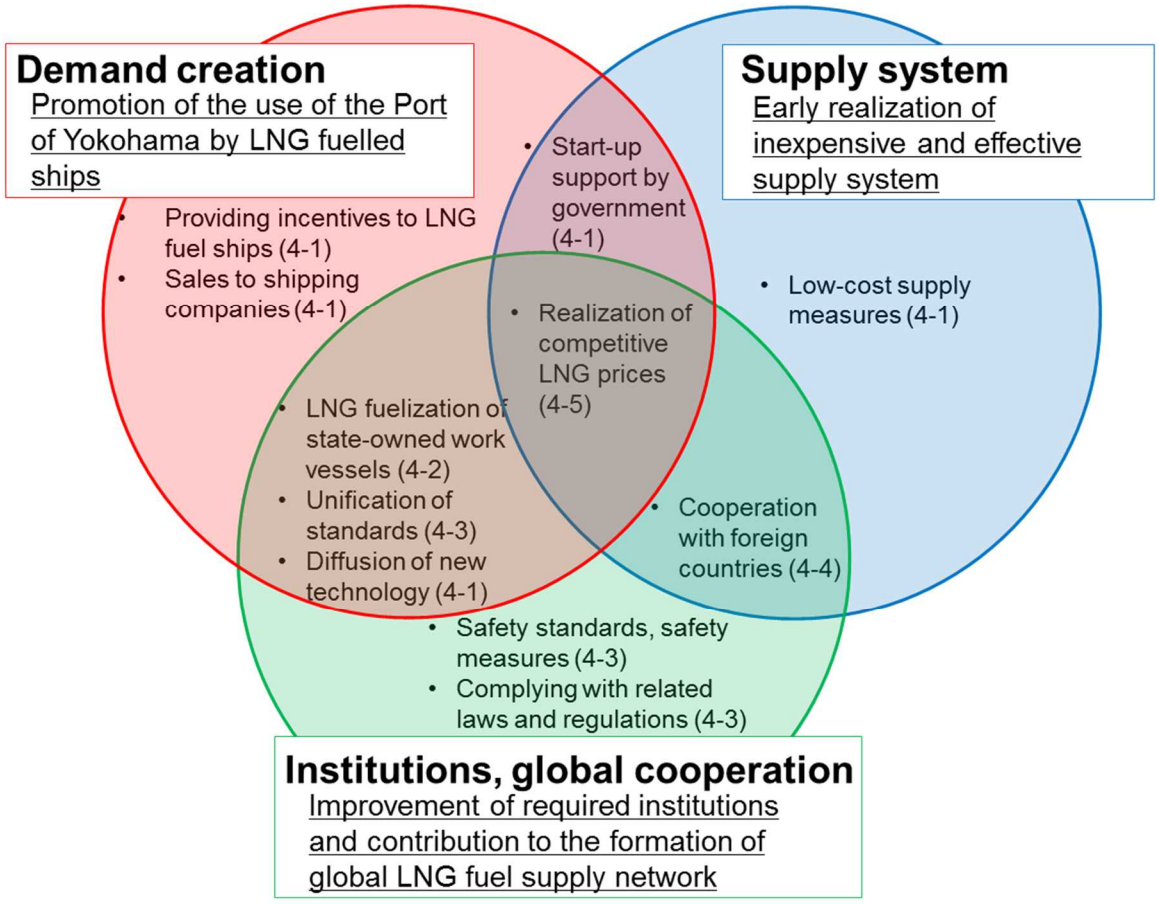


Figure 27. Measures towards the realization of LNG bunkering hub development

4-1. Measures to improve profitability at the stage of the business establishment

Although it is necessary to start Phase II in order to supply fuel to large LNG fuelled ships, it became clear that it is difficult to secure business profitability for both bunkering companies and ship owners immediately after the start of their business when the demand is low. However, as mentioned earlier, it is required to develop LNG Bunkering bases in Japan in terms of the improvement of the international competitiveness of our ports.

In other countries, there are cases that a low cost LNG fuel supply barge is introduced to carry out a LNG bunkering to large LNG fuelles ships. Since the construction cost of an LNG fuel supply barge is cheaper than that of an LNG bunkering ship and a method of bunkering from not only a shipping pier

but also from a lorry is being considered, there might be room for examining cost reduction measures by introducing a Ship to Ship bunkering by using a LNG fuel supply barge for the initial stage of the Phase II.

Figure 28. Image of a LNG fuel supply barge[3]

In addition to this cost reduction, it can also be considered as a measure that the government provides support to the launching to start the Phase II. In this feasibility study we performed sensitivity analysis to see how much the demand scale would change for establishing the project when a certain degree of support is provided to LNG bunkering companies and ship owners. The result showed that both LNG bunkering companies and ship owners could reduce the demand amount of LNG bunkering by about 30 to 60% to secure business profitability. Besides this, other measures are also required to promote port calls by LNG fuelled ships at the Port of Yokohama.

The Yokohama Port and Harbor Bureau, the port authority at the Port of Yokohama, is considering the following measures to promote port calls by LNG fuelled ships.

1. Establishment of an incentive system

- Make an adjustment for our participation in ESI (Environmental Ship Index, managed by IAPH) and Green Award (operated by Green Award Foundation), which urge port calls of environmentally friendly ships.
- Arrange a reduction of entrance fee for LNG fuelled ships (excluding LNG carriers) and LNG bunkering ships, along with the participation in the incentive system.

2. Approaches to shipping companies

- Conduct top sales to shipping companies such as passenger ships, container ships and pure car carriers.
- Aim to develop a home port for LNG ships with the improvement of new passenger terminal.

3 Source : Titan LNG

3. Support for dissemination of LNG ship technology

- Industrial promotions are carried out by industrial - academic - government cooperation at Kaiyo-toshi Yokohama Council (Office at Yokohama city), established in 2007, in which marine-related companies, research institutions, universities and administrations in ports, shipping and shipbuilding fields participate.
- Taking the advantage of such circumstances, aim at promoting a spread of LNG ship technology by information sharing and cooperation promotion by the industry, universities and the government.

4. Support for the bunkering business

- Consider measures for the conversion of existing heavy oil bunkering companies to an LNG bunkering business at the Port of Yokohama as an LNG bunkering business is considered to have affinity with a heavy oil bunkering business.
- Continue information exchange in order to cooperate with existing bunkering companies.

5. Direct support measures such as subsidy system

- Assistance for the maintenance of pier and supply facilities
- Assistance for the construction of LNG bunkering ships and LNG fuel supply barge
- Attracting bunkering facilities to the wharf
- Assistance for selling LNG at the initial operational stage to reduce LNG fuel cost
- Reduction of port facility fee for LNG fuelled ships and LNG bunkering ships

6. Discussion on safety aspects with the Maritime Bureau of the Ministry of Land, Infrastructure, Transport and Tourism, the Japan Coast Guard Headquarters and the city fire department.

- Consider the location of bunkering area and safety measures, assuming Ship to Ship bunkering.

Finally, as a reference, the following is the introduction of the support system of other countries for the spread of LNG fuelled ships.

【EU】

Under TEN – T (Trans – European Transport Network) project, EU started to provide subsidies for projects related to LNG ship fuelization in 2010 and also support up to 50% of the project cost. In 2012, they supported a total of 105 million euros for 7 projects related to LNG bunkering.

【Norway】

Norway has introduced a taxation system for NOx emissions since 2007. As a tax exemption for the NOx tax, the NOx Foundation, which was established by the Norwegian Ministry of the Environment and industry organizations in 2008, supported 80% of the cost of fuel conversion to LNG propulsion engines. The average amount of support per engine is about 360 million yen.

【U.S.A.】

The US Department of Transportation and Maritime Administration provided a loan guarantee of 324.6 million dollars through the Federal Ship Financing Program (Title XI) in April 2015 for the construction of two world's first LNG fuelled container ships. Moreover, they donated 900,000 dollars for remodeling existing RORO vessels to LNG fuelled ships in October 2015 and is planning to collect and investigate the operation data of LNG fuelled ships.

【Singapore】

Maritime and Port Authority of Singapore launched a pilot program aimed at establishing LNG bunkering operations and provide a subsidy of up to 2 million Singapore dollars / LNG ship for LNG fuelled ship constructions and an exemption from port facility fee for 5 years to LNG fuelled ships, which are registered in the country.

【Korea】

They promote LNG fuelization of ships owned by the government, local governments and private companies to create private demand. They provide incentives, such as tax benefit related to reductions and exemptions of port facility fee including the entrance fee and the registration and possessions for LNG fuelled ships, which satisfies specific requirements including domestic registration. In addition, they induce the construction of LNG fuelled ships taking advantage of a shipping fund "New ship Building Support Program" (approx. 2.4 billion dollars).

Moreover, they are planning to revise legal systems related to LNG fuelled ship operations, such as the Ship Safety Law, the enforcement ordinance of the Port Transportation Business Act, the Marine Environmental Management Law.

According to the "Industry development plan related to LNG ship promotion" announced by Korean

Ministry of Oceans and Fisheries in November 2016, the project cost of about 510 million dollars[4] will be allocated to the LNG bunkering facility planned to be built at Busan New Port.

4-2. LNG fuelization of state-owned work vessels

Since it is important that the government takes initiative in undertaking approaches in order to promote the introduction and create the demand of LNG fuelled ships in Japan, MLIT will promote the LNG fuelization of work vessels (Trailing Suction Hopper Dredger with Oil Recovery system, Sea Surface Cleaning Ship, Patrol and Survey Boat) owned by government agencies, such as the Regional Development Bureau of the Ministry of Land, Infrastructure, Transport and Tourism.

MLIT established the "LNG Fuelization Technology for Work Vessel Study Committee" in December 2016 and started the discussion with the aim of solving technical and institutional issues in LNG fuelization with the participation of experts, related private companies, relevant administrative agencies and the Ports and Harbours Bureau of Ministry of Land Infrastructure, Transport and Tourism , which will play a role of the secretariat.

MLIT will realize a technological development by private enterprises, the promotion of LNG fuelled ship construction, and a demand creation through the promotion of LNG fuelization of work vessels owned by the Regional Development Bureau of the Ministry of Land, Infrastructure and Transport and other agencies.

【Work vessels owned by the Regional Development Bureau of the Ministry of Land, Infrastructure and Transport and other agencies】

Regional Development Bureaus and other agencies own work vessels required for the steady implementation of Japan's port development and marine environment improvement projects and they are classified broadly as " Trailing Suction Hopper Dredger with Oil Recovery system, Sea Surface Cleaning Ship, Patrol and Survey Boat ".

- Trailing Suction Hopper Dredger with Oil Recovery system

  A Trailing Suction Hopper Dredger with Oil Recovery system is a work vessel with a dredging function to remove sediment at the bottom of the ocean and a recovery function to collect oil leaked in the ocean. As of December 2016, MLIT has those 3 ships in Japan, "Seiryumaru (Port of Nagoya)" "Kaishomaru (Port of Kitakyushu)" and "Hakusan (Port of Niigata)".

  They are normally engaged in dredging operations within routes and berths at each port but also

4 Converted as 1 won = 0.00085 dollars

prepared to carry out quick and reliable oil recovery work. They arrive at the site in the area around Japan within about 48 hours after dispatch at a request from the Japan Coast Guard Headquarters (Article 41-2, the Law on Prevention of Marine Pollution and Maritime Disasters) in the event of a large oil spill incident.

Figure 29. Trailing Suction Hopper Dredger with Oil Recovery system "Kaishomaru"

- Sea Surface Cleaning Ship

Sea Surface Cleaning Ship is engaged in collecting driftwood and rubbish floating on the sea and oil from ships in the closed waters of Tokyo Bay, Ise Bay, Seto Inland Sea and Ariake / Yatsushiro Sea (except for port district and fishing port areas) to ensure the safety of ship navigation and the conservation of marine environment. As of December 2016, those 12 vessels are placed in these sea areas.

Figure 30. Sea Surface Cleaning Ship "Bay Clean"

- Patrol and Survey Boat

Patrol and Survey Boat is a work vessel engaged in supervision and inspection of port constructions conducted by the Ministry of Land, Infrastructure, Transport and Tourism, surveys of sea areas and the maintenance of the Waterways to be Developed and Preserved*. It is also used for inspection of port facilities and transportation support activities for emergency supplies in the event of a disaster. As of December 2016, those 57 vessels are placed nationwide.

* Waterways to be Developed and Preserved: Routes required by the government for constructions related to development and conservation in order to ensure the traffic of ships in water area except for port areas managed by the port administrator and river zones prescribed by river act. (Paragraph 8, Article 2 of the Ports and Harbors Law)

Figure 31. Patrol and survey Boat "Bay Search"

Table 7. Specifications of work vessels owned by the Regional Development Bureau of the Ministry of Land, Infrastructure and Transport and other agencies

As of December 2016

Category	Number of ships (ship)	Gross tonnage (GT)	Total length (m)	Total width (m)	Mold depth (m)	Engine power (kW)	Fuel
Trailing Suction Hopper Dredger with Oil Recovery system	3	4,185～4,792	93.9～104.0	17.0～17.4	7.2～7.5	2,350 ～ 2,860 x 2 engines	A heavy oil
Sea Surface Cleaning Ship	12	99.0～199.0	27.0～37.0	9.0～11.6	2.8～4.3	720 ～ 1,320 x 2 engines	Light oil
Patrol and Survey Boat	57	10.0～76.0	11.9～27.4	3.5～8.3	1.3～3.1	260 ～ 1,109 x 2 engines (1 engine)	Light oil

【Overview of LNG Fuelization Technology for Work Ships Study Committee】

To install dual fuel engines that can use both light oil (or heavy oil) and LNG as fuel in work vessels (Trailing Suction Hopper Dredger with Oil Recovery system, Sea Surface Cleaning Ship, Patrol and survey Boat) owned by Regional Development Bureaus, MLIT have, first of all, set a marine

environment-improving ship as a model ship of LNG fuelization and are examining matters related to safety and required LNG fuel facilities and issues concerning the introduction of the engines.

4-3. Individual tasks and solutions

In addition to the issues discussed in the previous chapter and 4-1, the following issues were pointed out as individual tasks at the committee. Since the conclusion was not reached for some of the issues at this committee, further approaches by concerned parties are demanded.

【Handling of LNG local and foreign currencies and BOG】

(Issues)

Since both LNG for foreign currency and LNG for local currency will be treated at LNG terminals and on LNG bunkering ships, it will be required to confirm the handling of customs bond. In addition, it is necessary to confirm the procedures for using BOG (Boil Off Gas) from LNG foreign currency for bunkering ships as fuel.

(Solutions)

It is possible to make LNG for foreign currency in bond (petroleum and coal tax / consumption tax) through the following procedure. BOG can also be processed in the same procedure.

Clear the customs only for LNG for local currency and keep accounts of local and foreign currencies separately at LNG terminals.

Declare the "Declaration of Loading of Ship's Stores of Foreign Goods" only for LNG for foreign currency to customs when shipping from an LNG terminal to an LNG bunkering ship.

If there is a difference in the declared value when shipping from an LNG bunkering ship to an ocean shipping vessel, correct the quantity of the "Declaration of Loading of Ship's Stores of Foreign Goods" and the shipment amount of foreign / local currencies at the LNG terminal.

As for quantity determination methods, only the tank capacity is approved at present, which it is a future task.

【Regulations applicable to LNG supply facilities】

(Issues)

A supply hose of bunkering ships may be connected to an LNG fuelled ship or an LNG shipping berth. It is necessary to know which law is applied to which hose on each scene.

(Solutions)

Apply the Ship Safety Law to the use of ship equipment and the use of equipment between ships such as a Ship to Ship bunkering, and apply the High Pressure Gas Safety Act to the use of terminal facilities for a Shore to Ship bunkering.

【Standards for LNG supply facilities】

(Issues)

Standards for LNG quality as ship fuel, the caliber of LNG supply hoses, emergency withdrawal devices and weighing method for LNG bunkering are required.

(Solutions)

Consider and discuss the matter with foreign ports and international organizations referring to the ″Memorandum of Understanding on Cooperation on the Development of LNG as a Marine Fuel (MOU)″ mentioned below.

【Safety measures for bunkering operations】

(Issues)

It is required to Examine safety measures concerning navigation of bunkering ships and bunkering operations.

(Solutions)

Bunkering companies formulate specific safety measures with the cooperation of the Japan Coast Guard Headquarters and related parties when specifications of bunkering ships, navigation routes and work procedures are specifically determined.

4-4. Cooperation measures with overseas

It is necessary to form a network among LNG bunkering bases in multiple countries in order to further promote LNG fuelled ships. If the methods of bunkering operations vary significantly in each country, such as standards of the equipment, qualifications required for seafarers, safety measures, it will be complicated and unfavorable for operators of LNG fuelled ships. It is becoming the world's common understanding that it is required to develop infrastructure of LNG bunkering from both hard and soft aspects.

In October 2016, including Ports and Harbours Bureau of the Ministry of Land, Infrastructure, Transport and Tourism, the Port authorities of 8 representatives from seven countries 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 memorandum is to form a network among LNG bunkering bases and promote the conversion of ship fuel from heavy oil to LNG by harmonizing standards and specifications related to LNG bunkering. It is required to promote cooperation with related countries as a framework.
Especially, strengthening the cooperation with Singapore, which is the world's largest bunkering country, will lead to the development of a new LNG bunkering market.
Singapore would geographically become a bunkering hub in the Southeast Asia for ships heading towards Europe and Japan would be a bunkering hub in East Asia for ships heading towards North America, therefore, it would contribute to the realization of strengthening the competitiveness of Japanese port to develop LNG bunkering bases in Asia by cooperating with each other.

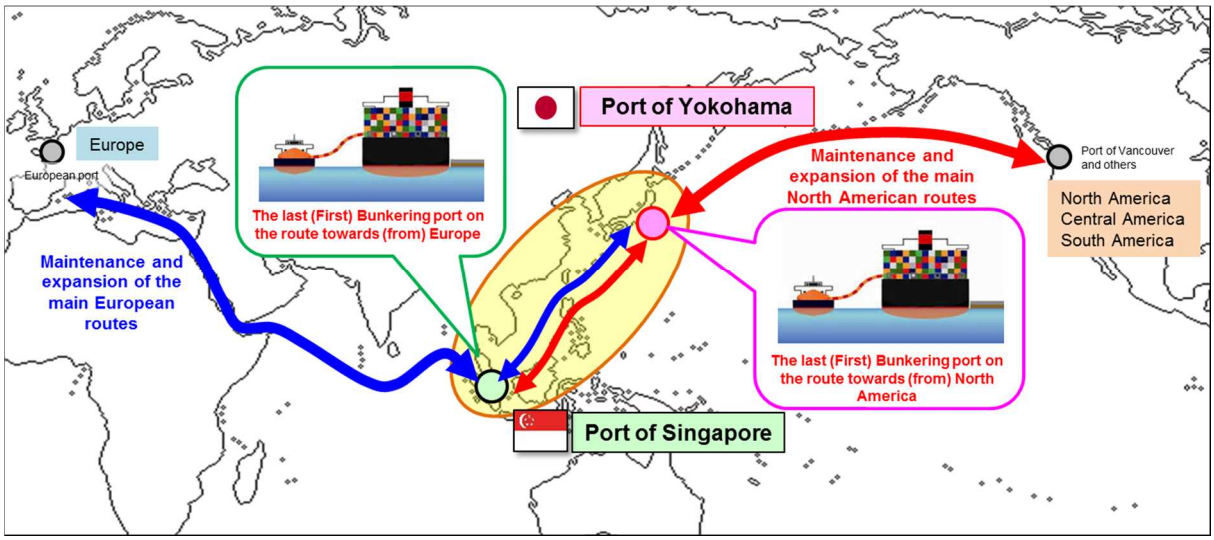


Figure 32. Formation of LNG bunkering hubs by collaboration between the Port of Yokohama and the Port of Singapore. (image)

4-5. Towards the realization of competitive LNG prices

In order to promote the development of an LNG bankaring base, it will be necessary to secure a certain demand for LNG bunkering to establish a bunkering project as a commercial business. It is also one of the important elements for Japan to procure LNG at low cost and supply LNG bunkering at inexpensive prices to secure demand.
Until now, when LNG was procured by Japanese companies, it was common to have a long-term contract period and use a price determination method based on crude oil prices. After The Great East Japan Earthquake, the prices increased due to the rise in crude oil prices and Japan suffered a trade deficit for several years after 2012. Low prices are also an important issue for the general economy of Japan.

On the other hand, the environment surrounding LNG trading has changed significantly in recent years. Other than in traditional LNG consuming countries such as Japan, Korea, LNG demand is expanding worldwide, including Southeast Asia.

In addition to these changes in demand, LNG supply continues to expand both in quality and quantity. LNG exports from the United States began in 2016, for example.

There are great changes in Japan. The electric market has been fully liberalized in 2016 and the gas market is also planned to be liberalized in 2017. It is expected that power and gas operators who were major LNG importers so far will aim at flexible procurement that will respond to the uncertainty of energy demand.

Based on these environmental changes, the Ministry of Economy, Trade and Industry announced the ″Strategy for LNG Market Development″ in May 2016 in order to develop a highly liquid international LNG market. Specifically, they aim to make Japan a base (hub) of transactions and price formation of LNG by the first half of the 2020s and realize a highly liquid LNG market by focusing on three points; the improvement of ease of trading, the establishment of price indicators reflecting supply and demand, and an open and sufficient infrastructure development.

Regarding the improvement of the ease of trading, they plan to cooperate with major LNG consuming countries such as Europe, South Korea, China and India as well as aiming at calling for an ease and an elimination of the destination clauses in cooperation with major consuming countries in the world. They also aim to conduct policy dialogues with related countries to expand new consumers by promoting the use of natural gas and LNG abroad, mainly in Asia.

Concerning the establishment of price indicators, they aim to improve the reliability by promoting the competition of spot price assessment by price reporting organizations and to introduce a third-party access system to LNG receiving terminals in terms of infrastructure improvement.

They also holds the ″LNG Producer - Consumer Conference″ every year in Tokyo as a platform to coordinate collaboration markets between producing and consuming countries towards the development of these LNG. On November 24th 2016, the fifth meeting was held to discuss measures for Asian LNG market development and improvement of the liquidity of LNG markets.

Through these efforts, they aim to improve the environment for stably procuring LNG at reasonable prices and procure inexpensive and stable LNG in Japan.

Conclusion

In this feasibility study, the Steering Committee examined the issues and measures for the development of LNG bunkering hub using the Port of Yokohama as a model case. It is important to increase the whole demand including not only ocean-going but also coastal LNG fuelled ships in order to attract ocean-going LNG fuelled ships.

The Steering Committee strongly hopes that the development of LNG Bunkering hub at ports in Japan, including the Port of Yokohama, will be proceeded and the competitiveness of our ports will be strengthened with the use of this report as reference.

List of Member

Chairman

Seizo Matsura	Director, Port Logistics Strategy Office, Ports and Harbours Bureau, Ministry of Land Infrastructure, Transport and Tourism (MLIT)

Member

Takayuki Gemma	General Manager, Regasification & Power Generation Dept., Tokyo Gas co., Ltd
Koji Shinozaki	Senior General Manager, Fuel Group, Nippon Yusen Kabushiki Kaisha (NYK Line)
Takashi Masaoka	General Manager, Planning Department, Yokohama-Kawasaki International Port co., Ltd
Hiroya Nakano	General Manager, Policy Coordination Department, Port and Harbor Bureau, City of Yokohama
Yu Teraoka	Senior Oil and Gas Strategist, Deputy Director, Agency for Natural Resources and Energy
Takashi Kawai	Deputy Director, Ocean Development and Environment Policy Division, MLIT
Yuji Sakanaka	Special Assistant to the Director, Navigation Guidance Office, Navigation Safety Division, Maritime Traffic Department, Japan Coast Guard Headquarters

Observer

Motoko Ogawa	Ministry of Economy, Trade and Industry
Naoki Takigawa	Special Assistant to the Director, Ocean and Environmental Policy Division, Ports and Harbours Bureau, MLIT
Yuichi Kousaka	Senior Director for Policy Planning, Kanto Regional Development Bureau, MLIT

Secretariat

Port Logistics Strategy Office, Ports and Harbours Bureau, MLIT

Event history

The first meeting on June 9, 2016

Establish the review meeting and elect a chairperson
Exchange opinions on the status of related stakeholders

The second meeting on July 14, 2016

Direction of arrangement and problem solving

The third meeting on August 24, 2016

Consideration of LNG price, demand, cost

The fourth meeting on September 26, 2016

Review of business profitability

The fifth meeting on October 24, 2016

Measures to improve business profitability
Consideration of direction of compilation

The sixth meeting on November 30, 2016

Measures to improve business profitability
Review of proposed compilation

The seventh meeting on December 20, 2016

Compilation