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The Potential of Using LNG as a fuel in Marine Transport

Gholamali Rahimi[1]*, Touraj Dehghani[2], Mohammad Sadegh Jokar[2]

[1]Research Instructor, Department of Innovation Management, Technology Research and Development, Faculty of Energy economics, Institute for International Energy Studies (IIES), Petroleum Ministry, Tehran, Iran.

[2]Assistant Professor, Department of Innovation Management, Technology Research and Development, Faculty of Energy economics, Institute for International Energy Studies (IIES), Petroleum Ministry, Tehran, Iran.

ABSTRACT

Considering that natural gas is the cleanest fuel among fossil fuels, LNG is also considered one of the best fuels in terms of environmental benefits compared to traditional fuels in the transport sector. LNG can be used as a fuel in the transportation sector for heavy trucks and for marine transport. LNG can be traded and traded with a positive profit margin in competition with gasoil, diesel, and boats fuel (MGO) and even CNG. One of the applications of small scale LNG is its use as a fuel in the maritime transport sector, which is considered as the most demand and one of the main drivers for the development of a small scale LNG in Scandinavia and the Baltics. In order to use LNG as a fuel in the maritime transport sector, ship owners and their tenants must comply with the rules laid down in the Sulfur Controls (SECAs). Maritime transportation is divided into two parts of emission control area (ECA) and shipping in international waters. The use of LNG ships for the ECA region is a good option because it also has a cost advantage for LNG prices in comparison with marine gasoil (MGO) and that LNG-powered engines have lower emissions of nitrogen oxides. Heavy fuel oil ships with equipment for reducing or removing sulfur oxides are less appealing to customers due to the need for waste management and space requirements. The contribution of LNG ships to various factors depends on:

- *The number of new ships*
- *The share of LNG from new ships as well as ships that have replaced their engines.*
- *Number of old diesels dropped out.*

Keywords: *Fuel, LNG, Marine transport, Gasoil, Diesel*

Corresponding author: Gholamali Rahimi
e-mail ✉ Alirahimigh2000 @ yahoo.com
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1. INTRODUCTION

The Current Status and Outlook of LNG-fueled vessels in the World

Currently, there are 79 LNG-fueled vessels in the world, 85% of which are in the European region, 9% in the US and 6% in Asia. Most of the world's operating ships are in Norway and its share of total LNG-fueled vessels by 2016 is estimated at over 67%.
In addition, there are 85 LNG-fueled vessels under construction in the world, which will be operational by 2018. Of these, about 71 percent will be in Europe, 26 percent in the US, 3 percent in Asia Pacific, and about 1 percent in the Middle East. Norway's share of the ships under construction is also around 12%. (Wurster et al., 2014)

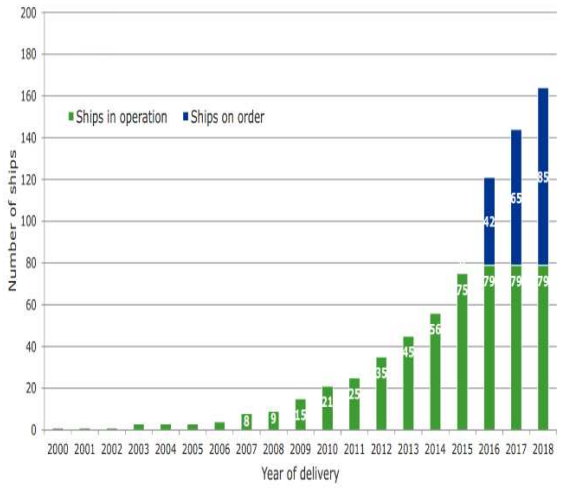

Figure 1. The geographical distribution of LNG fueled ships in different regions of the world

There are also about 50 new LNG-fueled ships to be built in the coming years. It will reach 200 ships.

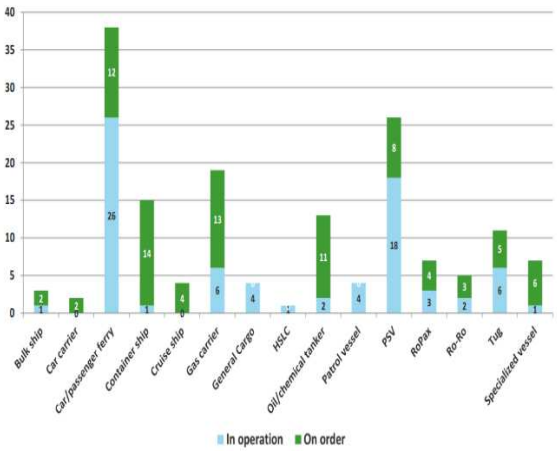

Figure 2. Current Status and Outlook of LNG fueled Ship by Type of Ship

The Current Status and Prospects of Using LNG as Fuel for Ships in the United States

As of 2015, the total number of US LNG ships under construction and planned was about 28, including the total number of new ships under construction, 17 and the number of modified fuel ships estimated to be more than 11.

More than 9 vessels are planned for operation in the Atlantic (Florida-Puerto Rico) and about 6 vessels are scheduled to operate in the Gulf of Mexico. The total number of LNG-fueled vessels in the United States is projected to increase to more than 376 by 2029.

Types of LNG refueling in ships (Nikolaos and Ventikos, 2016)

Similar to conventional fuel refueling with heavy fuel oil and offshore diesel, LNG fueled refueling is done in different ways. Currently, the bulk of LNG ship refueling is carried out through the LNG refueling system as well as through small-scale intermediate terminals. The following methods are generally used to refuel LNG ships:

- Truck to Ship (TTS)
- Intermediate Tank via Pipeline to Ship (ITPS)
- Ship to Ship (STS)
- Container to Ship (CTS)

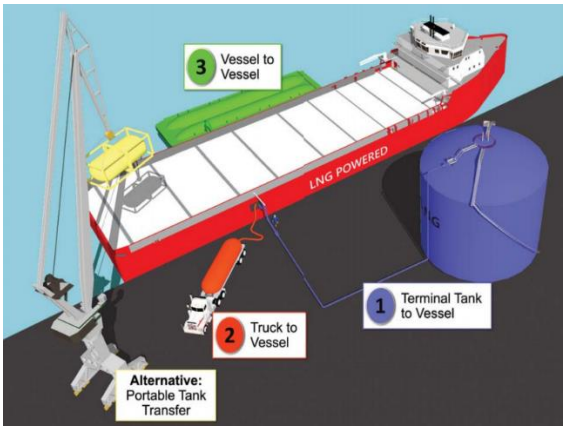

Figure 3. Types of LNG refueling methods

Truck to Ship (TTS)

Currently, the most common LNG refueling method is the LNG truck transfer method. This method is reasonable if the fuel requirements are low. An LNG truck can carry up to 22 tons of LNG. The capacity of LNG to be transported by a truck depends on factors such as the capacity of the LNG storage tank on the truck, national transport regulations, road infrastructure and road standards. If the LNG fuel required by the ship is being refueled (more than 50 tonnes) then other refueling techniques are usually used.

Figure 4. Refueling by truck-to-ship transmission system using two LNG carriers (Skangass Norway refueling station)

The most important advantage of refueling through the LNG truck is the low required initial investment and the possibility of using it for other purposes such as local LNG distribution. This advantage has made it a viable option for LNG refueling operations to commence operation of LNG refueling facilities. It also has a great deal of flexibility, and all types of LNG-fueled ships can be refueled at various docks.

On the other hand, the limited capacity of refueling is one of the limitations and disadvantages of this method. Another disadvantage of these methods is the possibility of interfering with the refueling activity of the dock with other docking activities such as freight and passenger loading. The LNG refueling site is not very flexible because it should be connected to the road transport infrastructure suitable for LNG transportation by truck. (Bekaert, 2016)

LNG storage tanks Refueling trucks are compact tanks and thus can be refueled by LNG transmission trucks in two modes: transfer to pressure storage tank and atmospheric pressure storage tank to LNG fueled vessels.

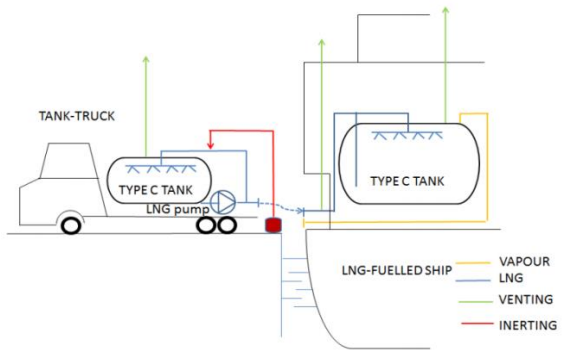

Figure 5. Overview of LNG refueling facilities via LNG transmission trucks (LNG storage tank is pressure vessel type)

Intermediate Tank via Pipeline to Ship (ITPS)

Another common method for refueling LNG is via pipeline from the intermediate terminal storage tank to the ship. Depending on the volume of LNG required for refueling, the storage capacity of the refueling intermediate storage tanks can range from small quantities of about a few tons to more than 50,000 tons. In this approach, the LNG required for refueling facilities can be provided by truck transport, small LNG vessel, large LNG vessels, or by pipeline from the local LNG liquefaction facility. In this method, even large scale LNG import terminals can be used directly to refuel LNG.

Figure 6. Refueling through the pipeline from the intermediate terminal storage tank to the ship
(Eidesvik Norway refueling station)

One of the limitations and disadvantages of using this method for LNG refueling is that due to the technical and operational limitations of LNG transmission over long distances, storage tanks for supplying LNG for refueling should be located adjacent to the refueling dock. Therefore, it is not possible to use this method in cases where there is not enough space for the storage tanks adjacent to the quay and other relevant safety equipment. The flexibility of these facilities is also low. Therefore, if there is a stabilized market with a significant guaranteed demand volume for LNG refueling in the area concerned or the facility can be used simultaneously for several purposes (local distribution of LNG for use in remote industries and areas) It would be possible to use this method. In this method, the storage tanks of the refueling facilities can be both pressure vessels and atmospheric tanks. (Wuersig Gerd-M. 2016)

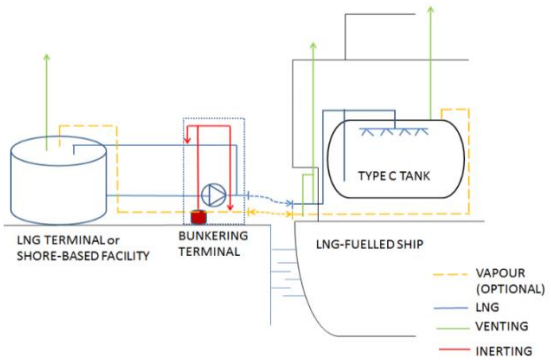

Figure 7. Overview of LNG Refueling Facilities via Pipeline from Terminal Intermediate Storage Tank
(LNG storage tank is pressure vessel type)

Ship to Ship (STS)

Both refueling via truck and LNG terminal have limitations on refueling capacity and flexibility. Therefore, to prevent and eliminate these limitations, the LNG refueling method is used in the same way as the refueling of fuel oil and gas oil vessels. Given the possibility of transferring different capacities of LNG and in different locations, this refueling method has considerable parental flexibility and almost all types of LNG fueled vessels and vessels can be refueled. Of course, this refueling method has its limitations too, such that its initial investment cost is considerable and if it is not developed sufficient demand for LNG refueling will not be economically feasible. It will also be necessary to use one or more tugboats when using unmanned vessels for storing LNG to move it from one location to another. LNG Storage Tank LNG refueling vessels can be both pressure vessels and atmospheric tanks. Therefore, in any of the above types of special infrastructure and refueling equipment will be required. The overview of the refueling stations in the case of a pressurized or conventional fuel tanker is shown below.

Figure 8. Sample of a fuel tanker with a capacity of 2800 cubic meters

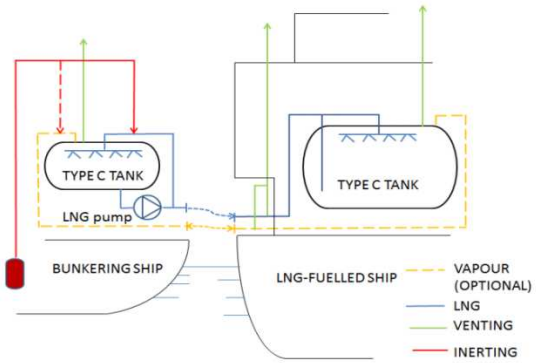

Figure 9. Overview of LNG refueling facilities through fuel ship (LNG storage tank is a fuel tanker and fuel tanker type pressure vessel)

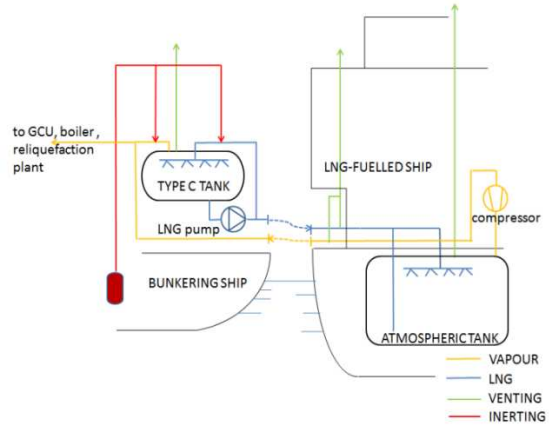

Figure 10. Overview of LNG refueling facilities through fuel ship
(LNG storage tank is a fuel tanker type atmospheric tank)

LNG fuel ships are usually used where there is a significant demand for LNG in the area. The capacity of these ships varies from a few hundred cubic meters to several thousand cubic meters depending on the volume of market demand. These types of vessels can be accommodated in special locations for which they are built or small marine terminals as well as small scale LNG transmission and import terminals. (Molitor et al., 2012)

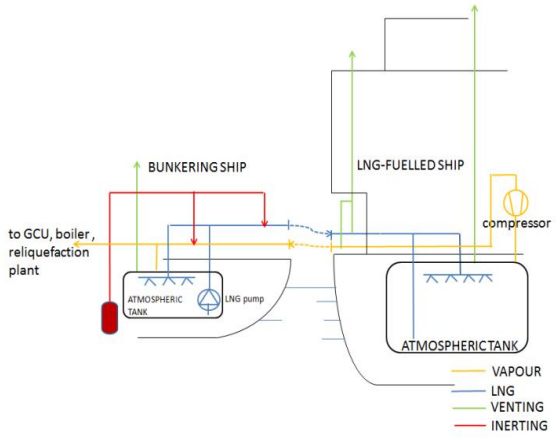

Figure 11. Overview of LNG refueling facilities through fuel ship
(LNG storage tank is a fuel tanker and a fuel tank type atmospheric tank)

Container to Ship (CTS)

Another method of LNG refueling is to use LNG containers on LNG fueled ships. In this method, which has not yet been widely used commercially, LNG is shipped in special containers from the liquefaction facility and placed on LNG fueled vessels. Due to the use of standard isolated containers, it is possible to use existing LNG infrastructures in this method. A standard 40-inch container can carry and store 17 tons of LNG.

One of the advantages of this method is its applicability to the existing infrastructure of the LNG supply chain. The main drawback of this method is the high cost and high weight of LNG storage containers for shipping.

The advantages and disadvantages of each of these refueling methods are summarized in the table below. (Poulovassilis, 2012)

Table 1. Advantages and Disadvantages of Each LNG Refueling Method

Refueling method	Advantages	Disadvantages
Truck to Ship (TTS)	• flexibility • Low infrastructure costs required	• Low LNG transmission capacity • Low LNG refueling capacity
Intermediate Tank via Pipeline to Ship (ITPS)	• Accessibility • High capacity for refueling • High capacity LNG storage tanks	• Need a dedicated dock • Occupy and take over part of the port • High cost of required infrastructure • Need for a second side
Ship to Ship (STS)	• flexibility • High capacity for refueling • High capacity LNG storage tanks • Possibility of refueling at the port	• High cost of required infrastructure
Container to Ship (CTS)	• Need easier support and logistics • Possibility of regular shipping of containers • Availability	• The high cost of LNG tankers • Need for extensive loading and unloading operations

Currently, 7 European ports offer ship refueling services. These ports by type of refueling stations are: (Bashar, 2015)

- Stockholm Port- Ship to Ship (STS)
- Port of Antwerp- Truck to Ship (TTS)
- Zeebrugge Port- Truck to Ship (TTS)
- Port of Amsterdam- Truck to Ship (TTS)
- Port of Moerdijk- Truck to Ship (TTS)
- Port of Brunsbuttel- Truck to Ship (TTS)
- Port of Hirtshals- Intermediate Tank via Pipeline to Ship (ITPS)

2. CONCLUSION

According to a 2012 study by Lioyds Regidter entitled "The LNG Outlook for LNG Bunker and LNG Fueled New Build Up to 2025" to forecast LNG demand as fuel in the maritime transport sector, The most important fuel ports are referred to the ships and the refueling rate of the vessels is specified. More than 35 percent of the world's ships are refueled in these 10 ports. Among these ports, the Islamic Republic of Iran ranks 10th in the world and has significant potential for LNG-fueled LNG ships in the coming years.

Table 2. The most important ship refueling ports in the world in 2012

Port	Throughput (in thousand tonnes)	Market Share
Singapore	39011	17%
Rotterdam	13000	6%
Fujairah	9500	4%
Antwerp	6108	3%
Hong Kong	5429	2%
Gibraltar	5047	2%
Korea (Busan)	4559	2%
West Africa	4100	2%
Tokyo Bay	3494	2%
Iran	3135	1%
Rest of World	138530	60%
Grand total	231913	100%

In this study, based on a survey of shipowners, they asked about the priority of their actions to comply with the GHG emission reduction laws. Based on the above study, the use of low sulfur furnace oil and installation of sulfur emission reduction equipment in ships has been introduced as a short-term solution. The use of sulfur emission reduction technologies has been announced as a mid-term solution. The use of LNG-fueled ships is a long-term solution in this regard.

This study considers three different scenarios for the prospect of LNG demand. In the reference scenario, it is assumed that given the current maximum sulfur emission for the ECA region at present and the maximum sulfur emission equivalent of 0.5% for the entire world by 2020, the number of new LNG burning vessels by 2025 will be more than 653 Shipbuilding has increased and demand for LNG will rise to more than 24 million tonnes (equivalent to 1.5 percent of total world LNG production and about 3.2 percent of total fuel consumption in the shipping sector).

Table 3. Outlook of Global LNG Ship Demand by 2025 Based on Forecast Reference Scenario

Deep Sea Ship types	Cumulative HFO bunker consumption MnT (2012-2025)	Cumulative LNG bunker consumption MnT (2012-2025)	LNG bunker as a % of global HFO bunker demand per ship type
Container ship	805	10.7	1.3%
Dry bulk carriers	1178	5.1	0.4%
Oil tankers	352	2.6	0.7%
Cruise ships	179	3.3	1.8%
Chemical tabkers	75	0	0%
LPG tankers	20	0	0.1%
General cargo ships	83	0.2	0.3%
Car carriers	123	1	0.8%
Grand total	2815	24	0.8%

In the high scenario for LNG demand is assumed to reduce the price of LNG by 25% compared to the reference scenario, and the tendency to build new LNG-type ships will increase by 75% over the period 2025-2025. According to this scenario, the number of new LNG-fueled vessels is projected to increase to more than 1963 by 2025, and demand for LNG will rise to more than 66 million tonnes (equivalent to 4.2 percent of global LNG production and about 8 percent of total oil consumption). Increase the heavy furnace in the shipping sector. (Graugaard, 2013)

Table 4. Outlook for Global LNG Ship Demand by 2025 Based on high Scenario

Deep Sea Ship types	Cumulative HFO bunker consumption MnT (2012-2025)	Cumulative LNG bunker consumption MnT (2012-2025)	LNG bunker as a % of global HFO bunker demand per ship type
Container ship	805	28.1	3.5%
Dry bulk carriers	1178	19.9	1.7%
Oil tankers	352	8.9	2.5%
Cruise ships	179	5.6	3.1%
Chemical tabkers	75	0.1	0.2%
LPG tankers	20	0.1	0.3%
General cargo ships	83	0.9	1.1%
Car carriers	123	2.3	1.9%
Grand total	2815	65.8	2.3%

In the low LNG demand scenario, it is assumed that the LNG price will rise by 25% over the reference scenario and that the implementation of the sulfur emission limitation rules be postponed until 2023, in which case the tendency to build new LNG vessels will be delayed. The burner will be greatly reduced. According to this scenario, the number of new LNG-fueled vessels is projected to increase to about 13 by 2025 and the demand level of LNG to be about 0.7 million tonnes (equivalent to 0.001% of total world LNG production and about 0.002% of total heavy oil consumption In the shipping sector). (Faber et al., 2015)

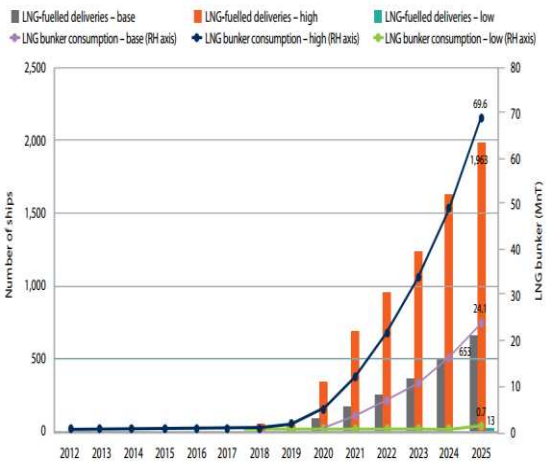

Figure 12. Comparison of Outlook of Global LNG Demand for Ship Fuels by 2025 Based on Three Low, Reference and High Forecast Scenarios

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