LNG AS MARINE FUEL: CHALLENGES TO BE OVERCOME

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KEYWORDS: LNG, fuel, bunker, marine, safety, regulations, standards, economics, supply chain, costs, economics, challenges

ABSTRACT

International Marine Organization (IMO) has introduced restrictions on emissions that will come into force in 2015 in the Emission Control Areas and 2020 for the rest of the world. In order to be compliant with these restrictions, business as usual is no longer an option for the ship-owners. Several solutions are being evaluated, however, LNG has the possibility of remaining the leading candidate in order to retain a substantial share of the world bunker market: proven technology (around 40 ships running on LNG), more than meeting the new emissions requirements and less CO2 emissions. In addition, economics are in many cases in favor of LNG. However, several uncertainties need to be further evaluated and solutions found in order to have LNG become the preferred choice also in this segment. Investments have to be committed all along the value chain and the market faces the classical chicken-and-egg dilemma: Longer term volume commitment from both suppliers and ship-owners that can justify the investments required. The solution will probably be a longer term ramp-up of supply and demand in line with progressive infrastructure investments. Development of regulations, codes and standards has to be made to balance carefully the excellent safety records of the LNG industry without too constraining barriers for the development of new LNG infrastructure required to supply the marine fleet. The world's potential bunker market is equal to the world's LNG production. Consequently, the questions of LNG availability and value/pricing have to be further evaluated. Bunker LNG has a realistic potential to represent around 45 Mtpa by 2030, which is equal to 9 LNG classic trains dedicated. In the future, with an expected even tighter energy market, LNG for bunker will naturally be in competition with other LNG markets.

ABBREVIATIONS

DME = DiMethyl-Ether
ECA = Emission Control Area
EU = European Union
IMO = International Maritime Organization
HH = Henry Hub
HFO = Heavy Fuel Oil
LNG = Liquefied Natural Gas
MARPOL = International Convention for the Prevention of Pollution from Ships
MDO = Marine Diesel Oil
Mtpa = Million tons per annum
NA = North America
NBP = National Balancing Point
ROI = Return On Investment
SCR = Selective Catalytic Reduction
INTRODUCTION

International Marine Organization (IMO) has put in place restrictions on emissions from ships that will come into force in 2015 in the Emission Control Areas and 2020 for the rest of the world. In order to be compliant with these restrictions, business as usual as regards fuel will no longer be possible for ship-owners!

Several solutions are possible and LNG is a very good alternative to retain a substantial share of the world bunker market: it is a proven technology (around 40 ships running on LNG), it meets emissions requirements and beyond, and emits less CO2. In addition, economics are in many cases in favor of LNG. However, many challenges need to be overcome.

From a pure economic point of view, new investments have to be made all along the value chain and the market faces a classical “chicken-and-egg” situation. This can only be overcome with long term commitments, aggregated volumes and long term vision from stakeholders. A progressive and risk limited ramp up of the market is required in order to meet long term objectives and requirements.

Regulation, codes and standards have to be developed in a manner whereby safety track record as regards the LNG industry is maintained, without introducing unnecessary too high barriers for the required infrastructure’s development.

Since the world’s bunker market has potentially the same demand as the world’s LNG production today, the question of LNG availability has also to be further studied. Bunker LNG could realistically represent around 35 Mtpa by 2030 which equals 7 LNG trains dedicated to this market only. In the future with tighter energy markets, bunker LNG would compete with other requirements/need for LNG.

The purpose of this paper is to provide an overview of the challenges and possibilities ahead for the development of LNG as marine fuel. First a general overview of the subject is presented (section 1) including economic valuation of each solution for shipowners (section 2), description and costs of the supply chain (section 3). Then the main challenges to be overcome are presented as well as each time an evaluation of the best way to approach these issues (Section 4 and 5).

1. DRIVERS

For decades, transport fuel was almost exclusively oil-products for the simple reason that oil was abundant, practical and cheap. Natural gas in general and LNG in particular were recognized as having attractive advantages over oil in terms of energy content (energy per mass unit) and environmental footprint. However, since it was less readily available and more expensive, LNG has continued on the whole to be limited in application to research and very small niche market. In recent years, however, several key trends have converged to radically alter the landscape and the situation is now on the brink of a material change.

The demand for energy is still outstripping the supply of cheap oil, with the result that oil prices have quickly risen to the marginal production cost of deep offshore or oil sands. According to BP historical data, the price of oil in 2011 US Dollars is at a historical high, and as high as at the very beginning of the oil industry (figure 1).
A growing portion of oil production is now operated by national companies, making oil a core geopolitical focus. This also restricts the availability of resources from certain countries, aggravating the imbalance between supply and demand.

In the mid-2010s, the US shale gas revolution brought considerable gas reserves to the market, and the surplus supply sparked a price drop in the USA. Spot gas prices became more competitive and started to de-correlate from oil prices. The North American reserves/production ratio is expected to climb from 12 years to as much as 250 years.

The same period saw quantities of LNG produced from new sources, with new producers Egypt, Equatorial Guinea, Norway, Peru and Yemen all eager to join the “club” of exporters, while the traditional producers, Qatar in the lead, upped their output.

Climate change and reduction of air emission became key issues, and not only for mature markets. This brought changes in the regulatory framework, reducing the thresholds of both GHG and local pollutants (particle matter, NOx, sulfur…). On this score, natural gas’ cleanliness and single carbon molecule enable it to meet the lower emission levels more easily than any other fuel of hydrocarbon origin. Electricity, on the other hand, eliminates local emissions but increases GHG effects depending on the fuel used in power plants, and is still limited by storage capacity.

The technological progress achieved in liquefaction, storage, handling and combustion of natural gas and LNG also contributed to the boom in interest for LNG.

All in all LNG has become a credible challenger to oil products for marine and heavy-duty transportation. However, the lack of infrastructure for LNG retailing and the limited number of LNG-fueled vehicles creates a challenge. Therefore, the emergence of an LNG market for marine and heavy-duty transport depends on powerful drivers being in place to break the stalemate. At least two of them are already identified:

a. Environmental driver
   i. IMO Regulations

In 2008, the IMO adopted a resolution to update Annex VI of the MARPOL convention on air emission control for ships. The revised Annex VI came into force on July 1, 2010 reducing the sulfur content in marine fuels from 4.5% to 3.5% maximum. In 2020, that cap will be further reduced to as low as 0.5% worldwide, pending a feasibility assessment to be performed in 2018 which may postpone enforcement of the new 0.5% rate to 2025.
This Annex also introduces the possibility for countries to enact more restrictive rules in the so-called Sulfur Emission Controlled Areas (SECA). The maximum sulfur content in SECA areas is limited to 1% from July 1, 2010 to January 1, 2015, at which date the cap will drop to 0.1%. As of today, the North Sea, Baltic Sea and part of the Channel are declared as SECA areas, together with a 200-mile stretch of the North American coast (fig 3). There is the potential for new areas to become SECA areas, and the Mediterranean Sea, central America coast, Singapore and others are considering this option.

Reducing NOx emissions is another target, and new-build ships are required to reduce by 80% from 2020. The NOx reduction policy implemented in Norway is one of the key factors explaining the success of LNG for short sea vessels.

In the long-term climate change perspective, CO2 emission from marine transport is still being negotiation. Before an agreement is achieved by IMO, the European Union is considering the potential gains of reducing GHG emissions along its coasts.

ii. Specific EU regulations

In Europe, directive 2012/32/EU dated Nov. 21, 2012 being an update of a former directive, addressing the sulfur content of marine fuel in Europe. It is aligned with the IMO Annex VI and eliminates the possibility to postpone the 0.5% sulfur content until after 2020.
Recently, the European Commission published a draft new Directive aimed at ensuring new infrastructure for alternative clean fuels. The draft directive identifies LNG as a preferred fuel for marine and heavy-duty transport and requires all European ports to be able to provide LNG bunker services.

Meanwhile, funds have been allocated by several European bodies to projects for building new LNG bunkering infrastructures. Most of them are located along the Northern European coast but Mediterranean countries have recently launched the COSTA study with the same objective.

iii. Security of Supply / Energy independence

Another important driver for the development of LNG as bunker fuel is the willingness for some countries to reduce their dependence of oil imports. More particularly, countries with gas reserves have an interest to promote the use of LNG as fuel in order to benefit from their resources.

2. LNG COMPETITIVENESS VERSUS OTHER SOLUTIONS

Ship-owners have only three realistic alternatives to achieve compliance with the SOx regulations: use MDO (marine diesel oil), install scrubbers on board the ships, or convert ships to run on LNG. The others (DME, nuclear, etc.) are considered having insufficient potential to represent significant volumes.

To meet the NOx regulations, only an LNG solution will in theory comply with Tier III. Ships will need to install systems to reduce NOx (like SCR systems) if running on MDO or HFO in any case.

a. Qualitative aspects

i. MDO Solution

Economic issues aside, MDO appears to be the easiest solution for ship-owners. Only new-build ships after 2016 will need to have an SCR installed on board, and its technology and feasibility are not seen as any major hurdle in either ship design or operability terms.

Most ship-owners are familiar with and use MDO. Besides, its market mechanisms and variations are very similar to HFO. MDO has the added advantage of necessitating no changes in commercial relations or general contract terms with bunker suppliers. The structure will continue to be based, as it is today, on product specifications clauses, incoterms, indexation and so on.

Usually, MDO is already available in ports and there are no problems regarding regulations, logistics or operations. Nevertheless, if the quantities of MDO delivered in ports rose significantly, the capacities of the current infrastructure and logistics means would need to increase to accommodate them. The logistics of oil products is well known and widely available, but capacities will need to be converted and/or further developed in most of the ports. Naturally, the level of investment needed is much lower than for LNG and the feasibility therefore higher.

Another probable challenge of significant additional demand is the impact on the refining balance of each region, which in turn might affect prices, especially in Europe, which already imports around 20 Mt of distillates each year. The impact on refining and on the price of distillates is outside the scope of this paper, as the subject is complex and would require considerable development.

ii. Use of Scrubbers

The use of exhaust-gas scrubbers appears a very promising solution for many ship-owners. The technology is not, for the time being, fully proven for ships but the stakes are high enough to serve as incentive to resolving the obstacles.
Scrubbers offer many advantages over other solutions, the most important being the ability for the ship-owners to maintain their current practices in terms of supply. Although the technology is not fully proven, it seems that retrofitting would be feasible for many of today’s ships. In any case, ship-owners can include in the design of the ship the possibility of installing a scrubber at a later date, which would make retrofitting possible.

This being said, scrubbers may cause problems of stability for some ships, since the exhaust gas treatment has to be installed on top of the exhaust stack. Ferries for example appear to be poor candidates for scrubbers. In addition, water treatment products and sludge management require additional logistics and operations for ships. Another drawback of scrubbers is that, in economic terms, fuel consumption will increase by between 1 and 3% and maintenance costs and OPEX are also higher.

iii. LNG

There are around 35 ships in the world today running on LNG, not counting LNG carriers and as many more are already on order or under construction. LNG technology is known and well proven and many players are dedicated to improve current products to optimize both costs and engine efficiency. LNG combustion emits zero SOx and engine manufacturers often claim that LNG engines will meet Tier III requirements, but this has yet to be proven for several engines.

Choosing LNG has a number of advantages compared to traditional fuels. In addition to complying with regulations concerning SOx and NOx, natural gas combustion emits around 20% less CO2 on a tank-to-wheels basis, although some studies deem reduction rather at around 10% on a well-to-wheels basis. Furthermore, a major advantage of LNG is that engines need much less maintenance as gas combustion is significantly cleaner than its HFO or MDO counterparts.

However, some drawbacks to the adoption of LNG as ship fuel certainly exist. While its density is much lower than that of traditional fuels, the space occupied by the tanks is higher. In addition, type C tanks are usually cylindrical which is not positive for optimizing space on board and, for safety reasons, more space is needed to isolate the gas system. The overall volume occupied for all LNG facilities on board is between 3 and 4 times higher than for conventional fuels, which represents a significant loss of cargo space for most types of ships. A membrane solution, currently under development, would definitely minimize this problem. In addition, retrofitting is very unlikely for most ships if their design has made no possibility for this option. Sometimes, however, it would be possible for tankers to install type C reservoirs on the deck.

However, the main disadvantage of LNG as a marine fuel is its availability. Not only does the supply chain yet have to be developed, but the challenge concerning availability makes LNG unsuitable for ships that require flexibility in their routes, like VLCCs or bulk carriers. Further limitations include safety requirements concerning LNG bunkering, maintenance and commercial operations, which adds complexity and the need for skilled and trained crews, and hence the types of ship suitable for running on LNG.

iv. Low-sulfur HFO

Many ship-owners have expressed their desire to see the refining industry offer a solution, being a low-sulfur HFO. According to some refining players, the cost of developing desulfurization capacities would be approximately the same as for deep conversion units, which would produce higher-value products. This option seems therefore unlikely to materialize and will therefore not be discussed further herein.
v. Summary

Table 1: Summary of Pros and Cons of the different solutions

<table>
<thead>
<tr>
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<th>Pros</th>
<th>Cons</th>
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<tbody>
<tr>
<td>Low-Sulfur HFO (0.5%)</td>
<td>Business as usual for ship-owners</td>
<td>Solutions other than blended products are highly unlikely. Desulfurization units would entail an investment equivalent to that required for the deep conversion processes.</td>
</tr>
<tr>
<td>HFO + Scrubber + SCR</td>
<td>Product Availability. Business as usual for ship-owners and refiners.</td>
<td>Solution has still to be proven Ship design and stability challenges Sludge management: need to create a logistics chain and adapt port infrastructure Higher OPEX, fuel consumption and maintenance costs</td>
</tr>
<tr>
<td>LNG</td>
<td>In principle, no need to install SCR. Potential CO₂ reduction (but methane slip has to be controlled). Much lower maintenance.</td>
<td>More space needed for the gas system on board Bunkering points and associated logistics to be created Safety aspects increase complexity of the supply chain, ship design and operations Skilled and trained crew.</td>
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b. Economic comparison

One of the most important criteria in determining the advantage for a ship-owner to invest in LNG-fuelled ships is of course the overall economic aspect.

i. Methodology

In order to compare the economics of the LNG solution with the alternatives, several factors have to be taken into account for each of the solutions and each of the segments defined below.

The price of the fuel is not considered as a base term in the assumptions but as a variable. The calculation seeks to answer the following question: “What is the minimum price differential between LNG and other competing fuels that would render the LNG solution competitive versus the others?”

For each solution, the differential are therefore expressed in $/MMBtu of fuel consumed (considering standard yearly consumption for each segment).

ii. Economic assumptions

For LNG-powered ships:

- Additional investments compared to a standard ship (engine, LNG tank, safety measures, control rooms, piping, insulation…)
- Loss of cargo space
- Lower OPEX and maintenance costs
- Higher Manning costs and crew training
Logistics costs for LNG (from import terminals or liquid gas hub, depending on the region)\(^1\). For ships with Scrubber:

- Additional investments compared to a standard ship (cost of the scrubber and the SCR, piping, installation…)
- Additional OPEX and maintenance costs
- Additional fuel consumption
- Logistics costs of treatment products and sludge management
- Logistics costs of HFO (from published FOB prices)

For MDO-fuelled ships:

- Logistics costs of MDO (from FOB published prices to the ship)

Other assumptions:

- All extra investments are considered as providing a ROI of 15% over 15 years which corresponds to a 5-6 years payback time
- All costs are relative to yearly consumption for each type of ship and expressed in $/MMBtu
- Economics are different depending on the type of ship\(^2\).

iii. Interpretation

This calculation determines, for each type of ship, the break-even spread of FOB prices, i.e.

- The minimum spread between LNG import price (or ex-liquefaction facility for producing countries) and HFO FOB price in order for LNG to be competitive against the Scrubber solution.
- The minimum spread between LNG import price (or ex-liquefaction facility for producing countries) and MDO FOB price in order for LNG to be competitive against the MDO solution

\(^1\) The detail of logistics cost will be presented further down, in section 3.

\(^2\) Ships considered are: small, medium, large and very large Bulk carriers, small, medium, large and very large container ships, Ferries, Ro-Ro’s, small, medium, large and very large Product tankers (including Crude carriers and gas tankers and excluding LNG carriers) and small and medium general cargo ships. Fishing and military vessels are excluded.
iv. Results

1. LNG versus HFO + Scrubber

Figure 4: Economic comparison between LNG and HFO+Srubber solutions for different type of vessels

This figure shows the break-even price spreads for different types of vessels. As an example, for “small/medium container” ships if the price difference between i) LNG in-tank at a terminal or liquefaction facility\(^3\) and ii) HFO FOB from a Refinery is higher than 1 $/MMBtu (LNG being cheaper), then LNG is competitive compared to HFO + Scrubber for “small/medium container” ships.

For a LNG price in Europe equivalent to NBP, LNG was competitive based on November 2012 published prices. But at Asian pricing, LNG HFO + Scrubber solution is the most economical solution.

In North America, based on current pricing LNG is competitive for all ships. LNG remains the most competitive solution for most of the ships even with a HH pricing around 7.5 $/MMBtu and current HFO prices.

2. LNG versus MDO

Figure 5: Economic comparison between LNG and MDO solutions for different type of vessels

\(^3\) Cost of liquefaction is considered being 4.00 $/MMBtu
LNG seems the most economical solution in all cases and all regions.

c. Market potential for LNG

There will obviously not be only one solution chosen for ship-owners to comply with the new regulations. Many factors have to be considered to determine the best solution: the type and age of the ship, its route, its secondary market, the owner’s financial strength, competition among ship-owners, qualification of crew, value of the cargo (and hence of the potential loss of cargo space), experience of the owners regarding LNG, global, regional and local availability of the products etc… The world bunker market will certainly be split between the different solutions.

LNG appears to be a suitable solution in many cases. Certainly, the economics are not always in favor of LNG (depending on forecasted prices) but all aspects have to be addressed. The development of LNG as bunker fuel will necessarily be progressive and slow.

In a first phase of development, short sea ships in ECA with fixed routes will develop a high proportion of new-build ferries and RO-ROs and a small share of new-build or existing product tankers. The ships will be impacted by the regulations in 2015 and competition between ship-owners is strong. Because of design and stability issues, many of these ships will not be able to install scrubbers. Many inland ships will run on LNG as well, which should increase the LNG quantities available in port in order to reach a certain scale.

The expected volumes in 2020 represent between 3 and 5 Mtpa of LNG in the North Sea and the Baltic sea and the same volume in North America. Mediterranean ships could represent an additional 2 to 3 Mtpa by 2020.

In a second phase, some deep sea liners will run on LNG. These will be mostly new-builds since retrofitting appears very challenging to perform. Major container-ship operators will first test this solution by ordering a few ships to run on LNG, but in view of the consumption, this would add up to significant volumes. If the tests prove positive on operational and economic aspects, container-ship owners will most likely decide to diversify their fuel and technological risks by switching part of their fleet to LNG.

By 2020, deep-sea container ships are expected to represent only 2 Mtpa of LNG consumption but this will grow progressively to 5 Mtpa in 2020 and 15 Mtpa in 2030.

A third phase of development will start around 2025, once LNG is available in several ports in North America, Europe and Asia. Short sea ships without fixed routes but sailing in regions where LNG is available may then convert. Some deep sea VLCCs or Bulk carriers could run on LNG as well, but the need for flexibility in the routes could reduce this possibility. It is naturally difficult to predict the volumes at stake that might switch to LNG in this phase but it is unlikely that LNG will be a common fuel for these ships. A conservative estimation would be around 5-10 Mtpa by 2030.

<table>
<thead>
<tr>
<th>Bunker LNG estimates (Mtpa)</th>
<th>2020</th>
<th>2025</th>
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<td></td>
<td>10</td>
<td>15</td>
<td>30-35</td>
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\[4\] In-house Company calculation model based on total consumption per region and type of vessel, by adding the probability for each segment of using LNG over time.

\[5\] Corresponding to 25-30 new-build ships in order for the ship-owners to start preparing the 2020/2025 deadline

\[6\] In-house Company calculation model based on total consumption per region and type of vessel, by adding the probability for each segment of using LNG over time.
3. SUPPLY CHAIN

The requirement to initiate and construct the complete supply chain is seen as a major hurdle for the development of bunker LNG. Effectively, there are very few supply points for bunker LNG, even though LNG is already available in many places. The further logistics are required to transport it to the port, store and bunker the ship.

a. Starting point

The starting point of this supply chain depends on the region and thereby its availability of LNG or pipe gas, importing or exporting region, extension of the region and port density and so on. Every case has to be considered separately, taking these characteristics into account. We will focus further on as regards Europe and North America as an example that can be partly transposed to other regions.

i. Europe

In Europe, where LNG is available in regasification terminals, these terminals will be the starting point of the supply chain. Some of them already have facilities for loading LNG into trucks (Spanish terminals, Zeebrugge, Montoir after July 2013), smaller ships (Zeebrugge, Huelva, and others are planning to develop such export capacities.

As LNG in Europe is imported, it makes no sense, economically, to use pipe gas and liquefaction capacities as starting point, except possibly in producing regions such as Norway or Eastern Europe for future shale gas production.

The North Sea, Mediterranean Sea and Atlantic coast have sufficient LNG terminals to cover most of the ports in Europe. However, in order to supply Baltic Sea ports, new import terminals to be used as distribution hubs are already under development in the region. They will receive LNG from large import terminals in Europe through small-size LNG Carriers (15,000 – 30,000 m3).

ii. North America

It is anticipated that LNG will no longer be imported through the regasification terminals in North America, and instead USA will soon be exporting. The LNG chain starting point could therefore be the export liquefaction facilities, peak shavers or small-scale liquefaction plants could also be constructed for the sole purpose of supplying LNG as fuel (for bunkers but also for trucks or inland shipping) and industrial customers at a long distance from the gas network.

The origin of supply to a port will depend on its distance to an existing liquefaction facility and the expected LNG consumption in the port, but since the cost difference between large-scale and small-scale liquefaction seems to be small, it might be economically advantageous to build liquefaction facilities near the applicable sites. However, the risk of investment in such facilities without the corresponding outlet is too high. Most likely, bunker suppliers in ports will first import from existing facilities (large liquefaction plants, existing small-scale facilities or peak shavers) before obtaining the volumes that justify investing in liquefaction.

In any case, if the market for LNG as fuel (trucks, bunkers) develops as expected in North America, construction of small/medium scale liquefaction capacities will be required.

b. Transportation, storage and bunkering

The rest of the supply chain depends very much on the size and type of the market to be supplied. Two categories has been considered: "small ports" and "large ports"
i. “Small Ports”

This term refers to ports supplying between 1 and 5 vessels for consumption from 20 kt to 10 kt. Small ports include specifically ferry ports, which are very likely to be running on LNG after 2015.

In this case, port storage facilities are supplied by truck or ship. Economically, truck supply is more interesting than supply by ship below 300 kt. A first phase of development therefore inevitably involves truck transportation. Once several ports in the same area are equipped with LNG facilities (or demand from one port has grown beyond this limit), it is more economical to invest in a supply barge to supply all ports. It is also important from a Safety standpoint to reduce the number of LNG trucks in the ports.

For some specific cases where storage capacity on board the vessel is low, ships can be supplier directly by trucks. This is the case specially for ferries sailing short distances on a unique route.

Facilities in ports will be made up of type-C LNG storage tanks connected to a fixed bunkering location (the ship in the bunkering station could be connected with a flexible hose or an arm). The tanks will be refilled through a truck loading and unloading facility (mainly flexible hoses in a suitable zones) or through a ship loading and unloading facility.

Even if technology exists for all components there is still room for technological progress on some of the components involved, to fully meet industry requirements: flow meters, standard connections, loading and unloading arms fitted for bunkering at affordable price… The balance between safe and reliable operations and economically viable facilities design is relatively challenging. The technology used in large-scale LNG facilities is sometimes too expensive to maintain the economics of the business case. The industry is developing fit-for-purpose products to enter this market.

![Figure 6: Layout of possible supply chains for small ports](image)

ii. “Large Ports”

This term refers to ports with high LNG consumption (generally above 100 kt) and several types of ships supplied. A larger infrastructure is needed in these ports and more precisely a large LNG atmospheric storage unit (~15 000 – 30 000 m3) to be used as storage for loading bunker ships and trucks. The bunker ships will then supply the customers ship-to-ship. Trucks will supply smaller ships directly truck-to-ship and will export LNG to LNG stations for heavy-duty trucks and to industrial customers with no connection to the gas network.

Secondary small fixed storage units (onshore or floating), supplied by truck or barge, could also be developed to create fixed bunkering locations or to supply ships mooring in fixed locations.

Inland barges could also load from the tank to export LNG for onward distribution (inland shipping fuel, industrial customers, LNG stations, etc.).
The above description represents a supply chain for a port in which substantial volumes of LNG are supplied. This configuration has to be considered as a long-term objective but some of the component parts can be considered separately as single options for smaller markets.

For example, in a first development, trucks and a bunker barge will suffice to service a maximum market size of between 0.3 and 1 Mtpa (depending on the unit consumption of the ships supplied and on loading frequency).

Furthermore, for ports that already have an LNG terminal (like Dunkirk, Rotterdam, Barcelona, Zeebrugge, and so on), an atmospheric storage tank might not be needed if the LNG terminals or infrastructure players accept to invest in export capacities. LNG terminals would be required to develop either loading capacities for smaller ships and trucks directly, or export LNG pipeline capacities from the terminal to facilities adjacent to it where other investors will develop the loading facilities.

This layout enables a supply chain to develop progressively in order to minimize risks. To begin with, only export capacities from the terminal, a bunker barge and some trucks are needed to launch the business and service a significant market.
c. Cost estimation

i. “Small Ports”

Logistic costs for small ports are around 3.5 $/MMBtu and 2 $/MMBtu. Costs for facilities is around 1.5 $/MMBtu and cost for truck transportation around 2.2 $/MMBtu. For a ferry supplied directly by trucks the costs is around 2.2 $/MMBtu or lower if it is close the loading point.

Economies of scale are reached at around 0.3 Mtpa of LNG supplied which is equivalent to 3-4 small /medium ports.

Figure 9: Logistic Cost comparison in $/MMBtu depending on the supply chain considered

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Figure 10: Logistic Cost comparison in $/MMBtu depending on the supply chain considered
For large ports, unit costs can be lower than for small ports but initial investment is higher. Risk of overinvestment is very high if the market supplied is less than 0.25 Mtpa. Once the market reaches 0.75-1 Mtpa, it is not only necessary but also advantageous to invest in port infrastructures (LNG buffer storage…).

d. Ongoing projects

There are many projects in progress or being studied. This subsection is not exhaustive but seeks to outline the status of supply chain development in some regions. More information about these and other projects can be easily found on the web.

i. Europe

Many initiatives have begun or are under study in European ports and Terminals.

The European Union (EU) has identified the development of LNG as a fuel as key to its transport strategy for 2020. Funding mechanisms have been put in place both for studies and infrastructure investments. A draft Directive proposes, among other things, the obligation to equip 139 maritime and inland ports with LNG bunkering facilities by 2020. LNG is seen as a major European transport and environmental target and is likely to obtain strong support from European and national administrations.

The COSTA Project in southern Europe aims to develop a framework that will accommodate and promote the development of LNG as bunker fuel in the Mediterranean Sea, the North Atlantic Ocean and Black Sea areas. It involves EU member states Greece, Italy, Spain, UK, Portugal and Germany.

Moreover, many ports are busy adapting their regulations in order to be able to introduce LNG facilities, transport and transfers, while new ports are taking initiatives to work on safety and regulations.

On top of this, many concrete projects are under study or being launched both on the customer and infrastructure side: the Port of Dunkirk has been granted funds of 1 M€ to study a proposal to build a bunkering station in the port; Antwerp has launched studies to order an LNG bunker barge; GATE shareholders are willing to develop truck and bunker barge loading facilities; operations are already being done in Norway and the Baltic sea; many ferry projects are under study in the North Sea, the Baltic and the Mediterranean… Bunker LNG is becoming a reality in Europe.

ii. North-America

North America is witnessing the development of LNG as fuel in many sectors, and more especially for heavy-duty trucks. There is political interest in supporting the use of gas in order to reduce oil imports and as an economic driver to take advantage of the spread between oil and gas. The spread is big enough to offer an economic advantage to all the economic players involved in this industry (retailers, LNG producers, infrastructure providers, truck manufacturers, customers…). Both initiatives and investors in this new market have multiplied in the last few years.

So far, there has been less interest to develop LNG as marine fuel, but a number of concrete initiatives have appeared: Staten Island ferry, container ships to serve Puerto Rico from mainland USA (TOTE), Washington state Ferries, BC Ferries in Canada… So far, no major port seems to have undertaken large-scale developments for LNG but economic, political and environmental drivers are likely to prompt new projects.

iii. Caribbean region

There is substantial potential for LNG as bunker fuel in the Caribbean region too. First of all, the potential market in this area for passenger and general cargo ships is high. Secondly, several islands are considering the possibility of importing LNG at a smaller scale than usual LNG regasification terminals. This LNG would come directly from US exports or from standard regasification terminals in the region acting as a physical hub. Gas will replace fuel oil for power generation or for large industrial customers. Volumes need to be
aggregation for economies of scale before this type of project can be launched. Bunker LNG will therefore be interesting for these islands for several reasons: i) to contribute to aggregation of LNG imports and therefore reduce the unit cost for the supply chain for all uses of LNG; ii) to replace HFO for environmental reasons and iii) to use a more economical fuel (though economics in these particular cases have to be challenged).

iv. Asia

A number of South-East Asian countries are considering importing LNG for the same reasons as the Caribbean Islands but at a larger scale. Developing bunker LNG could therefore be an upside for imported LNG in this region with high short sea consumption as well.

A number of initiatives have got off the ground, but they are not part of a global trend and correspond rather to private or public strategies to develop either the LNG market or gas as a transportation fuel. The Port of Singapore, for example, is willing to couple the development of its LNG import terminal with that of a physical hub for the region and a bunkering point for Asian traffic. In Korea, Kogas has ordered from DNV a feasibility study for the development of bunker LNG. China is more generally developing CNG and LNG already as transportation fuels, apparently as a strategy i) to diversify consumption, especially if shale gas develops, and ii) to reduce pollution.

These Asian initiatives show a promising future for LNG as a fuel in the region. Nevertheless, at current Asian spot or long-term prices, it seems that the economics compared with a Scrubber solution, or even in some cases against gasoil, is not in favor of LNG. There does not appear to be any clear economic driver so far, making this development more uncertain than in other regions of the world.

4. SUPPLY CHAIN BARRIERS

LNG seems to have a bright future as a marine fuel and the trend in developing initiatives might suggest this is the beginning of the S-curve. So far, there have been no major showstoppers, but stakeholders have many issues to address. Stakeholders will have to adapt current standards and good practices, listen and learn from the other industries involved in the development. The below underlines some of the major issues that have to be addressed and propose ways of tackling them.

a. Safety

Since the very beginning in 1964, the LNG industry has enjoyed the highest safety record. The lessons learnt from the Cleveland accident in 1944 have contributed to building a safe, reliable and dynamic industry. The good safety records can be explained by multiple factors. On the technical side, better knowledge of cryogenic materials, metallurgy and thermodynamics, which are the basic disciplines. Engineers were able to design LNG tanks, pipes, pumps, heat exchangers and all the equipment necessary for LNG at the appropriate and required safety levels. From the very beginning, safety has been built into LNG design, resulting in high standards, proved practices and permanent innovations to improve the safety level.

But safety is also a question of manpower and behavior. Plant operators, like engineering and construction companies or ship-owners, have trained their employees to design, build and operate LNG plants in the highest possible safe conditions. Their safety philosophy is implemented from the earliest design phase and throughout the life of any plant. Today, the LNG industry capitalizes half a century of good practices and experience. New technologies, materials and concepts have brought it to maturity and allowed spectacular growth without compromising on safety. The same care has gone into reducing the environmental impact.

However, LNG for bunkering is a very new and innovative way of using LNG. One of the main changes is the downsizing and multiplication of the equipment, with a retail network to be built up and very large number of users and actors. One of the side effects of downsizing is that LNG has become more easily accessible to new entrants – equipment suppliers, engineering companies, operators, users – with limited experience. It is...
very important for all of them to understand and apply today’s standards and new practices in order to maintain the safety level.

Quality assurance should be implemented throughout the design and construction phase to prevent deviation from best practices and standards. Training courses are also to be provided to as many persons as required, as and when deemed necessary or recommended, and sanctioned by a license or certification.

Even if LNG has the highest energy content (mass) in the hydrocarbon family, along with a very low temperature that can cause cold burns and severe injury, its physical characteristics make it safer than many other energy sources. LNG is non toxic and simply evaporates when released, to become a natural gas lighter than air above -100°C or so. It is critical for this emergent bunker fuel sector to demonstrate that it is at least as safe as the main LNG chain, and for historical LNG operators to share their experience with new operators.

b. Standards

As natural gas is more complex and expensive to transport than oil, the gas market has been organized in regional areas for a long time. As a result, the need for international standards was not a major issue and many current standards are purely regional (Americas, Europe, Asia). The trend towards globalization of the LNG market, expressed in the growing share of spot cargoes, is also reflected in standards. ISO TC67 WG10 (Equipment for LNG) for example has started building international standards for LNG equipment.

In the case of bunkering, new standards are required to enable deep sea ships to fill their tanks anywhere in the world. For short sea, international standards are not a requirement but would be useful for shipyards as regards the design of LNG equipment. Standards, when applied, are also a safeguard against sub-standard installation. Once the size of retail installations decreases and their number drastically increases, codes and standards should bring additional confidence in the safety level. Majors as well as gas suppliers, ship-owners and the entire stakeholder chain are encouraged to contribute to this effort for new standards.

A new IMO IGF code is currently being written, for LNG to begin with and to be expanded subsequently to other fuels. Once adopted, it will provide guidance for shipyards to design LNG-fuelled vessels.

The ISO TC 67 WG10 mentioned earlier has launched a working Group for bunkering operations and will provide good practices and guidance for them. The scope of this standard is still under discussion and is to be adjusted in line with the IGF code.

Other standards on Gas Quality, methane number content and LNG bunkering stations are also under consideration and planned to be finalized in the coming months.

c. Regulations

A clear, stable regulatory framework is essential to develop the market. It should address each part of the value chain: truck and ship transportation, storage and bunkering facilities, ships using gas as fuel, and transfers between them all. So far, many uncertainties subsist concerning regulations, which are clearly a barrier to development. Investments in building the supply chain have therefore an implicit regulatory risk that has to be reduced.

In most of these cases, a framework does exist but does not apply specifically to LNG. In Europe for example, EU and local laws and regulations for most members offer an adequate legal framework for LNG. They are not, however, specifically focused on LNG, still less on its new uses. LNG specificities have to be taken into account and regulations will doubtless evolve as LNG use develops. In the meantime, investments in the supply chain are at risk because they are potentially non compliant ex-post.
On the other hand, regulations cannot be developed until there are concrete cases to serve as basis for addressing the regulatory framework.

A number of countries have found a good way to approach this issue. It involves cross-functional working groups with representatives from the industry and administration, an essential factor to allow regulations to develop relatively fast. It is in everybody’s interest for the different stakeholders to work together in order to move forward, ensure a stable regulatory framework and a safe supply chain to foster realistic and economically feasible development investments.

5. SUPPLY AND CONTRACTUAL ASPECTS

a. Contractual generalities

There is a substantial gap between commercial contracts for HFO bunker and for gas or LNG that has to be reduced. Bunker contracts operate on a short-term basis but in many ports where competition is high, there are only spot transactions. Minimum take-off commitments are very rare, and pricing is often based on indexes and transparent. As a result, competition among suppliers is high and ship-owners not only have many supply possibilities between different ports but also between different suppliers in most of the ports.

Some ship-owners might be reluctant to commit on mid/long term LNG with a sole supplier and to agree to take-or-pay clauses. However, all the parties need to commit in order to secure investments. The investor in infrastructure will need a minimum commitment from the users which can range from 5-8 years for small/medium infrastructure to 15-20 years for larger developments. The supplier (if different from the infrastructure investor) will be required to commit and therefore be willing to secure this risk through a commercial contract. But, on the other side, ship-owners will need the guarantee that if they choose LNG, they will have fuel available for 15-20 years or more.

All parties seem to agree on long-term commitments but 5-8 years seems to be a reasonable balance between risk reduction and the possibility for ship-owners to ensure competitive pricing. In addition to that, even if contracts do not always allow the most capitalistic investments to be secured, subsidies and funding will reduce the risks. Besides, 5-8 years is a reasonable timeframe for launching the market in a given area or port, after which both customers and suppliers will have reached sufficient volumes to lower risks for all the stakeholders and reduce contract durations.

b. Gas quality

Unlike conventional fuels for which clear, precise specifications regulate the content, there are not as yet any standards for LNG as a fuel, not even for measuring gas quality. The so-called Methane Number is the most commonly used measurement but its calculation has not yet been standardized though standardization bodies have taken up the subject.

Furthermore, the relationship between gas composition and Methane Number is relatively complex. There is no linear relationship between the methane content of gas and its methane number. The standards of the gas industry are therefore difficult to transpose to gas for use as fuel.

The Methane Number is used by engine manufacturers to calibrate the engine for optimal efficiency. A very wide Methane Number range may therefore cause differences in engine fuel efficiency. According to many engine manufacturers, engines would still run even with a very low Methane Number (within the range of current LNG qualities) but with lower efficiency.

As long as LNG as a fuel remains an upside of the global LNG business, it will not be realistic to consider LNG content will be modified or that a process treatment will be used to bring it in line with engine specifications, at least not in the first phases of development of the market.
In all probability, this issue will be resolved by contractual arrangements and financial adjustments to the selling price, but a clear understanding of Methane Number variations has to be shared between shareholders so that negotiations are possible.

c. Impact on traditional LNG business

Bunker LNG will, at least in the short and mid-term, be only an added offshoot to the real LNG business. It is likely to interfere with a much larger business, only when significant volumes of LNG are being used for transportation purposes. Mitigation measures have then to be considered to avoid affecting traditional business opportunities by reducing LNG flexibility.

i. LNG terminal business model

LNG regasification terminals or large liquefaction facilities will often be the starting point of the supply chain. Trucks and small/medium size barges will load at these facilities. To be able to manage this new business, operators of terminals and liquefaction plants will have not only to invest but also to adapt their business models.

Truck loading will generate a new activity with many operations to be handled. The number of commercial relationships for the terminal will increase significantly. Operations, scheduling, contracts, back office and other activities will have to be implemented which will have a significant impact on manpower and staffing. Besides this, truck loading will most likely generate (at least in the first phases) low revenues which will make this business appear unattractive for operators. In addition to that, road traffic will increase, which could be problematic in terms of acceptability by local stakeholders.

Barges loading at the terminal will also affect terminal activity. Commercial activity will be impacted less than trucks but operations will feel a higher effect as the terminal will have to handle smaller vessels than usual, which will mean adapting marine and operating procedures. The biggest impact of this new business will concern slot availability for small vessels and interference with traditional operations. If both frequency and terminal activity are high, investment in a dedicated jetty will be needed.

Furthermore, today’s commercial business model and design are angled to traditional users’ needs. In the case of a regasification terminal, tanks are used to provide up- or down-stream flexibility to the customer. The commercial business model and design have been decided in order to balance customer needs in terms of flexibility and tariff for the capacities. Very often, terminal Throughput Agreements make no provision for the possibility to store LNG for long periods (sometimes not even for short periods). Yet storage capacities will be needed to secure LNG availability and develop LNG as bunker fuel. This type of contract does not always exist and when it does, it would affect global flexibility for current shippers. This business model is not suited to shippers with very low capacities. As the bunker business will, for some time yet, be only an extra offshoot to the traditional LNG business, shippers prepared to access the terminal for bunker purposes (or other LNG exports), which will not often be the case. They could be either commercial agreements for the sale and purchase of LNG ex-terminal, or swap agreements to exchange LNG or gas vs. LNG. They have to be made on an arm’s length basis and, in the case of exchanges, must be financially neutral. In some terminals, there is a risk of a dominant position for shippers that could be extremely harmful for the development of the market and free competition.

ii. LNG availability

Another issue that has to be addressed concerning the fact that the current LNG business is not adapted to small quantities is the example of LNG terminals in Europe in the last months. Due to high spreads between European markets and sport LNG delivered to Asia, LNG is being redirected to Asia, leaving European terminals with a very low stock level. LNG delivery commitments are being replaced by pipeline gas. But, it
will not be possible to swap commitments to deliver LNG for bunker by pipeline gas since the molecule is needed in liquid form. Yet these future commitments are essential in enabling the ship-owners to rely on supply. Since volumes are presumed to be small in the initial phase of development, there is a risk of loss of opportunity for a redirection in order to honor a commitment on a small quantity. Pricing of LNG has to include this potential loss of opportunity to attract upstream suppliers ready to commit. In addition to this, it is important, here too, that LNG importers cooperate in order to share risks by pooling some volumes and exchanging others on a financially neutral basis.

d. Funding programs and subsidies

Many investments must be made to launch the market. The investment capacities of many stakeholders along the supply chain might not be sufficient. Funding programs, subsidies and/or tax benefits are needed to support the industry to create what is necessary for ship-owners to comply with regulations.

e. Pricing

Pricing does not seem to be a major issue. Most ship-owners are interested in securing the extra investments needed for LNG propulsion. So, discounted prices in relation to gasoil- or oil-indexed contracts for a given duration will ensure that ship-owners meet their payback time expectations. Except for the odd unknowns, an substantial part of the LNG economic advantages could be then defined contractually. Oil-indexed pricing for LNG is the industry standard for current contracts so it seems that suppliers’ and ship-owners’ expectations could easily converge.

6. CONCLUSIONS AND WAY FORWARD

The last two years LNG as bunker Fuel has become a subject of high interest for various stakeholders. IMO restrictions on emissions and price opportunities have established the necessary environment that creates a unique opportunity for increased LNG demand within a new sector. After many considerations and only two years before the 2015 deadline, it seems rather certain that LNG will replace a material share of the HFO used in the bunker market. The question is not anymore to know if LNG could be a solution but rather how much of the market will be replaced by LNG and further how to best introduce LNG as the preferred fuel.

The main concern in this development will certainly be safety. LNG has maintained for years a exemplary safety track record that has to be maintained in order to protect the whole LNG industry. As always, the stakes are higher than the sole business potential for bunker LNG itself.

In order to be able to develop a sustainable market there are many challenges to overcome but there has not been identified any showstopper. However, as described herein, it is essential that all stakeholders from regulators to ship owners to suppliers work together in order to provide a solid and commonly agreed framework that allow LNG to take its share of this new demand to the interest of all involved parties.