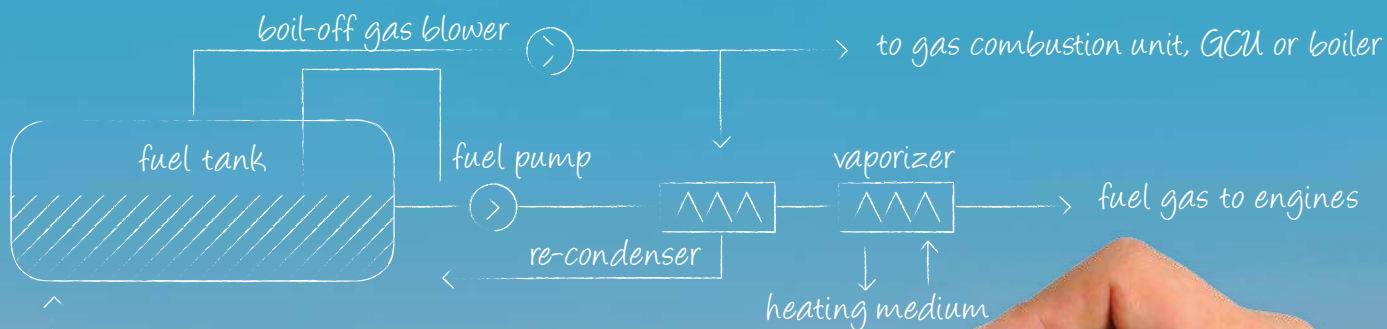




MARITIME

# IN FOCUS - LNG AS SHIP FUEL

Latest developments and projects in the LNG industry



# GET THE MOST OUT OF LNG WITH OUR EXPERT SUPPORT

As emission regulations become stricter, you need an expert partner on your side who can help you decide if LNG is an option for your vessel. At DNV GL, we have contributed significantly to the evolution of LNG as ship fuel over the past 15 years.

This long involvement has resulted in our in-depth and proven advisory service portfolio, and has given us a leading role in the classification of gas-fuelled ships. LNG as fuel is ready to set course, and we can help you succeed.

[Learn more at \[dnvgl.com/maritime\]\(https://dnvgl.com/maritime\)](https://dnvgl.com/maritime)

## EDITORIAL

We are pleased to present the second edition of the LNG Report, which takes a look at the latest developments and projects in the LNG industry. With almost 150 LNG-fuelled ships either in operation or on order, design solutions and propulsion systems using liquefied natural gas (LNG) are constantly evolving.

15 years after the first LNG-fuelled ferry based on DNV GL standards was launched, LNG has not only become an option for smaller vessels operating in coastal areas, but will also be used by some of the world's biggest container ships travelling between Asia and Europe. In this issue we examine a complex LNG conversion project and a LNG-fuelled newbuilding constructed for Ems AG. The German shipping company is among the first owners in the region to invest into LNG-fuelled ferries that operate in Emission Control Area that extends throughout the Baltic and North Seas.

In an article by the United Arab Shipping Company (UASC), their experts explain how the design of a series of six 18 800 TEU container vessels was adapted for using LNG as ship fuel. The first in the series, the MV Barzan, was named in Korea recently and is the first vessel to receive the new DNV GL GAS READY class notation.

Looking to the future, oil is simply too valuable and limited a commodity for the world to continue to consume as a fuel; increasing our use of LNG preserves the world's resources to use in value-adding products such as plastics, coatings and consumer goods. The importance in the reductions in local air pollution that can be achieved through switching (cutting NO<sub>x</sub> 80%, almost eliminating SO<sub>x</sub> and particulate matter, and reducing CO<sub>2</sub>) also cannot be understated.

The projects in the LNG Report, alongside many more that are being undertaken around the world, show that the ground work needed for LNG to thrive in the shipping and transport sectors has been laid – and we invite you to come and take the next steps together with us.



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## LNG AS SHIP FUEL

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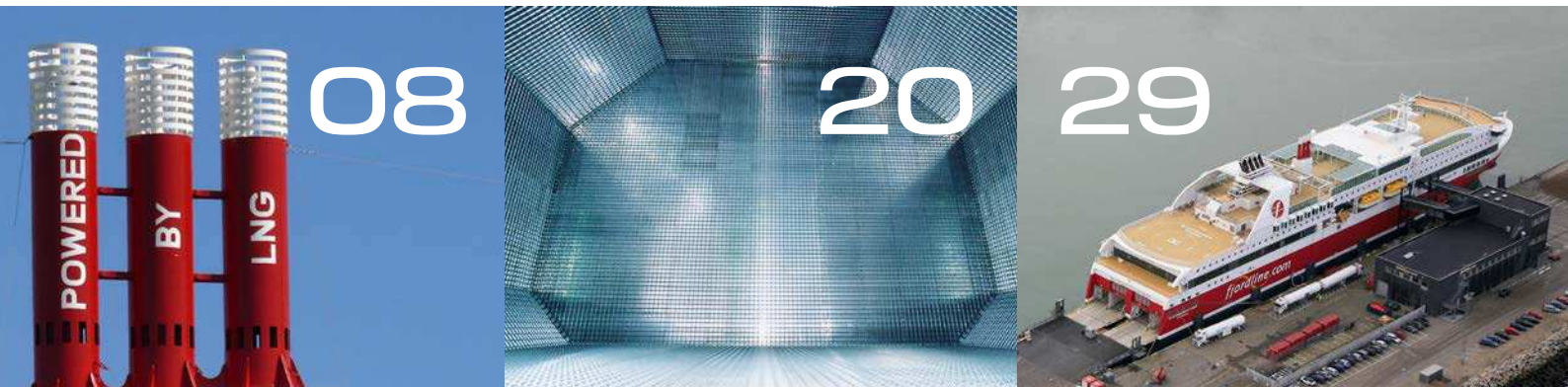
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# LNG TODAY AND TOMORROW

LNG as fuel is now a proven and available solution. While conventional oil-based fuels will remain the main fuel option for most existing vessels in the near future, the commercial opportunities of LNG are interesting for many newbuild and conversion projects. But taking the leap to LNG can only be made on the basis of the best possible information and a thorough analysis of your needs, both today and in the future. We developed this magazine to assist you in working with the factors that come into play, based on our experience with this young technology in newbuilding, conversion projects and advisory services related to the design, construction and operation of LNG-fuelled vessels.

The number of ships using LNG as fuel is increasing fast and more and more infrastructure projects are planned or proposed along the main shipping lanes. 63 LNG-fuelled ships (excluding LNG carriers) already operate worldwide, while another 76 newbuildings are confirmed (as of May 2015). In line with this dynamic development, DNV GL expects LNG to grow even more rapidly over the next five to ten years. The uptake of LNG as a ship fuel will continue to advance as we head toward 2020, and we firmly believe that we will reach the number of 1,000 non-LNG carrier

vessels running on LNG in 2020 or shortly thereafter. At the same time, LNG is commercially attractive and available worldwide in quantities able to meet the fuel demand of shipping in the coming decades.

As well as the commercial aspects, the main argument for believing in LNG as a ship fuel and in the replacement of conventional oil-based fuels (heavy fuel oil, marine gas oil, or distillate fuels) by LNG is the significant reduction in local air pollution - ranging from emissions of SO<sub>x</sub> and NO<sub>x</sub> to carbon dioxide, particulates (PM) and black carbon. The complete removal of SO<sub>x</sub> and particle PM emissions and a reduction of NO<sub>x</sub> emission of up to 85% by using LNG is a strong argument for the use of LNG, especially in coastal and sensitive ecosystems. In addition, LNG also reduces CO<sub>2</sub> emissions by at least 20%. As a fuelling option, LNG offers multiple advantages to both human health and the environment.

Today, gas engines cover a broad range of power outputs. Concepts include gas-only engines, dual-fuel four-stroke and two-stroke. Methane slip has now been practically eliminated in some engine concepts and minimized in others. Further reductions can

be expected in the future. We give an overview of the state of gas and dual-fuel engines on page 30.

With a ship lifetime of 25 years and more, shipowners have to look at the possibilities of meeting the challenges of the future with regard to future ship fuels and legislation. DNV GL offers the "LNG Ready" Service, which analyses the individual business case for a vessel using LNG as a fuel and preparations for a possible later conversion to LNG. You can read more about this service on page 12.

Tanks are one of the greatest capital expenses in outfitting LNG vessels. We look at potential improvements in the context of a LNG-fuelled box ship on page 20.

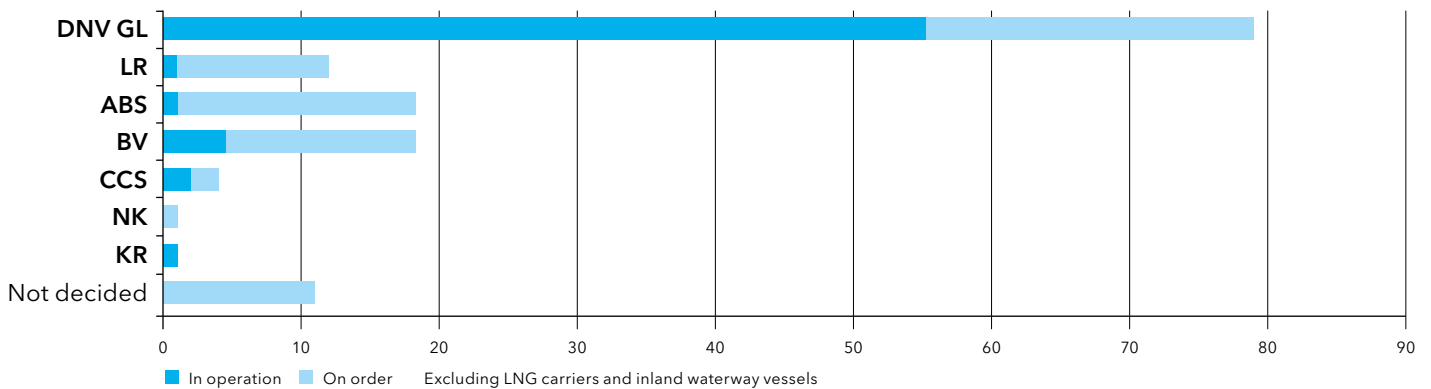
The infrastructure, which will enable the growing wave of LNG new builds and conversions to operate, is on the way. From Norway to the Netherlands, Singapore to Sri Lanka, new projects are springing up every week. DNV GL expert Jan Tellkamp assesses the bunkering and infrastructure picture on page 36 and explains the DNV GL recommended practice on bunkering.

DNV GL has been helping companies and authorities to utilize LNG safely as a source of clean, reliable energy in the maritime industry through a complete set of services for nearly 20 years. Our breadth of services and our outreach through our regional gas and LNG Ready teams is unmatched. On page 48, we look at our approach to helping customers choose the best fuel option and implement it successfully.

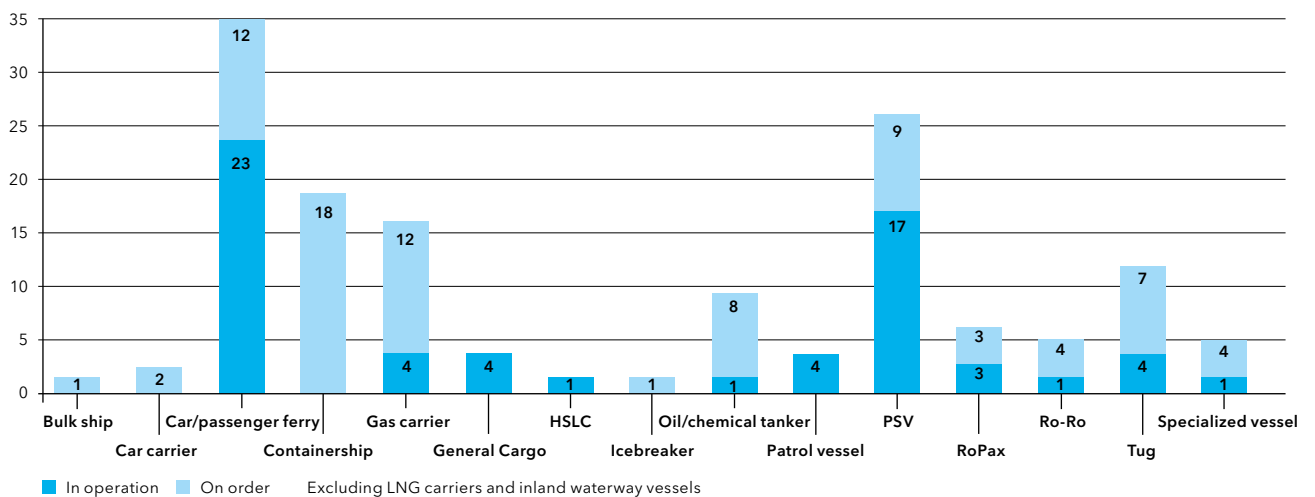
Many market players still have the perception that the commercial risk of choosing LNG as ship fuel is still high. But, on the other hand, what might the risks be of not considering LNG? A vessel ordered today will still be operating in the 2030s, in a world with unknown fuel availability, fuel prices which will almost certainly be higher, and, if trends persist, stricter regulatory requirements.

Making the wrong fuel choice today can have major implications for the commercial performance of a ship over its lifetime, including tradability and the second hand value. ■

### LNG-fuelled fleet by class society



### LNG-fuelled fleet per segment





# ALTERNATIVE FUELS FO

The merchant world fleet gradually shifted from sail to a full engine powered fleet from about 1870 to 1940. Steamships burning coal dominated up to 1920, and since then coal has gradually been replaced by marine oils, due to the shift to diesel engines and oil-fired steam boilers. The shift from wind to coal was driven by the developments in steam engines, and offered the opportunity for more reliable transit times, to a large extent independent of the weather conditions and prevailing wind directions. The following shift, from coal to oil, was driven by increased efficiency, ease of handling, and cleaner operations.

The main drivers leading to the advent of alternative fuels in the future can be classified in two broad categories:

- Regulatory requirements and environmental concerns, and
- Availability of fossil fuels, cost and energy security.

The upcoming requirements for reduced sulphur content in the fuel will increase the cost of the fuel. This effect will be more pronounced after 2020 (or 2025, depending on when the new regulations are enforced), when the sulphur content globally will be at 0.5% (or 5,000 ppm), which is lower than current levels for the ECAs. Introducing exhaust gas aftertreatment systems, such as SO<sub>x</sub> scrubbers and urea-based catalysts for NO<sub>x</sub> reduction, can add significantly to the cost of a ship. These systems are both space-demanding and costly, while they can increase the fuel consumption by 2-3%. On the other hand, they allow for the use of less expensive, high sulphur fuels. Introducing new, sulphur-free fuels can be a viable solution for this problem, provided that these fuels and the necessary technology are offered at competitive price levels.

The fuel consumption in the ECAs is estimated at approximately 30-50 million tons of fuel per year and it is going to increase if more areas are included in the ECAs in the future. These figures are important for evaluating the potential of each one of the alternative fuels presented in this report for replacing oil-based fuels.

## Fuel availability and cost

Estimates of future oil production vary and are controversial. Advanced methods of oil extraction have started becoming economically feasible due to high oil prices in the last few years. The use of unconventional resources, such as shale oil and tar sands is gaining ground, while in the future there may be enhanced pressure to expand oil and gas activities in the Arctic. In the USA, the shale oil production of recent years has reshaped the North American energy market. Despite the potential of the Arctic for future oil and gas production, it is not clear how much the global production could increase in the future. This is mainly due to high costs and difficult conditions even with reduced sea-ice. The potential consequences of an accident in the Arctic could also be very severe.

## World oil and gas reserves

The figure shows the world oil and gas reserves: Reserve-to-Production ratio for 2009-2013. When the reserves remaining at the end of any year are divided by the production in that year, the result is the length of time that those remaining reserves would last if production were to continue at that rate.

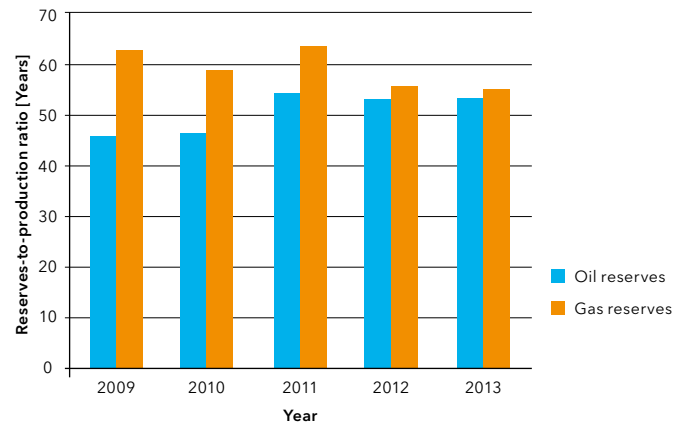


Figure 1: World oil and gas reserves

Reserves are generally taken to be those quantities that geological and engineering information indicates with reasonable certainty can be recovered in the future from known reservoirs under existing economic and operating conditions.

Precise information regarding the location and quantity of global oil reserves is difficult to obtain, because many oil producing nations often make public claims that cannot be easily verified. In addition, the world largely depends on oil supplies from potentially politically unstable regions, which can have an adverse effect on fuel security. For some countries, this is a major driver for developing technology for exploitation of local unconventional resources, such as shale oil and gas in USA, and for investing in the development of biofuels, such as ethanol in Brazil and in USA, and biodiesel in Europe.

## Challenges and barriers

For many shipowners, finding capital to fund proven fuel saving technologies can be a challenge - even for technologies that pay for themselves in a matter of years. When introducing a new fuel, existing ships may have to be retrofitted because of incompatible machinery. This makes changes a long term investment. For pioneers - owners who take the risk to invest in new technology solutions - unforeseen technical issues often result in significant delays, requiring additional capital.

At the same time, bunker costs for certain shipping segments are paid for by the charterer, removing incentives for owners to explore alternative fuels or even fuel efficiency measures. Patch-

# R SHIPPING

work regulations, enforced by different government bodies, and lack of standards, have also slowed coordinated actions.

Lack of appropriate infrastructure, such as bunkering facilities and supply chains, and uncertainty regarding long-term availability of fuel are additional barriers for the introduction of any new fuel. Owners will not start using new fuels if an infrastructure is not available, and energy providers will not finance expensive infrastructure without first securing customers. Breaking this deadlock will require a coordinated, industry-wide effort and the political will to invest in the development of new infrastructure.

## Overview of potential alternatives

Over the next four decades, it is likely that the energy mix will be characterised by a high degree of diversification. LNG has the potential to become the fuel of choice for all shipping segments, provided the infrastructure is in place, while liquid biofuels could gradually also replace oil-based fuels. Electricity from the grid will most likely be used more and more to charge batteries for ship operations in ports, but also for propulsion of relatively small vessels. Renewable electricity could also be used to produce hydrogen, which in turn can be used to power fuel cells, providing auxiliary or propulsion power. If a drastic reduction of GHG emissions is required and appropriate alternative fuels are not readily available, carbon capture systems could provide a radical solution for substantial reduction of CO<sub>2</sub>.

While renewable energy (solar, wind) may have some potential to mitigate carbon emissions, this is not seen as a viable alternative for commercial shipping. Certainly, vessels equipped with sails, wind kites or solar panels may be able to supplement existing power generating systems, but the relative unreliability of these energy sources make them appropriate only for special cases where favourable weather conditions prevail.

## Liquefied Natural Gas - LNG

Using LNG as fuel offers clear environmental benefits: elimination of SO<sub>x</sub> emissions, significant reduction of NO<sub>x</sub> and particulate matter, and a small reduction in greenhouse gas (GHG) emissions.

LNG as fuel is now a proven and available solution, with gas engines covering a broad range of power outputs. Engine concepts include gas-only engines, dual-fuel four-stroke and two-stroke. Methane slip (contributing to GHG) during combustion has been practically eliminated in modern two-stroke engines, and further reductions should be expected from four-stroke engines. On the production side, the recent boom in non-traditional gas (shale) has had a dramatic effect on the market for gas, particularly in North America. Exploitation of shale gas in other parts of the world could also prove to be significant for LNG. However, the extraction process

(hydraulic fracturing or “fracking”) remains a controversial technology, due to growing public concerns on its impact on public health and the environment, regarding both air and water quality.

There are currently around 50 LNG-fuelled ships (excluding LNG carriers) in operation worldwide, while another 69 newbuilding orders are now confirmed. The relatively high capital cost of the system installation can be a barrier in some cases. LNG uptake is expected to grow fast in the next 5 to 10 years, first on relatively small ships operating in areas with developed gas bunkering infrastructure, where LNG prices are competitive to HFO prices.

LNG as a ship fuel has the long term advantage that is available worldwide with increasing significance as an energy carrier (compare Figure 2).

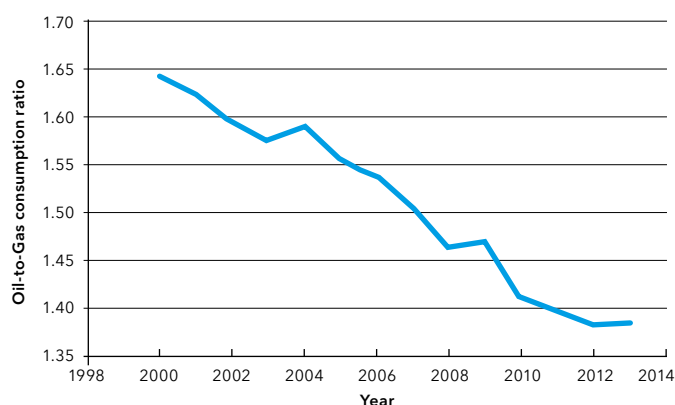


Figure 2: Oil-to-gas consumption ratio, in terms of energy content. Consumption in all sectors and industries is included.

## Ship electrification and renewables

Recent developments in ship electrification hold significant promise for more efficient use of energy. Renewable power production can be exploited to produce electricity in order to power ships at berth (cold ironing) and to charge batteries for fully electric and hybrid ships. Enhancing the role of electricity on ships will contribute towards improved energy management and fuel efficiency on larger vessels. For example, shifting from AC to on board DC grids would allow engines to operate at variable speeds, helping to reduce energy losses. Additional benefits include power redundancy and noise and vibration reduction, which is particularly significant for passenger ferries.

Energy storage devices are critical for the use of electricity for ship propulsion, while they are also important for optimization of the use of energy on board in hybrid ships. There are several energy storage technologies currently available. Battery powered propulsion systems are the most popular ones, and they are already being

engineered for smaller ships. For larger vessels, engine manufacturers are focussing on hybrid battery solutions. Challenges related to safety, availability of materials used and lifetime must be addressed to ensure that battery-driven vessels are competitive with conventional ones, but the pace of technology is advancing rapidly. Other energy storage technologies that could find application in shipping in the future include flywheels, supercapacitors, and thermal energy storage devices.

Electrification has generated strong interest, particularly for ship types with frequent load variations. Significant growth in hybrid ships, such as harbour tugs, offshore service vessels, and passenger ferries should be expected in the next few years.

**Biofuels**

Biofuels can be derived from three primary sources: (a) edible crops, (b) non-edible crops (waste, or crops harvested on marginal land) and (c) algae, which can grow on water and does not compete with food production. In addition to having the potential to contribute to a substantial reduction in overall greenhouse gas emissions, biofuels also biodegrade rapidly, posing far less of a risk to the marine environment in the event of a spill. Biofuels are also flexible: they can be mixed with conventional fossil fuels to power conventional internal combustion engines, while biogas produced from waste can replace LNG.

Biofuels derived from waste have many benefits, but securing the necessary production volume can be a challenge. The logistics of collecting and transporting biomass to a processing facility contribute significantly to cost. Algae-based biofuels seem to be very promising, but more work needs to be done to identify processes that would be suitable for efficient large scale production.

Experimentation with various types of biofuels has already started on ships, and the first results are encouraging. Concerns related to long-term storage stability of biofuels on board, and issues with corrosion need to be addressed, but the main obstacle to be overcome is related to fuel availability. Advances in the development of biofuels derived from waste or algae will depend on the price of oil and gas. It is expected that by 2030 biofuels are set to play a larger role, provided that significant quantities can be produced sustainably, and at an attractive price.

The world ship fuel consumption today is approx. 400 mio. tons per annum. The development of world bio fuel production (Figure 3) indicates the challenge for biofuel as a major ship fuel.

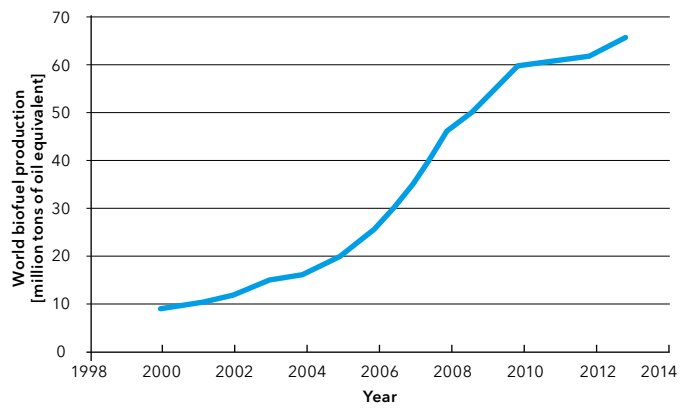
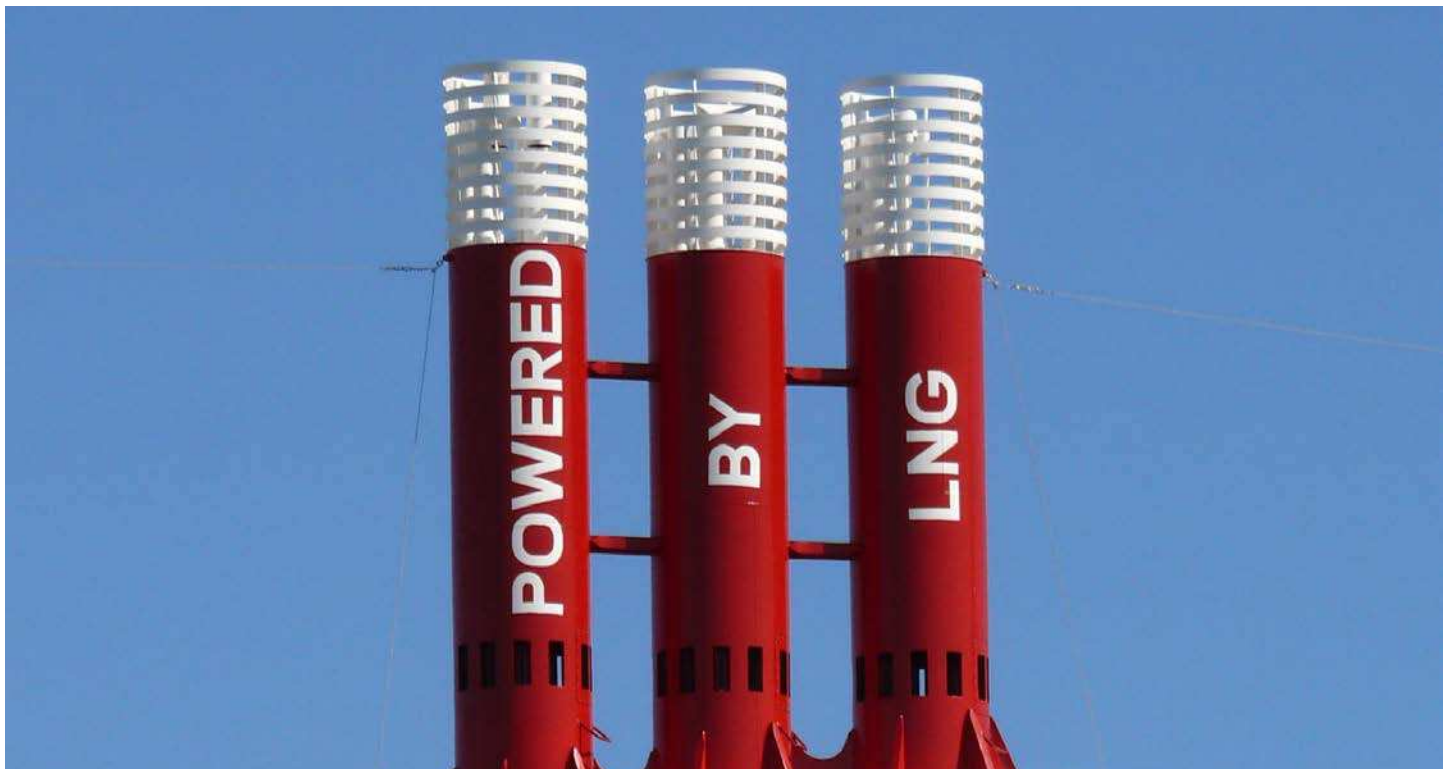


Figure 3: World biofuel production, in million tons of oil equivalent.





### **Methanol, LPG and other liquid or gaseous fuel options**

A number of other liquid fuels can be used in dual-fuel engines. In these engines a small quantity of marine fuel oil is typically used as pilot fuel, to initiate the ignition process, followed by combustion of the selected alternative fuel. Some of the fuels that can be used are Liquefied Petroleum Gas (LPG –a mixture of propane and butane), Methanol, Ethanol, and Di-Methyl Ether (DME). Most of these fuels offer significant reductions of NO<sub>x</sub> and Particulate Matter emissions, while they are sulphur free and can be used for compliance with ECAs regulations.

Marine engine manufacturers offer dual-fuel engines that can be operated with the fuel options mentioned above. Depending on the type of fuel, special designs for fuel tanks and piping are required. However, these fuels do not require cryogenic temperatures for storage (as opposed to LNG); hence, the fuel tanks and related equipment are simpler and less expensive.

In July 2013, DNV released rules for using low flashpoint liquid (LFL) fuels, such as methanol, as bunker fuel. Interest in methanol as fuel for passenger ferries is growing in Sweden in response to the need to reduce NO<sub>x</sub> and SO<sub>x</sub> emissions. Methanol has a relatively low flashpoint, is toxic when it comes into contact with the skin or when inhaled or ingested and its vapour is denser than air. As a result of these properties, additional safety barriers are required by DNV GL.

The new mandatory notation LFL FUELLED covers aspects such as materials, arrangement, fire safety, electrical systems, control and monitoring, machinery components and some ship segment specific considerations.

Due to the relatively limited availability of all these fuels (compared to oil and gas), it is not expected that they will penetrate deep sea shipping sectors in the near to medium term future. However, they can become important parts of the fuel mix in local markets or specialized segments, such as local ferries or chemical tankers.

### **Hydrogen**

Renewable electricity can be employed to produce hydrogen, which can be utilized to power fuel cells on board ships. However, hydrogen as fuel can be difficult and costly to produce, transport, and store. Compressed hydrogen has a very low energy density by volume requiring six to seven times more space than HFO. Liquid hydrogen on the other hand, requires cryogenic storage at very low temperatures, associated with large energy losses, and very well insulated fuel tanks.

Fuel cells are the most commonly used devices to convert the chemical energy of hydrogen into electricity. When a fuel reformer is available, other fuels, such as natural gas or methanol can also be used to power a fuel cell. Although operational experience has shown that fuel cell technology can perform well in a maritime environment, further work is necessary before fuel cells can compete with existing technologies powering ships. Challenges include high investment costs, the volume and weight of fuel cell installations, and their expected lifetime. Special consideration has to be given to storage of hydrogen on board ships, to ensure safe operations.

### **The way forward**

The introduction of any alternative energy source will take place at a very slow pace initially as technologies mature and the necessary infrastructure becomes available. In addition, introduction of any new fuel will most likely take place first in regions where the fuel supply will be secure in the long-term. Due to uncertainty related to the development of appropriate infrastructure, the new energy carriers will first be utilised in smaller short sea vessels, and small ferries are expected to be some of the first movers. As technologies mature and the infrastructure starts to develop, each new fuel can be used in larger vessels.

At present, LNG represents the first and most likely alternative fuel to be seen as a genuine replacement for HFO for ships. The adoption of LNG will be driven by fuel price developments, technology, regulation, increased availability of gas and the development of the appropriate infrastructure. The introduction of batteries in ships for assisting propulsion and auxiliary power demands is also a promising low carbon energy source. Ship types involved in frequent transient operations (such as frequent manoeuvring, dynamic positioning, etc.) can benefit most from the introduction of batteries through a hybrid configuration. Moreover, energy storage devices can be used in combination with waste heat recovery systems to optimise the use of energy on board. Cold ironing could become a standard procedure in many ports around the world.

The pace of development for other alternative fuels, particularly biofuels produced from locally available waste biomass, will accelerate, and may soon compliment LNG and oil-based fuels. Indeed, it is likely that a number of different biofuels could become available in different parts of the world between 2020 and 2030. Maritime applications for renewable energy (solar, wind) will certainly continue to be developed, but it is unclear if these will have a significant impact on carbon emissions.

It is very likely that in the future there will be a more diverse fuel mix where LNG, biofuels, renewable electricity and maybe hydrogen all play important roles. Electrification and energy storage enable a broader range of energy sources to be used. Renewable energy such as wind and solar can be produced and stored for use on ships either in batteries or as hydrogen.

Besides IMO rules and ISO standards, development of appropriate Rules and Recommended Practices is necessary for the safe implementation of any of these technologies in the future. To achieve this, the role of Class Societies will be crucial. Adopting new technologies is likely to be an uncomfortable position for shipowners. To ensure confidence that technologies will work as intended, Technology Qualification from neutral third parties, such as classification societies, is also likely to be more widely used. ■

# LNG - THE RIGHT OPTION?

## HOW TO PREPARE FOR THE FUTURE TODAY

The decision to invest in LNG as a bunker fuel is not an easy one. There can be substantial premiums to be paid; up to 30 per cent for certain ship types in the most expensive cases. This high cost, combined with the lack of confirmed LNG availability for bunkering, in particular for segments dominated by the tramp trade, goes a long way to explaining the hesitation of many shipowners and charterers to move toward LNG-fuelled propulsion for newbuilds.

A shipowner has two options when considering the use of LNG as fuel in a new building phase:

1. Building a LNG Ready ship - a ship ready for future retrofit, and
2. Building a LNG-fuelled ship - a ship ready for LNG operation from day one

To assist our clients in making an informed decision and to improve project performance, we have developed the DNV GL LNG Ready service.

### DNV GL LNG Ready Service

An LNG Ready ship is a good option in situations where LNG is unlikely to be available for another few years in the vessel's intended area of operation, or if the current commercial terms are not sufficiently favourable for the required extra investment. By making a newbuild LNG Ready, prepared for cost-efficient retrofitting to LNG fuel with class approved designs, shipowners can reserve their final decision and delay the major investment until a point in time when the terms are favourable and the risk level is acceptable. A small amount of effort and investment upfront can pay off in terms of increased flexibility and tradability, an extended commercial lifetime and increased second-hand value.

The second option, an LNG-fuelled ship, is the preferred option when there are no anticipated barriers to using LNG from the date of delivery and the business case for LNG is already favourable.

The LNG Ready Service assists shipowners, operators, yards and designers in identifying the most attractive compliance option for their ships. Through a detailed technical and financial feasibility study, the LNG Ready Service investigates all the potential options for compliance and fuel cost reduction, and uncovers any technical showstoppers, as well as calculating the financial attractiveness of each option. The base case includes a comparison between a fuel switch to MGO, installation of a scrubber system with HFO and a conversion to using LNG as fuel. Other fuel alternatives, such as methanol, DME (Dimethyl ether), etc. can be included on request. The service takes the process all the way from the business case and concept stage to the initial design stage, where normal class activities take over.

The tried-and-tested LNG Ready Service unites all of DNV GL's pre-contract services for shipowners and charterers for LNG as

fuel. It is a stepwise approach that combines advisory and class services in a way which makes the process smooth and consistent, as well as time and cost efficient for the client.

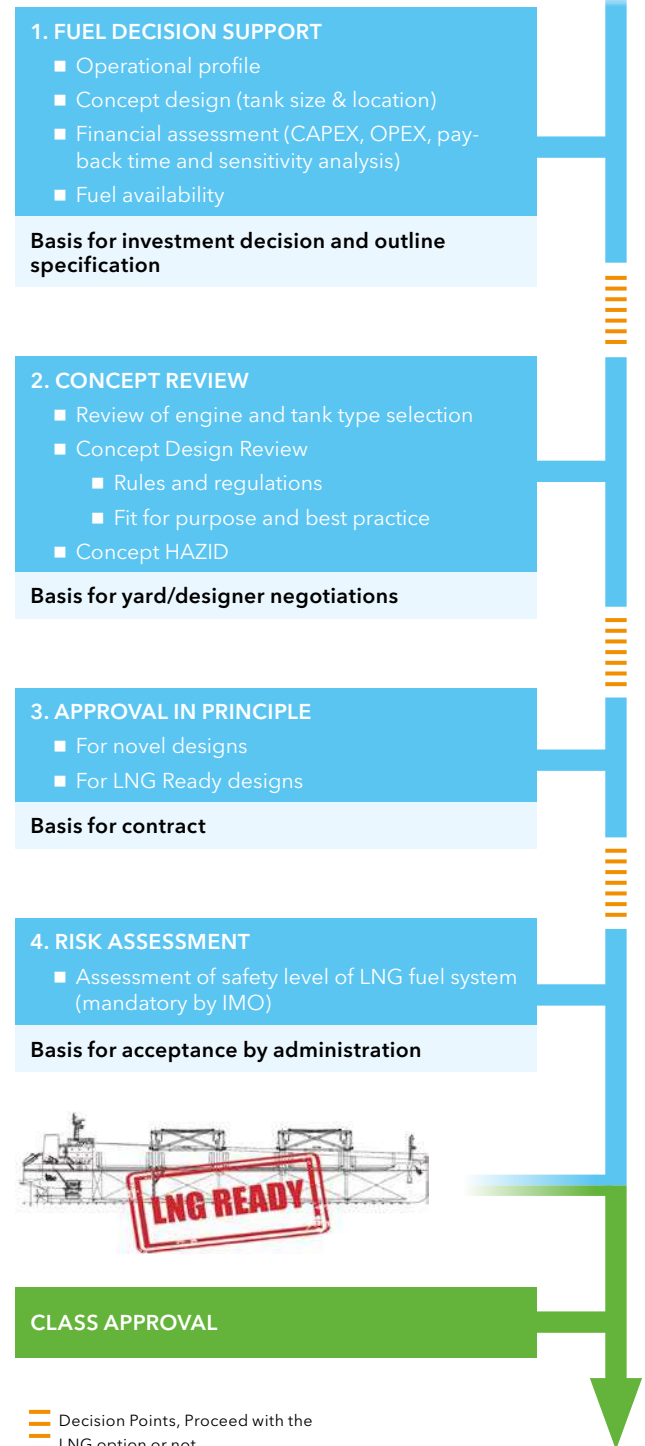


Figure 1: the 4 steps to become LNG Ready

The design work has limited value if it has not been thoroughly reviewed by a classification society. Thus, DNV GL strongly recommends shipowners to undertake an Approval in Principle for LNG Ready ships in order to confirm compliance with both the current and the expected future regulations.

For LNG-fuelled projects and novel ship design in general, it is highly beneficial to have class involvement at the beginning of the design phase with regular follow up as the design work proceeds towards final class approval. Such cooperation confirms the feasibility of the project for the project team, management, investors and regulators, and ensures that issues and potential showstoppers are addressed at an early stage. The approval process can be documented for DNV GL ships by the new Class Notation GAS READY.

DNV GL has worked in this way for all gas-fuelled ships currently in DNV GL class and is currently working on several LNG-fuelled new builds to be delivered in the years to come.

Since the launch of the service, the DNV GL LNG Ready team has assisted more than 25 clients interested in exploring the possibility of using LNG as a fuel for their vessels, providing technical and financial decision support for more than 40 different vessel designs. The majority of these have already gone on to undertake HAZID/

Risk Assessment studies and several designs have already been given an Approval in Principle. The biggest highlight of the service during its first year of operation was the 17 LNG Ready container-ships (11 vessels of 14,000 TEU and 6 vessels of 18,000 TEU) ordered at Hyundai Heavy Industries (HHI) in Korea from United Arab Shipping Company (UASC), worth over US\$ 2 billion. These are the first vessels with our new GAS READY class notation. In addition, DNV GL has helped many clients increase their in-house technical and operational competence on LNG by providing seminars and workshops involving field experts. ■

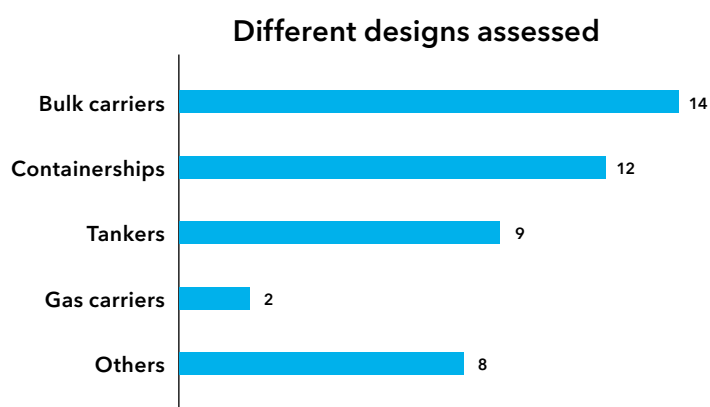


Figure 2: Different designs assessed as of May 2015

### Global LNG Ready Service network

The points of contact in your region can be found below and are ready to assist you:

Local hub	Point of contact	Email	Telephone Number
Global support	Gerd Michael Wuersig	Gerd.Wuersig@dnvgl.com	+49 40 36149 6757
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# LNG FUELS FERRIES AT

Two ferries with LNG powered main drive and auxiliary systems will begin operating in German coastal waters this summer. DNV GL has been working with the owner and the shipyards to realize these green shipping concepts every step of the way. Both vessels will significantly cut emissions and be forerunners in green coastal shipping.



# AG EMS



The 30th of April marked an important day for AG Ems, when the German Shipping company's vessel "MS Ostfriesland" became the first German flagged ship to bunker LNG as fuel. In June, the retrofitted ferry will be joined in AG Ems' portfolio by a second LNG-fuelled vessel, the "MS Helgoland". This newbuilding, currently in the final stages of construction, will be operated by AG Ems subsidiary Cassen Eils.

Both of these vessels will operate in the newly introduced ECA zone. The ECA - emission control area - extends throughout the Baltic and North Seas and means that all ships operating within the area must either use low sulphur fuels or treat the emissions from their engines to reduce the sulphur content, by using highly expensive marine diesel or installing a so called scrubber system for example. LNG is considered one of the most important alternative fuels to meet these restrictions and help the shipping industry reduce its environmental impact as vessels operating on LNG have greatly reduced SO<sub>x</sub>, NO<sub>x</sub> and particulate emissions while also emitting less CO<sub>2</sub>.

### Retrofit grows by roughly 15 metres

After successfully carrying out the first fuelling test with 40 cubic meters of LNG on board the "MS Ostfriesland", the 94-meter RORO passenger ferry will start sea and quay side trials before entering into service from Emden to the island of Borkum in the middle of June. Operating in an ECA would normally require the vessel to switch to marine gas oil or other low sulphur fuels. "MS Ostfriesland" will save more than one million liters of marine diesel per year as a result of the LNG conversion.

"As the aft section is being cut off completely and the new prefabricated section welded to the ship including a new engine room, so that the vessel will be operational shortly after conversion. That makes this project very special," says Henning Pewe, PTP Lead Gas technology expert at DNV GL - Maritime.

This new aft section and a large LNG tank have made the ship just over 15 metres longer than before. The vessel's new gas-electric propulsion system was installed using two different engine room concepts - a gas safe engine room and two emergency shut down engine rooms. The LNG tank is mounted centrally in the midships.





“The gas-diesel electric drive concept is tailored to the operating area. Four engines enable flexible operation modes both at sea and in port,” Pewe says.



This cooperation inspired the promotion of LNG as ship fuel via the development of a draft LNG bunkering procedure for Germany and a draft training concept. “Through our close cooperation with AG Ems we advanced the project and managed to obtain relevant approval very quickly,” he adds.

**“MS Helgoland” can carry up to 1060 passengers**

“This vessel is the greatest investment in 170 years of company history,” says AG Ems Director Dr. Bernhard Brons. “DNV GL was a very reliable partner in this project and we are convinced we are on the right track.”

When completed, the “MS Helgoland” will be able to carry 1060 passengers from Cuxhaven and Hamburg to the island of Helgo-





land at a speed of up to 20 knots. And its LNG propulsion system makes it fully compliant with the ECA sulphur limits.

The 83-metre-newbuild will bunker 53 cubic meters of LNG. The eco-friendly drive concept will reduce CO<sub>2</sub> emission by 20 percent and cut nitric oxide (NO<sub>x</sub>) emissions by 90 percent and sulfur oxide (SO<sub>x</sub>) emissions by 95 percent, particulate matter emissions will be essentially eliminated.

The "MS Helgoland" is fitted with a twin screw propulsion system that has a maximum capacity of 5000kw. Each main engine drives a controllable pitch propeller and can be operated both with LNG and MGO. "A cold recovery system that uses the cold air emitted by the LNG during the fuel preparation process meets the ferry's

need for heating, ventilation, or air conditioning without creating any additional energy requirements. A similar system is also installed on the 'MS Ostfriesland,'" Pewe explains.

With almost 150 LNG-fuelled vessels either in operation or on order, even though the technology is mature, in practice the infrastructure and practical operation is still evolving. Dr. Bernhard Brons is positive, but cautious: "Currently we want to wait and see how LNG operation works in practice, before we consider retrofitting more of our vessels," says Brons. He also called for more common standards. "As a shipowner you want to have an engine that has a type certification, but this has not yet been realized for all of the engine parts on board." ■

Text: Mohamed Zaitoun, Asst. Vice President New Building Technical Projects, UASC  
 Albrecht Delius, Naval Architect, TECHNOLOG, Consultant to UASC  
 Gerd-Michael Wuersig, Business Director LNG-fuelled ships, DNV GL

# THE NEW REFERENCE FOR LNG PROPULSION

Development of emission reductions from 4,200 TEU to present 18,800 TEU ships of UASC with LNG as fuel on Asia to Europe trading route



Fuel consumption is the major cost driver in shipping. Only the most fuel efficient ships will survive in tomorrow's markets! This thesis has become the challenge for United Arab Shipping Company (UASC) with their German Consultant and Ship Designer TECHNOLOG Services GmbH from Hamburg. The TECHNOLOG Consultants have been engaged by UASC with design optimizations of their earlier UASC newbuilding series since 1997, which have grown steadily in capacity over the years from the initial Panmax size of 4,100 TEU (A4) via 7,200 TEU (A7) to 13,500 TEU (A13) ships in 2010. UASC is now doubling its fleet capacity with eleven 15,000 TEU (15,000 TEU) and six 18,800 TEU (18,800 TEU). The 18,800 TEU ultra large container vessels are the world's most environmentally friendly. High efficiency and low fuel consumption generally also means fewer emissions. These seventeen ships have been ordered from Hyundai Heavy Industries and Hyundai Samho Heavy Industries and will be under DNV GL classification.

They will all come into service by autumn 2016. The first of the series, MV Sajir (15,000 TEU), started operations in November 2014. The first 18,800 TEU vessel, MV Barzan, was recently named at Hyundai Samho Heavy Industries (HSHI) in Mokpo, South Korea. It is also the first vessel to receive the new GAS READY notation. Her five sister ships, as well as eleven 15,000 TEU vessels of UASC's newest eco-ship generation, will be given this specific notation as well.

The class notation GAS READY with nominators (D,S,MEc,AEi) demonstrates that the vessel is in compliance with the gas fuelled notation rules, that structural reinforcements to support fuel con-

tainment system (LNG tank) have been verified (S), that the main engines installed can be converted to dual fuel (MEc) and that the auxiliary engines installed can be operated on gas (AEi).

This article will demonstrate the efficiency gains and reductions in emissions by UASC in recent years until the intended application of LNG as ship fuel. At the end of the article, an outlook/summary on the emission reduction potential through the use of LNG as fuel in these vessels is given. It should be noted that LNG will only become competitive and therefore commercially feasible, if it can be offered below the HFO price, or if the 0.5% sulphur regulations come into force in 2020. UASC is the Middle East's leading liner company serving AEC8 ports between Shanghai and Hamburg with their Asia to Europe service. The string of ten 4,100 TEU (A4 class) ships operated on this route between 1999 and 2008. In 2008, these A4 class vessels were replaced by the new larger eight (+one) 7,100 TEU (A7 Class) vessels on this route. These ships were propelled by Wärtsilä 11 RT-flex 96C engines with an NCR power of 56,628 kW.

## The new standard - UASC's 15,000 TEU and 18,800 TEU class

While the previous vessels were all standard shipyard designs that only underwent limited optimization and were trimmed for the common high operational speeds at that time, the new vessels of 15,000 TEU (15,000 TEU class) and 18,800 TEU (18,800 TEU class) were developed for economy and best fuel consumption by UASC with their consultant TECHNOLOG and the tendering shipyards, and later the selected builders HHI, in successful partnership.



These newbuilds have the following particulars:

Main Particulars	A15	A18
Length, overall: abt.	368.00 m	400.00 m max.
Length, betw. Perp.:	352.00 m	383.00 m
Breadth, molded:	51.00 m	58.60 m
Design draught:	14.50 m	14.50 m
Scantling draught:	15.50 m	16.00 m
Flag:	Marshall Islands	Malta
Class: DNV + 1A1, Container Carrier, DG-P, BIS, TMON, BWM-T, E0, NAUT-OC, Recyclable, CLEAN, NAUTICUS(Newbuilding) further extended by LNG preparation and hull stress monitoring		

Both vessel types follow an identical design and outfitting strategy. All of them have been designed and equipped for fuel economy with hull form optimization. With all the vessels having their keel laying dates before end 2015, they are IMO Tier II compliant concerning NOX emissions. The 15,000 TEU class ships achieved a considerably reduced CO2 footprint compared to the A13 vessels.

The six new 18,800 TEUs will operate in alliance with five new CSCL vessels in partnership, therefore only the six UASC vessels have been evaluated. The yearly CO2 output of these six ships will be 0.50 million tonnes. The CO2 output per TEU/nm is 52.3 gram, which is more than 60% below the 13,500 TEU vessels delivered just three years ago. When the ships are eventually retrofitted to use LNG as fuel, there will be a CO2 reduction of 25%, a NOx reduction for these IMO Tier II vessels of 25%, a SOx reduction of 97% and a Diesel particle reduction of 95%.

LNG is considered one of the most important alternative fuels to help the shipping industry reduce its environmental impact as vessels operating on LNG have greatly reduced SOx, NOx and particulate emissions while emitting less CO2.

#### Challenges related to the use of LNG as fuel compared to existing applications

These new vessels must be very competitive when put into service compared to (still) conventional ships and, moreover, the most competitive in the years to come, while complying with the increasing environmental demands of IMO MARPOL VI concerning emissions of SOx, NOx, diesel particles and CO2. With the increasing environmental consciousness of global warming by coastal countries, Emission Controlled Areas will certainly extend. UASC has opted for LNG as a fuel rather than investing in scrubbers and SCR's, and with this decision has accepted the role as market leader for LNG as a ship fuel with mega box container carriers and large scale bunkering.

Challenges are related to pragmatic decisions for navigation in ECA only zones or globally, endurance, suitable LNG tank size, tank construction type and costs, the location of the tank in the ship and economy of retrofitting, the selection of fuel gas supply system (F.G.S.S.), as well as the position of bunker stations and the vent mast for the least loss of precious container stowage space. Bunkering logistics along the trading routes need to be developed further regarding an adequate number of LNG bunker quantities. They also need to become more efficient to ensure ships can refuel without losing much time.

#### Technical concept of UASC for 15,000 TEU and 18,800 TEU class vessels

From a retrofitting perspective, it became obvious that the cargo hold directly in front of the engine room would be the most suitable location, with short piping routes to the LNG tank. Further, a type 'B' tank will have a greatest stowage density compared to several smaller cylindrical type 'C' tanks, and thereby have far fewer container slot losses. The Approval in Principle (AIP) for the LNG plant design was obtained from DNV GL through technical cooperation between the UASC Newbuilding Team with HHI shipbuilders, Hyundai Engine & Machinery Division (HHI-EMD) and Japan Marine United Corporation (JMU) for the Self-supporting Prismatic-shape IMO type-B LNG Tank (IHI-SPB Tank).

This was officially presented to HHI and UASC during the SMM exhibition in Hamburg in September 2014. The retrofit concept is based on the fact that the tank will be positioned between the longitudinal hold bulkheads with a safety distance between the outside insulation of the tank to shell being B/10. The tank connection space, the Fuel Gas Supply System rooms and the LNG Bunker Stations are located above the tank. All the requirements follow the latest version of the IMO IGF-Code.

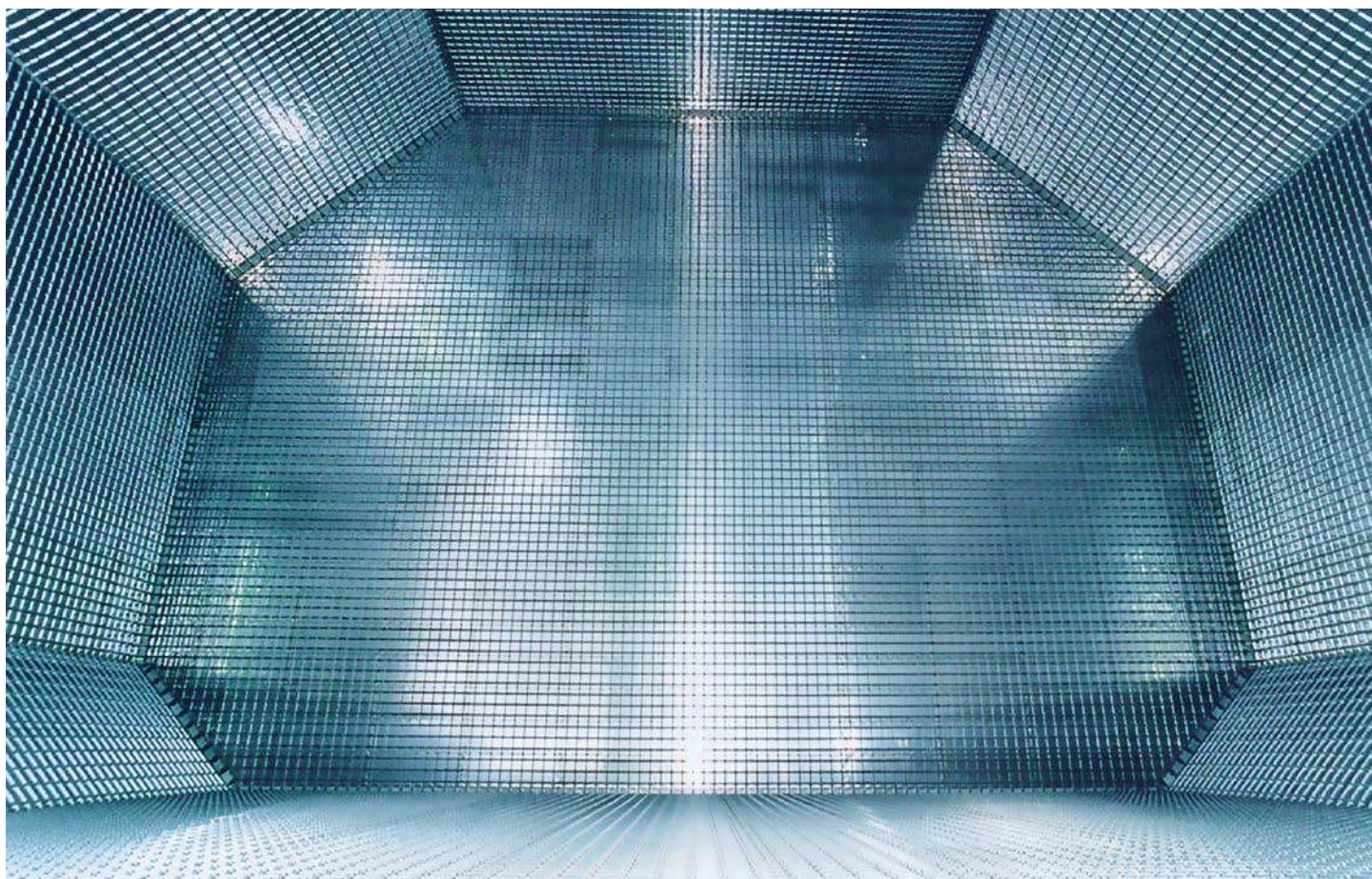
#### LNG as ship fuel

LNG as a fuel appears to be the most commercially attractive option when comparing the expected prices from 2020 of low sulphur heavy fuel oil (LSHFO) or Marine Gas Oil (MGO), and the extensive long term availability of natural gas. For Europe, we compared similar prices between LNG and HFO until 2020, but from 2020 onwards (if not delayed until 2025) we will have to compare the attractive LNG prices with those for higher cost distillates or blends. The still sizeable investment costs for LNG retrofit will achieve very fast payback times once the fuel price differences become visible. LNG is the most environmentally friendly ship fuel. From January 2015 onwards, the vessels have to run on MGO within the ECA area in Europe and will run on HFO outside the ECA zones. This reference scenario (NO 1) gives the 100% reference with regard to CO2 emissions. 6.2% of the emissions are related to the ECA operation and 93.8% to the operation outside of the ECA. ■

Scenario	Fuel consumption until 2020 (0.1% S in ECAs)					Fuel consumption after 2020 (0.5% S world wide)				
	MGO	HFO	LSFO	LNG	Sum	MGO	HFO	LSFO	LNG	Sum
1. Oil fuel alternative (baseline)	6.2	93.8			100.0	6.2		93.3		99.6
2. HFO only		104.4			104.4		104.4			104.4
3. LNG @ HFO & HFO - LNG below HFO price	0.3	33.2		52.1	85.6	0.3	0.5		74.4	75.2

% CO<sub>2</sub> (Case 1. = 100%)





Membrane tanks make efficient use of the available on board space

# LNG FUEL TANK CONCEPTS FOR LARGE VESSELS

Large ship types are the next frontier for LNG propulsion technology. Proven fuel tank concepts can be adapted for long-range LNG operation of container vessels.

The advent of LNG as a low-emission, comparatively cost-efficient future fuel for merchant ships has prompted a surge of development activities across the shipbuilding industry. Hanjin, GTT and DNV GL have signed an agreement to jointly investigate and develop a gas-fuelled large container vessel concept equipped with membrane fuel tanks. Based on current fuel price forecasts the joint development project focusses on long-distance endurance of an LNG propulsion system. The concept relies on well-proven

(containment of LNG as cargo) or market-ready technologies (dual-fuel, low-speed two-stroke engines).

The study envisions a 16,300 TEU container vessel equipped with two membrane tanks capable of bunkering up to 11,000 cubic metres, enough for approximately 15,000 nautical miles. Designed by Hanjin Shipyard, the ship is intended to travel between Asia and Europe. It will have to cross at least one Emission Control

Area (SECA) in European waters where the new, strict sulphur emission limits will be in effect. The tank size can be adjusted to the given operational profile, in particular, the expected sailing time or distance in ECA areas.

### Efficient LNG storage

The project focuses on the LNG fuel system, consisting of the bunker station, LNG fuel tanks, gas preparation and fuel supply systems. Hanjin is designing the key components for the LNG supply system, GTT is responsible for the integration of the fuel containment system, and DNV GL is handling the design review, hazard identification and, upon successful completion of the project, the Approval in Principle (AiP) of the design. The safety performance assessment for the gas supply system and the tank system integration will be key aspects of DNV GL's contribution. Apart from the technical aspects, the project will also investigate economic feasibility criteria based on the LNG Ready Step 1 procedure. This includes evaluation of the LNG tank location and range in gas mode based on the ship's operational profile, outlining the requirements for an LNG Ready, or LNG-fuelled design, and an assessment of prospective LNG availability at relevant locations. The GTT tank system uses proven technology which has been in use for many years on board LNG carriers. The biggest advantage of membrane tanks is that they make efficient use of the space available on board, requiring little more than half the hold space occupied by spherical or cylindrical tanks. The Mark III membrane system chosen for this large container vessel concept consists of a cryogenic liner directly supported by the ship's inner hull. The liner is composed of a primary metallic membrane with an insulation layer and a secondary membrane underneath.

### The boil-off challenge

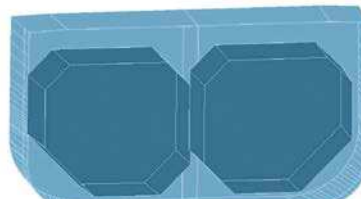
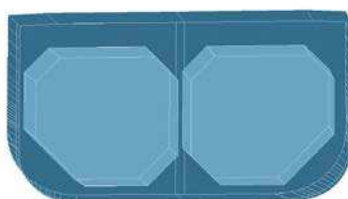
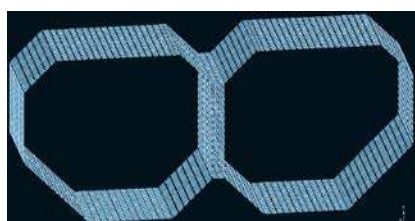
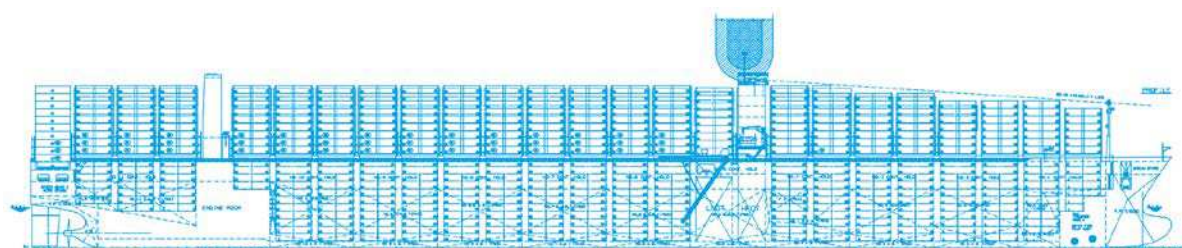
One key issue has been the treatment of boil-off gas from the LNG tanks. The pressure increase inside the membrane tank system, which is designed for a maximum of 700 mbarg, must be limited without releasing gas to the atmosphere. This can be achieved by using the boil-off gas to power the auxiliary engines and the boiler. Most of the time the power demand by far exceeds the

natural boil-off from the tanks, so the system must actually vaporise additional volumes of LNG to meet the fuel demand while maintaining a low operating pressure inside the tanks (typically between 50 and 300 mbarg). However, when the ship is idle (at anchorage for instance) and the power demand is very low, gas pressure will build up inside the tank. As long as some gas is drawn to power the minimum hotel load, the pressure will increase relatively slowly. Should the pressure inside the tanks exceed a preset value (around 600 mbarg) – a case not foreseen in the operating profile envisioned for the ship – the excess boil-off will be directed to the boiler (as a gas combusting unit) for incineration. For operating profiles including longer idle periods, a Mark III Flex membrane system could be used, which would provide 50 per cent more time for the pressure to reach the GCU threshold. A Mark III Flex membrane has 400 millimetres of PU foam insulation versus 270 millimetres in a standard Mark III system.

Today 50 LNG-fuelled ships are in service and the milestone of 100 confirmed LNG projects worldwide was achieved this year. There is no longer any doubt that LNG will be a major ship fuel in the future. Yards and component manufacturers have developed fuel-efficient and eco-friendly LNG propulsion systems for all types of vessel. The joint project of Hanjin, GTT and DNV GL demonstrates that efficient concepts for large ships are feasible and available to meet the needs of tomorrow's maritime industry. ■

### Main particulars of the ship concept

Length overall:	approx. 397 m
Breadth:	56.1 m
Design draught (MLD):	14.5 m
Fuel tanks (LNG): (symmetric with centreline)	2x5,500 m <sup>3</sup>
Tank length:	approx. 12 m
Tank height	approx. 22 m
Tank breadth	approx. 24 m
Engine:	dual-fuel MEGI engine



Photos: Hanjin - GTT - DNV GL



# INNOVATING FOR SAFER AND SUSTAINABLE SHIPPING

The Viking Lady, an offshore supply vessel in daily operation in the North Sea, is a full-scale “test laboratory”: LNG-fuelled with battery-hybrid propulsion.



Figure 1. The Viking Lady OSV: a full-scale test lab.

Viking Lady is a 92 meter-long DNV GL classed offshore supply vessel owned by Eidesvik Offshore ASA. She was built in 2009 with a conventional diesel-electric propulsion system comprising of four dual-fuel engines that drive five thrusters for propulsion, manoeuvring, dynamic positioning (DP), and any required electricity demand. Viking Lady operates daily in the North Sea (Figure 1), running on LNG.

What makes Viking Lady special is that over the last years she has been a full-scale test laboratory for assessing the potential and possible benefits of new propulsion and energy storage technologies within the FellowSHIP series of research & development projects.

In the first phase of the FellowSHIP project, which began in 2003, a feasibility study to assess the potential use of fuel cell (FC) technology on board a commercial vessel was carried out. During the second phase, the FC was specified and selected, and then a molten carbonate fuel cell (MCFC) was installed, with a nominal power of 320 kW, on-board Viking Lady to supply auxiliary power. The fuel cell has been in operation for more than 20,000 hours running with LNG as a fuel in real operational conditions.

In the third phase of this R&D series, FellowSHIP III or HybridSHIP, the project went one step further. A 450kWh capacity lithium-ion battery was added, enabling the use of hybrid-electric propulsion.

FellowSHIP III was coordinated by DNV GL, with shipping company Eidesvik Offshore ASA and manufacturer Wärtsilä as project partners. The project was co-funded by the Research Council of Norway.

Figure 2 presents the Viking Lady propulsion configuration as shown in a COSSMOS model flowsheet. The battery acts as an energy buffer which is able to cover the intense load variations that can occur, especially in DP and standby operations. This means that the gen-sets can operate at a relatively constant load and in an optimal way. This effectively increases the propulsion system's available power and redundancy - thereby increasing the level of safety in high-risk operations. This also means that the gen-sets operate with a relatively constant load and in an optimal way - making operations safer and more energy-efficient. Other benefits of hybrid propulsion include the lower maintenance requirements and costs, as well as lower levels of noise and vibrations. COSSMOS, DNV GL's in-house computer platform for modelling and simulating complex integrated ship machinery systems, played an important role in FellowSHIP III. COSSMOS provides an early-phase feasibility analysis of new ship machinery systems, estimating the expected benefits in terms of energy efficiency, emissions and economics. Advanced simulations and optimisation can direct the implementation of optimal power management strategies to arrive at maximum gains while ensuring the safety and operational capabilities of the vessel.



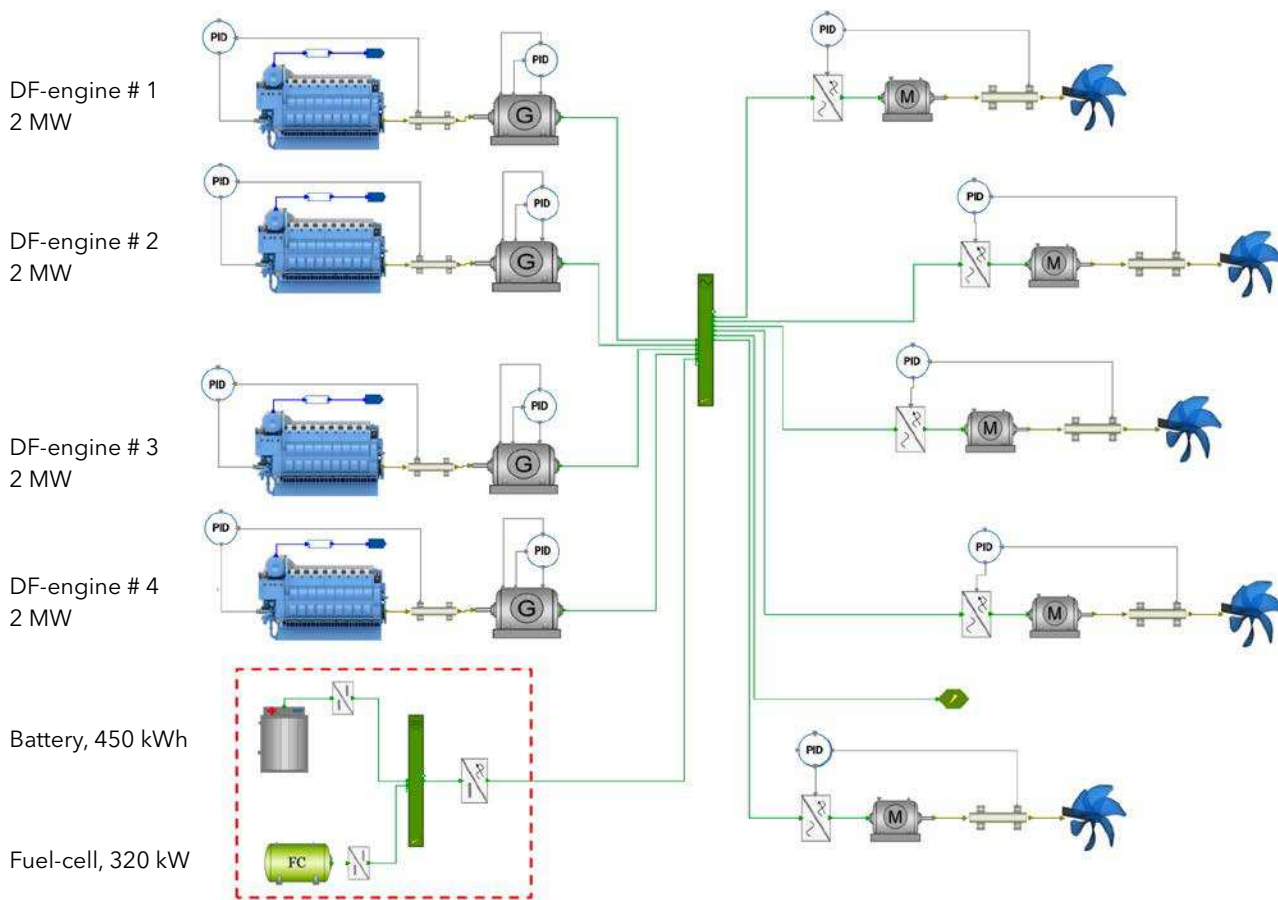


Figure 2. COSSMOS model of the Viking Lady hybrid propulsion system.

The battery hybrid installation was tested in sea trials in May 2014. The fuel cell stack was not operated. Figures 3 and 4 summarize the sea trial results for DP in good and bad weather, respectively. The hybrid operation is compared against the conventional one (only gen-sets). In both figures, the green columns (hybrid) show the benefit of switching off the one gen-set while operating on batteries. In hybrid operation, significant fuel savings and emissions reductions are achieved, due to the combination of appropriate battery sizing together with optimal power management strategies. An annualised projection of the results for all of the vessel's operational modes (transit, DP, standby, harbour) show

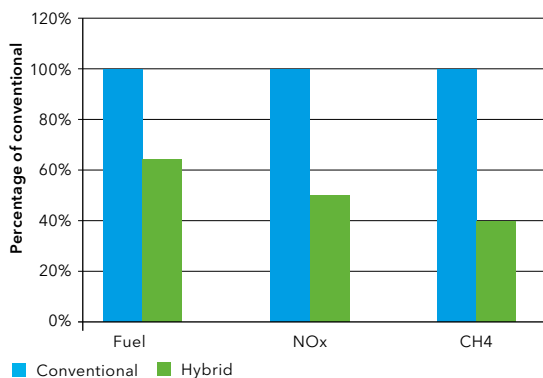


Figure 3. Sea trials: Hybrid system performance in DP mode in calm weather.

that a 15% reduction in fuel consumption, 25% reduction in NO<sub>x</sub> emissions and 30% reduction in GHG emissions can be realised in practice, with marked improvements especially in DP operations.

To complement the project, classification rules had to be developed to ensure the safe installation and operation of a large battery power pack on a ship. Thus DNV GL has had tentative rules for battery power since 2012 that cover all of the significant aspects of using battery packs in the maritime context, from design, through to installation and verification. The entire procedure is expected to be finalized within 2015. ■

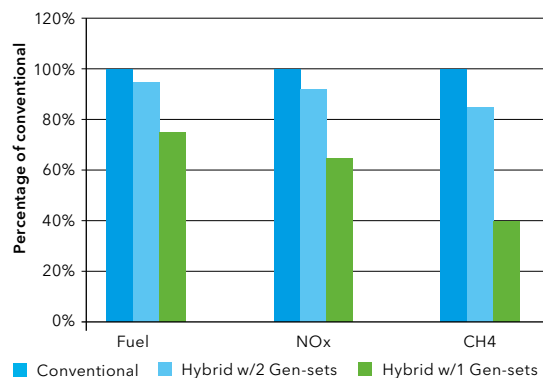


Figure 4. Sea trials: Hybrid system performance in DP mode in bad weather.



# RULES FOR GAS-FUELLED SHIPS

## IGF Code

Due to the lack of international regulations for gas as fuel for ships other than gas tankers, the development of an International Code of Safety for ships using gases or other low flashpoint fuels (IGF Code) was proposed to the Marine Safety Committee (MSC) of IMO in 2004. The goal of the IGF Code is to provide an international standard for ships with natural gas-fuelled engine installations.

The first result of the international development was the Interim Guidelines MSC.285(86) adopted in 2009. It specifies criteria for the arrangement and installation of LNG-fuelled machinery to achieve a level of integrity in terms of safety, reliability and dependability equivalent to conventional oil-fuelled machinery. After 2009, the development of a mandatory international code (IGF code) continued and this work is now in its final stages with regard to its implementation in 2017. The IGF Code will be mandated by SOLAS and therefore serve as an addition to SOLAS.

A phase two development of the IGF Code is initiated for development of measures for low flashpoint fuels which will include methyl-/ethyl alcohols, fuel cells and low flashpoint diesel.

## New rules

DNV GL has acknowledged the need for modernising the rules to keep up with the fast developing technology, and keeping the risk within acceptable limits.

The new rules are building on relevant real life experience as well as risk assessment tools. They contain functional requirements allowing for the ability to consider innovative solutions within the framework of the rules, but also include clear and prescriptive guidance for building safe gas-fuelled ships with known solutions.

This for instance means more clear guidance for spaces around "new" types of LNG fuel tanks and better requirements for cryogenic fuel piping going through the ship and for fuel preparation spaces. The updated rules also provide more precise certification requirements for components used in LNG fuel ship systems.

Hence, the uncertainties for the owners and yards are reduced, both when looking into standard solutions and more innovative designs. The main outcome is however to more efficiently lower the risks for gas-fuelled ship designs.

The new DNV GL Rules for Gas Fuelled Ship Installations will be consistent with the IGF Code and are planned to enter into force in January 2016. ■



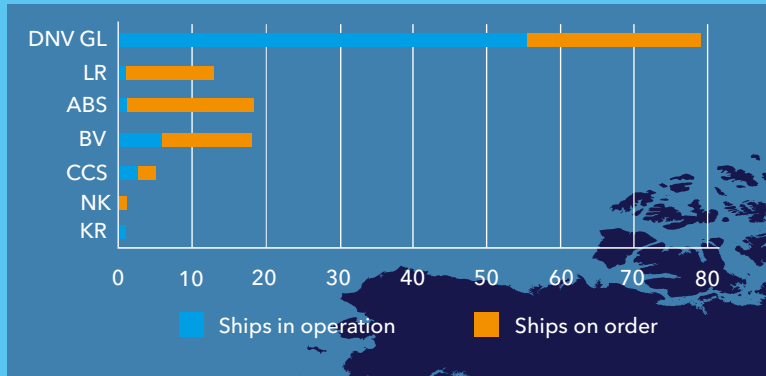
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AND USED AS A POSTER.





# 2015 STATUS OF LNG AS SHIP FUEL

DNV GL takes LNG ship fuel global



**2013**  
Port of Antwerp contracts DNV GL to develop bunkering procedures, to ensure safe and efficient bunkering of LNG.



**2011**  
Bit Viking is the first vessel to be converted to LNG fuel.



**2018**  
Matson's 2 LNG fuelled container vessel will enter into operation.



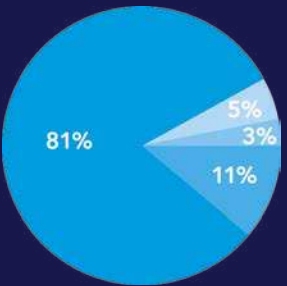
**2017**  
Crowley's 2 ConRo vessels will join TOTE's container vessels on the U.S. - Puerto Rico trade.



**2013**  
López Mena is the first LNG-fuelled vessel deployed outside Norway, and set a world speed record with 58 knots.

## 63 LNG-fuelled ships in operation

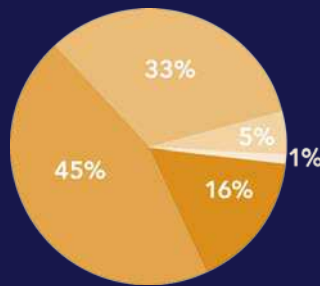
- Norway
- Europe
- America
- Asia & Pacific



Per 01.05.2015

## 76 LNG-fuelled ships on order

- Norway
- Europe
- America
- Asia & Pacific
- Middle East



## Important events

**2000**

The first LNG-fuelled ship Glutra enters into operation.

**2001**

DNV publishes the first rules for gas-fuelled ships.

**2010**

IMO Interim Guidelines for gas-fuelled ships is developed based on DNV rules. Enabler for design and operation of LNG-fuelled ships worldwide.

**2011**

DNV recognises the need for a standard for LNG bunkering and initiates an ISO working group. ISO TC 67 - Guidelines for systems and installations for supply of LNG as fuel to ships is finalized in 2014.

DNV·GL



essel  
LNG



**2013**  
The world's first bunker vessel SeaGas enters into operation fuelling the RoPax Viking Grace.



**2013**  
Fjordline takes delivery of Stavangerfjord, the world's first ship with pure gas engines not deployed in domestic trade.



**2013**  
UASC demonstrates that LNG fuel is also an option for mega container vessels and orders 17 LNG Ready vessels to DNV GL class.



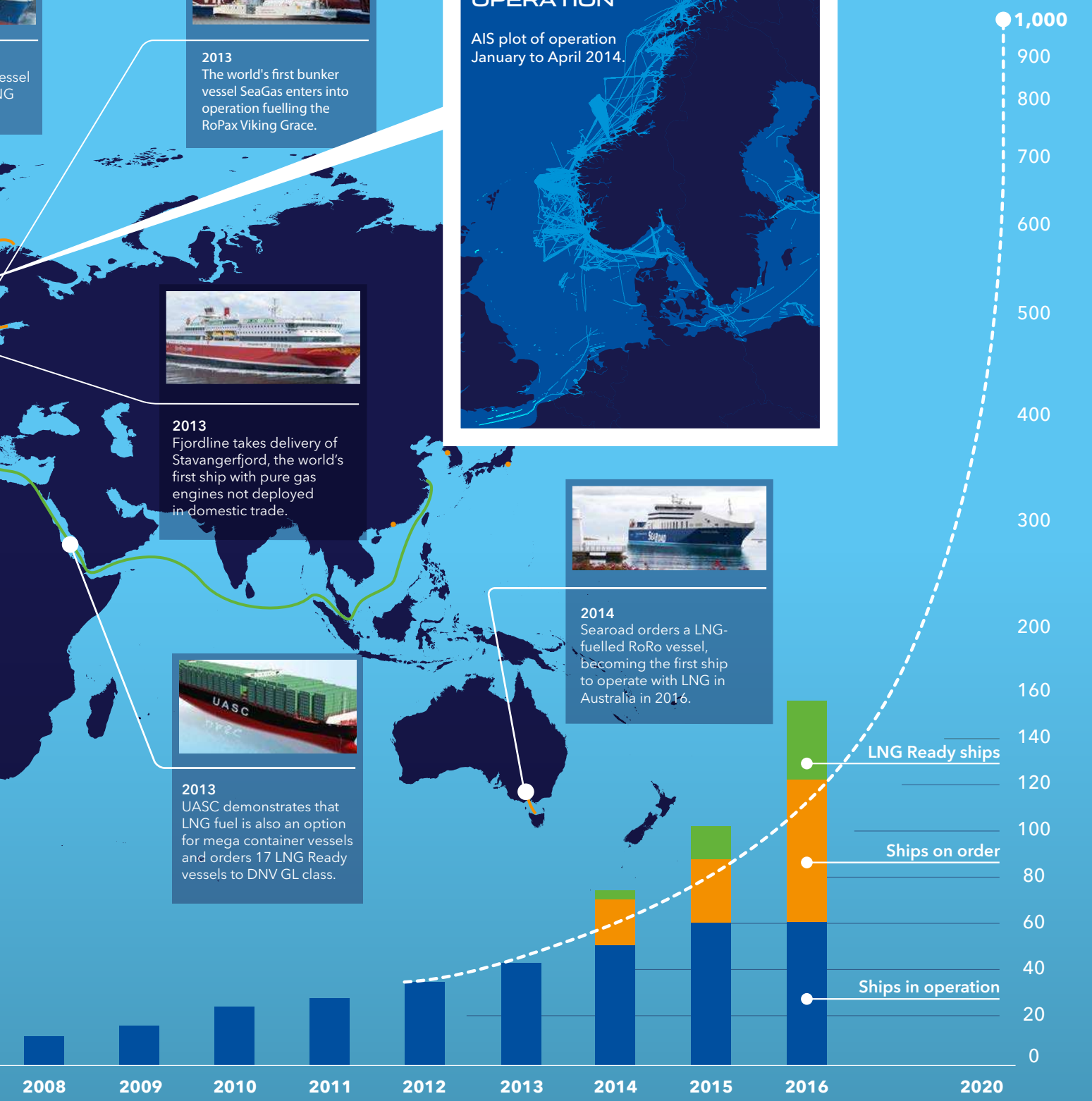
**LNG-FUELLED SHIPS IN OPERATION**

AIS plot of operation January to April 2014.



**2014**  
Searoad orders a LNG-fuelled RoRo vessel, becoming the first ship to operate with LNG in Australia in 2016.

**LNG-fuelled ships**



**2013**  
DNV GL launches the LNG Ready concept, which is quickly picked up by the industry.

DNV GL launches Recommended Practice for LNG Bunkering, providing the industry with the first practical tool for developing bunkering procedures.

**2014**  
NYK places order for a purpose built LNG bunker vessel (5100 m³), that will operate out of Zeebrugge from 2016. Several more orders for bunker vessels are imminent.

The IGF code is scheduled for completion and will reduce uncertainty for LNG fuel designs.

**2015**  
The 0.10% sulphur limit for SECAs will enter into force and accelerate the uptake of LNG fuel.

**2016**  
IMO NOx Tier III will take effect in the North American ECA, further increasing the rationale for choosing LNG for new ships that intend to have any extent of operation here.

**2020**  
The global sulphur limit of 0.50% will enter into force, pending a fuel availability review in 2018, and will drive uptake of LNG fuel in the deep sea segments. Enforcement in EU is not subject to the availability review.

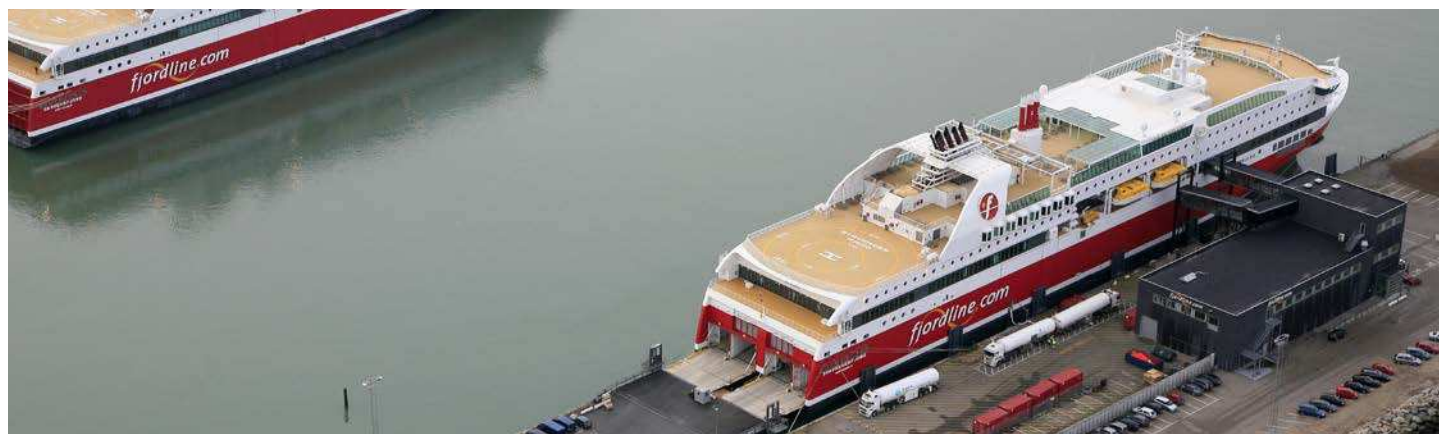




# SKANGASS:

## AN EARLY MOVER ON LNG BUNKERING SOLUTIONS

LNG may be the marine fuel of the future, but questions about the LNG bunkering infrastructure have made some owners reluctant to embrace LNG as a fuel. However, with decades of experience in providing land-based LNG distribution infrastructure, Skangass may have the answer.



Skangass of Stavanger is ready to deliver when the ships come in. Finnish Gasum acquired a 51% share in Skangass in May of this year, pushing Gasum into the lead spot in Nordic LNG. Skangass will provide a major part of the new company's LNG infrastructure, as well as assuming control of Gasum's existing distribution infrastructure.

While supply to industry has driven Skangass's expansion, the marine market is beginning to show a real upside. "This acquisition strengthens our position as a leading LNG player in the Nordic market," says Skangass CEO Tor Morten Osmundsen. "The new boost to the infrastructure will contribute to continued growth in the number of LNG-fuelled cargo and passenger vessels in the North Sea and Baltic Sea, which will result in emission cuts in maritime transport in particular."

### Breakthroughs in LNG bunkering

Skangass is already breaking new ground in the LNG bunkering business, with its newly approved truck-to-ferry bunkering solution at the Risavika harbour outside Stavanger. The approval allows Fjord Line to bunker its two cruise ferries - the Stavangerfjord and Bergensfjord; classed by DNV GL - in Norway.

Two key elements in the development are the permits to deliver and bunker from trucks and to bunker while passengers are embarking and disembarking in Risavika. "The fact that the Norwegian Directorate for Civil Protection (DSB) has granted us permission for a temporary truck bunkering solution is important for us in order to maintain the delivery security for Fjord Line," says Mr Osmundsen. "We started the first bunkering in Risavika with passengers on board as early as in mid-March."

In January, Skangass received permission to establish a permanent bunkering station at Risavika and planning is expected to be completed by the spring of 2015. In connection with its LNG terminal at Lysekil, a permanent terminal for distribution to a bunker vessel is under consideration.

### The next step?

"We're in the process of realising plans for a ship-to-ship dedicated bunker vessel," reports Skangass Director of Special Projects Peter Blomberg. "We are now in negotiations with a shipowner to build and operate the ship and have been granted funding through the EU pending the final decision, so there are good incentives to proceed.

"With marine LNG, it's always a question of the chicken or the egg - do you ensure supply so the customers will come, or do you wait for the customers and then build up supply?" Blomberg reflects. "But we believe it's important to take this step, to make it easier for shipowners to decide to go with LNG by being where they are, instead of them having to come to us," he concludes.

Founded in 2007, Skangass began its LNG operations in 2011 and has already come a long way towards its goals: to build up a leading position, keep up the pace and take an active role in developing the marine LNG market. Whether it is the chicken or the egg, one has to come first and Skangass is set on being a first mover in the Nordic market. ■

# ENGINES FOR GAS-FUELLED SHIPS

The engine technology to use natural gas as ship fuel is available today. A wide range of engines in all power ranges are on the market. This article highlights the basic working principles of the different engine types and indicates the positive effects on emissions to air gained through switching from oil based fuel to natural gas.



## Engines for gas-fuelled ships

The use of gas as a ship fuel outside of the LNG carrier business is a young technology, as are gas/dual-fuel engines. While gas engines have been used in industry for decades, the first non-LNG carrier vessel, the LNG-fuelled ferry GLUTRA with gas engines and storage, came into service in the year 2000. The engines of this vessel are pure gas Otto cycle engines. The Mitsubishi GS12R-PTK ultra lean burn natural gas engines in V12 configuration attain a power output of 675 kW at 1500 rpm.



Four-stroke gas engines on board the MS GLUTRA.

The engine room configuration of the GLUTRA is an ESD engine room configuration, as currently defined in the IMO IGF-Code. Since GLUTRA's first sailing, some 50 more LNG-fuelled vessels have come into service - 35 since 2010.

It should be noted that until 2013 all vessels operated in Norwegian waters. In 2013, the Fjordline Cruise ship-like ferry Stavangerfjord started operating between Denmark and Norway. The Viking Grace, which is a similar ferry, operated by Viking Line came into service between Stockholm and Turku and the fast ferry Francisco, operated by Buquebus started operating between Buenos Aires and Montevideo. Today, the orderbook for the next four years contains approximately 70 vessels, with 14 containerships among them.

The Stavangerfjord uses Rolls Royce gas engines, while the Viking Grace uses Wärtsilä dual-fuel engines. Both engine types are four-stroke Otto Cycle engines, fulfilling the IGF-Code requirements for the so-called "inherently safe" engine room. Wärtsilä was the first manufacturer to introduce four-stroke dual-fuel engines in 2005. Today Wärtsilä, MAN, Caterpillar and HiMSEN are the most prominent manufacturers of dual-fuel engines.

### Diesel and Otto Processes: volume-pressure diagram

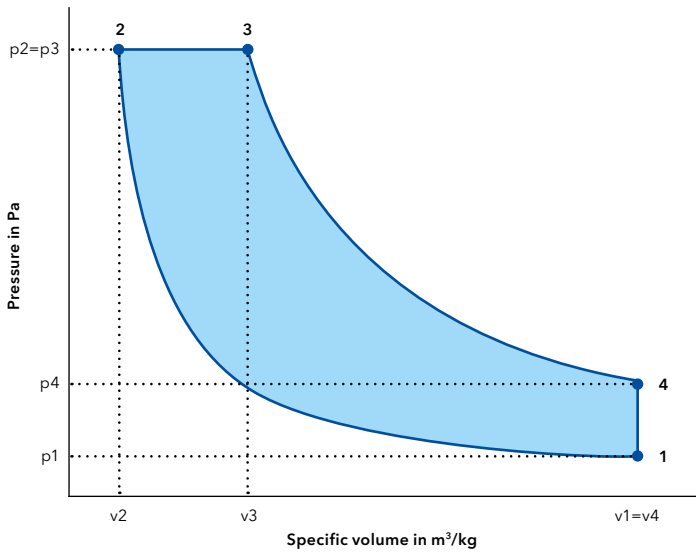


Figure 1: Diesel-Process: const. pressure during combustion (2→3)

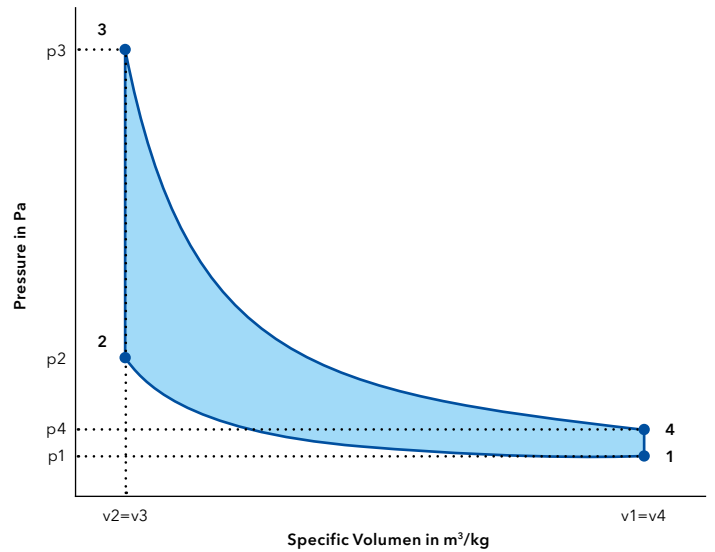


Figure 2: Otto-Process: const. volume during combustion (2→3)

The workhorse of shipping is the two-stroke engine. Two-stroke natural gas-fuelled engines have been available for the market since late 2012 when MAN presented their ME GI engine at HHI on 9th of November 2012. Wärtsilä as the second big player in this market sold their first dual-fuel two-stroke engines in 2014 (RT-flex50, X62DF). The two-stroke technology for gas as a ship fuel has been on the market for less than two years. This short availability of this core technology has to be considered when looking to the relatively small number of ships already running on LNG.

#### Low pressure engine

All of the four-stroke engines available today are low pressure engines. The fuel/air mixture formation takes place outside of the cylinder behind the turbocharger. This means that the fuel gas pressure is approximately 5 to 6 bar because it must be higher than the charge air pressure after the turbocharger.

Nevertheless, the pressure is low and therefore the gas can be provided either directly from a pressurised storage tank or by use of a compressor. If a compressor is used, the specific energy consumption of the compressor is below 1% of the lower heating value of the gas ( $H_u$ ), even if 10 bar pressure is required as needed for the two-stroke low pressure engines from Wärtsilä. If the gas has to be compressed to a high pressure of 300 bar, the compressor's specific energy consumption will be much higher, approx. 4% of  $H_u$  (Figure 4). This is the reason the two-stroke MAN engines use pumps to increase the pressure to 300 bar in the liquid phase and not in the gaseous phase of the fuel.

#### Engine operating principles

An overview of piston engine principles for gas-fuelled ships is given in Figure 1. The self-ignition temperature of natural gas stored as LNG is too high to be reached by the compression cycle in the cylinder. Thus, the combustion must be initiated by

#### Overview of piston engine principles for gas-fuelled ships

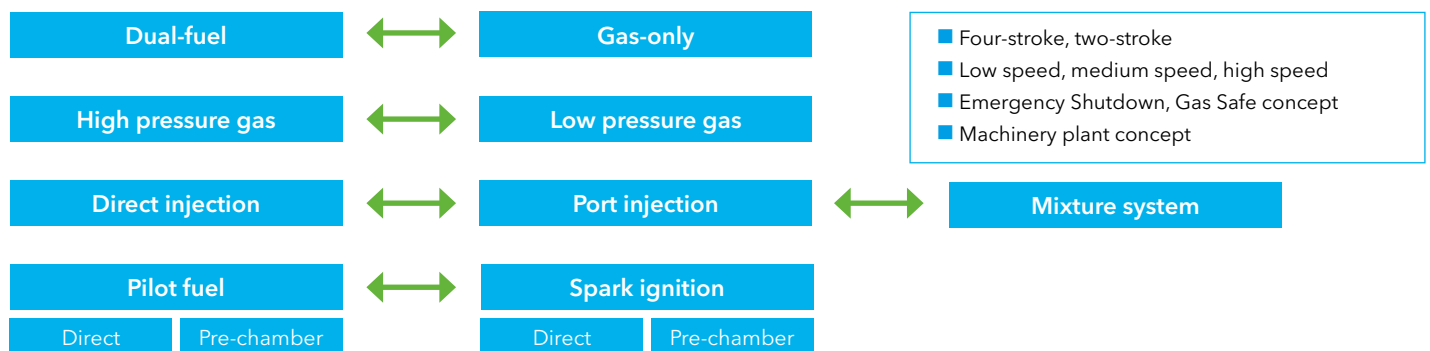
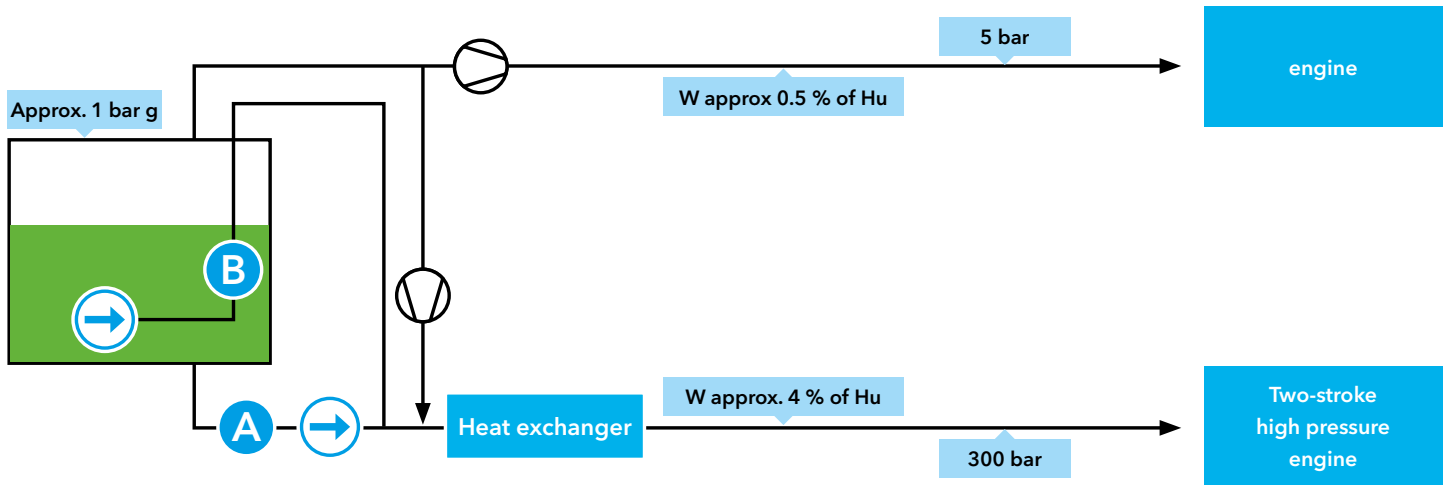


Figure 3



### Gas supply to engine



- A** Bottom line from tank (exclude loss of tank content in case of pipe failure)
- B** In-tank pump (redundancy required, Boil Off must be handled separately)

Hu= lower heating value

Figure 4

an ignition source. Engines running only on gas use a spark plug to initiate the combustion process. The dual-fuel engines use so-called pilot fuel to start the combustion process. A small amount of pilot fuel is injected into the cylinder, where it is ignited by the high temperature of the gas air mixture at the end of the compression cycle. Typically, the amount of pilot fuel oil is below 1% of the energy used by the engine.

DF engines run on gas or on diesel fuel. In gas mode, the engines run on the Otto-Cycle and in diesel mode they run on the Diesel-Cycle (Figures 1 and 2). The main manufacturers of dual-fuel four-stroke engines are Wärtsilä, MAN and Caterpillar. It is also possible to run diesel engines partly on gas. In such engines, up to approx. 70% of the energy is provided by gas and 30% by diesel fuel. This option can, in particular, be a refit option for engines which cannot be converted to DF engines.

MAN and Wärtsilä also offer two-stroke engines for ship propulsion. The MAN engines compress the air, start the combustion

process by injecting fuel oil and inject the gas into the burning air/oil fuel mixture. This also enables the operation according to the diesel cycle in gas mode as well and is the reason that the gas pressure must be high (300 bar for natural gas). The Wärtsilä engines inject the gas at the beginning of the compression after the air has entered the cylinder. At the low pressure at the beginning of compression, only a low gas pressure is required. The gas/air mixture is ignited at the end of the compression stroke by the pilot oil. The engine thus works as an Otto-Cycle engine.

#### Emissions

Compared to HFO, LNG greatly reduces emissions to air (Table 1 Environmental Emissions). In terms of NO<sub>x</sub> emissions, the four-stroke and two-stroke low pressure engines reduce these emissions by 85% compared to HFO. While the high pressure two-stroke engines still reduce NO<sub>x</sub> by 40% without exhaust gas treatment. Particle emissions are reduced by 95% and more. Because LNG does not contain sulphur, these emissions are eliminated completely. All emissions to the atmosphere relevant

ENVIRONMENTAL REGULATIONS		
Emission component	Emission reduction with LNG as fuel	Comments
SO <sub>x</sub>	100%	Complies with ECA and global sulphur cap
NOx, Low pressure engines (Otto cycle)	85%	Complies ECA 2016 Tier III regulations
NOx, High pressure engines (Diesel cycle)	40%	Need EGR/SCR to comply with ECA 2016 Tier III regulations
CO <sub>2</sub>	25-30%	Benefit for the EEDI requirement, no other regulations (yet)
Particulate matter	95-100%	No regulations (yet)

Table 1

COMPARISON OF EMISSIONS FROM DIFFERENT FUELS					
Data from DNV No 2011-1449, rev 1 (Tab 16 mainly); DNV NO 2012-0719	CO <sub>2</sub> equivalent [g/MJ] (Tab 3, DNV-2012-0719)			% CO <sub>2</sub> (HFO=100 %)	
	Well To Tank CO <sub>2</sub> emissions (WTT)	Tank To Propeller CO <sub>2</sub> emissions (TTP)	Total CO <sub>2</sub> emissions	% Total	% Tank To Propeller (TTP)
Oil fuel (HFO)	9.80	77.70	87.50	100.00	100.00
Oil fuel (MGO)	12.70	74.40	87.10	99.54	95.75
LNG (from Qatar used in Europe)	10.70	69.50	80.20	91.66	89.45
LNG (from Qatar used in Qatar)	7.70	69.50	77.20	88.23	89.45

Table 2

for human health and the so-called “black carbon” effect on global warming are reduced significantly by burning natural gas instead of HFO or MGO. As explained below, the effect on CO<sub>2</sub> emissions is also positive.

DNV GL evaluated the greenhouse gas emissions from production to the tank of the ship (Well To Tank; WTT) and the emissions from the combustion of the fuel (Tank To Propeller; TTP) in two studies in 2012. Methane has a much higher greenhouse warming potential than CO<sub>2</sub>. The Kyoto protocol gives Methane a value that is 21 times the global warming potential (GWP) of CO<sub>2</sub>. This means that an unburned methane molecule has 21 times the GWP of one molecule of CO<sub>2</sub>.

A comparison of emissions from different fuels indicates that the WTT emissions for HFO, MGO and LNG are similar and small compared to the TTP emissions (Table 2). For LNG, the methane slip has been considered for WTT and TTP. In the engine process, methane is mainly released as blow-by of the cylinders into

the crankcase, valve overlapping effects and from incomplete combustion.

The DNV GL study assumed the methane slip for four-stroke engines at 1.5% of the fuel. Taking this into account, the GWP is still reduced by 8 to 12%, as can be seen in Table 2. The greatest reduction in greenhouse emissions is reached by the high pressure engines, which reduce the CO<sub>2</sub> effect by 26% compared to HFO, compare article on page 14. ■

# GTT HARNESSSES THE POWER AND POTENTIAL OF LNG AS FUEL

With abundant gas supplies in North America, building the infrastructure for widespread use of LNG as fuel is the next big step. GTT's flexible storage solutions ranging in size from export terminal (200.000 m<sup>3</sup>) to fuel tanks for tugs and barges (2.000 m<sup>3</sup>), may provide many pieces of the puzzle that is the LNG value chain.

"Through GTT's expertise in storing LNG safely and reliably while preserving its energy, we are uniquely positioned to help usher in the era of LNG as a marine fuel in the US. We have already formed strong new partnerships with owners and engineering companies," says Aziz Bamik, General Manager, GTT North America.

"The foundation for our work is sound, reliable, foolproof and cost-effective design. But that is just a good start," he says. "Technology is not enough," he explains. "Competence and experience make the real difference. When dealing with LNG, you have to get it right the first time. There is a price to pay to get into LNG: It takes time and effort to get ready and do things right, not just on paper. LNG enjoys an incredible safety record, and we must maintain this excellent safety record."

Developing the industry locally is vital, according to Bamik. "We draw on the expertise the industry already has here in the US, as well as what we bring. Our office is now well established with six employees, mainly LNG project engineers, representing relevant expertise from shipyards both in the US and internationally. We are also drawing on our headquarters' technical expertise," he says. An example of how GTT North America wants to work is their collaboration with Conrad Shipyard, a major US shipbuilder headquartered in Morgan City, Louisiana, for the production of LNG membrane tanks using GTT's technology. GTT's engineers and LNG experts trained, prepared, and continue to support Conrad Shipyard to offer GTT's membrane containment technologies for LNG storage, transportation, and fuel tanks. The training process, which commenced in Q3 2014, included the construction of a membrane tank model, specifically a complex corner, to exhibit Conrad Shipyard's manufacturing and installation expertise. The successful construction of the model tank demonstrates to both regulatory agencies and classification societies the shipyard's skills and experience in the production of sophisticated membrane technologies.



This important milestone not only represents a return of membrane technology to the US maritime industry, but also enabled Conrad Shipyard to capture the contract for the first dedicated LNG bunker barge for service in North America.

The barge, for WesPac Midstream LLC and Clean Marine Energy, is expected to be delivered in the first half of 2016 and will be built with GTT's innovative Mark III Flex cargo containment technology. The barge is also intended to feature GTT's patented REACH4 (Refueling Equipment Arm Methane [CH<sub>4</sub>]) bunker mast design to ensure a simple and safe transfer of LNG fuel to the client vessels of TOTE, which will bunker in Tacoma and Jacksonville.

"Soon we will enter similar agreements with other shipyards and installation outfitters to accomplish the same," Bamik says. Such localized customer training is complemented by dedicated facilities and experienced officers in France. GTT also offers LNG familiarization training, as well as more advanced courses.



### Understanding the local market

While GTT has enjoyed success for decades internationally, the North America subsidiary is relatively new (July 2013) and the workload is high: "We will expand and make sure that we have the capacity to support the full lifecycle of our products," he says.

"My role so far has been to understand the specifics of the local market and engage all the stakeholders in the value chain. For example, to engage with US Coast Guard and classification societies, to contribute to the regulations, and help streamline procedures and standards. There are also complex investment considerations for owners and operators that we need to understand, in order to offer the appropriate solutions."

According to Bamik, GTT directly addresses two unique needs of the US market right now: on the demand side, the volumetric efficiency of GTT's tanks allows shipping companies to reap the benefits of LNG as fuel without giving up much of their cargo capacity. This makes this new technology more attractive, as extra investments are necessary for LNG-fuelled vessels.

The second, on the supply side, is the scalability and flexibility of GTT's technology. "By being able to provide several missing pieces to the value chain, from big onshore tanks to small bunkering barges, or small tanks that can be easily shipped around the country, we can contribute significantly to a quicker roll-out of the LNG infrastructure in the US. This removes some uncertainty from the complex investment decisions that the operator needs to make."

Competence and experience remain a vital part of GTT's service offering, also through research and innovation. With six decades of operational experience, GTT has been able to research and innovate in areas such as lower boil-off rates. "We can now adjust to different operating profiles and voyage speed to get the boil-off rate down to less than 0.1 percent per day. We do so without increasing the price of the ship, so the savings from that alone can be USD 20 million over 10 years for each ship."

### Partnerships

"GTT is all about partnerships with stakeholders and customers. Working closely with DNV GL is natural for us in GTT: DNV GL shares our commitment to safety and quality, which are integral parts of both our brands. DNV GL is also widely respected within LNG, and your technical skills are well known. DNV GL has made notable contributions to paving the way for LNG, also here in the US, most recently with the MARAD report on LNG bunkering and the IMO report on feasibility for LNG as fuel in North America. So I know we will be working with DNV GL for years to come," says Bamik. ■

GTT (Gaztransport & Technigaz) is an engineering company specialized in the design of membrane containment systems for the maritime transportation and storage of LNG.

GTT was formed in 1994 by the merger of the two major players in the field of LNG (Liquefied Natural Gas) membrane containment systems: Gaztransport and S.N.Technigaz, resulting in a cumulative experience of more than 60 years in the field of cryogenics and storage of liquefied gases.

GTT's two main areas of expertise are cargo containment systems (CCS) for LNG carriers and land storage of LNG. LNG carriers and tanks designed with GTT containment systems have also been used to carry and store other liquefied gases (LPG, Ethylene, etc.).

GTT licenses its technologies to world leading shipyards and EPCs for the construction of LNG carriers and land storage tanks.

The GTT systems are approved by all the major classification societies and the capacity range for existing vessels is 20.000 to 266.000 m<sup>3</sup> and for installed land storage tanks is 8.000 to 200.000 m<sup>3</sup>.

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**"WORKING CLOSELY WITH DNV GL IS NATURAL FOR US IN GTT: DNV GL SHARES OUR COMMITMENT TO SAFETY AND QUALITY, WHICH ARE INTEGRAL PARTS OF BOTH OUR BRANDS."**

Aziz Bamik,  
General Manager, GTT North America

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# SMALL-SCALE LNG INFRASTRUCTURE DEVELOPMENT

## DNV GL RECOMMENDED PRACTICE FOR DEVELOPMENT AND OPERATION OF LNG BUNKERING FACILITIES

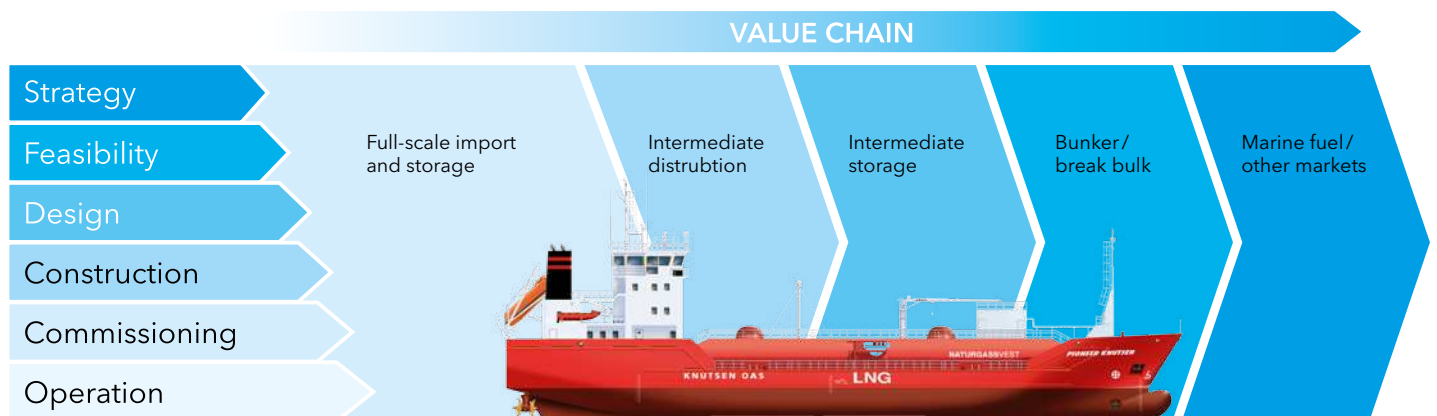


Figure 1 - Small scale LNG: an emerging industry in its infancy

The first shipments of LNG as cargo started with a single ship in the 1950s. Today, the global LNG shipping fleet numbers several hundred carriers, ranging in cargo volume from 1,000 m<sup>3</sup> to the current largest carriers with 266,000 m<sup>3</sup>. This is a well-established industry with pricing mechanisms, established contractual models and, last but not least, proven technology and operations. The industry segment is considered one of the safest in shipping, providing a link between LNG production and liquefaction plants and suitable import terminals on the consumption side, like a virtual LNG pipe. Even if the industry is now experiencing what may be a new era with the appearance of North America as a significant gas producer, the industry as such is mature.

The re-export of small quantities of LNG from full-scale import or export terminals with the further distribution to end consumers such as ships is not currently industrialised. Technically this can already be done, and is carried out for individual operations or projects. Thus, this is far from being a well-established industry, but it is emerging and can be lucrative.

There is one major difference between a small-scale LNG value chain like LNG bunkering and conventional marine bunkering, in that the price of an HFO bunker can be found on the internet for most major ports. Such openness is not present for LNG as a fuel or for LNG in small quantities. The LNG “prices” that can be found in public sources are not the prices a shipping company

would pay for LNG bunkering, but those prices are either at a gas hub or at delivery to an LNG import terminal. They do not include redistribution costs, mark up etc. As a result, the price for a certain amount of LNG delivered to a ship in one port depends heavily on the availability of the transport infrastructure. This is typical for goods that are non-commoditised. As of today, a small-scale LNG infrastructure does not exist in the sense of an electricity grid or a grid for pipeline gas.

LNG infrastructure must tolerate very low temperatures and needs to provide a satisfactory level of safety. Consequently, investments in LNG infrastructure are hefty financial commitments. The time horizon for the amortisation of investments in infrastructure is counted in years, perhaps in decades. Charter parties between a shipowner and a charterer cover a time frame of some months, in the best case a few years. This mismatch between the time horizons has an impact on infrastructure development, which in turn is reflected in the price single projects have to pay.

These factors suggest that a well-established small-scale LNG industry does not yet exist, as illustrated by Figure 1. Today, efforts are being made to develop an understanding of future markets. This understanding is guiding today’s infrastructure development which, in turn, will establish tomorrow’s markets. Only when an open well-functioning small-scale market is developed will prices for LNG as fuel be found on the web in real-time.

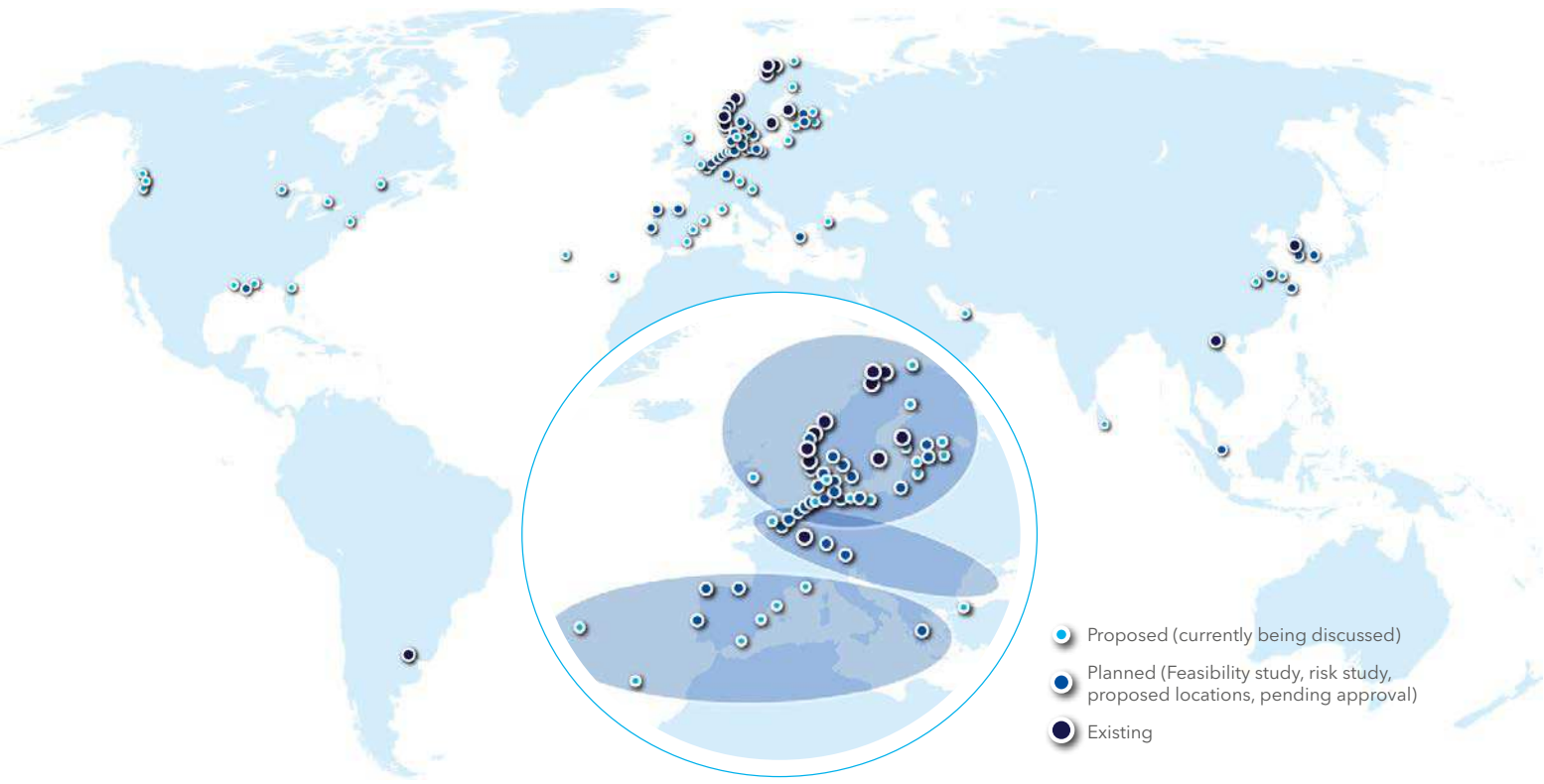


Figure 2 - Global LNG cluster

Figure 3 - Main European regions with respect to LNG

Figure 2 identifies five global areas where LNG is high on the agenda - Canada, the US, Europe, Middle East and the Far East. Canada and the US seem to be developing into major LNG exporters and while they also see increasing domestic demand for LNG as fuel, Europe will soon see a significant uptake of LNG as fuel. The Middle East is both a producer of LNG and may soon also serve as supplier for LNG fuel, while the Far East is an established large-volume LNG consumer and may soon also see growth in the uptake of LNG as fuel.

Looking at Europe, three main geographic regions can be identified, as shown in Figure 3. The northern region is the European ECA. In the central region, natural gas (NG) is traditionally supplied by pipelines to private households and industrial users. The southern-most area is the Mediterranean Sea and the eastern part of the North Atlantic.

From January 01 2015, the sulphur content in fuel of ships will be limited to 0.1%, in the northern area. This is the main driver for considering LNG as a fuel here. The central region is seeing a lot of activities related to establishing a common legal framework and harmonisation of risk assessments for LNG storage. In Central

Europe, reduction of NO<sub>x</sub> in the exhaust gas from inland waterway vessels is one main driver for reviewing options to use LNG as fuel. Another driver is bottlenecks in the European gas grid. In Southwest Europe, LNG is an established energy carrier and is available at multiple import terminals. The hinterland is used to distribute LNG by tanker trucks. The main driver for Southern Europe to investigate LNG bunkering is their potential position to sell services to vessels that pass the Mediterranean on their Europe-Asia trade routes. There are typically six cornerstones for all initiatives that aim at introducing a small-scale LNG value chain, as shown in Figure 4.

To help facilitate the development of small-scale LNG infrastructure, DNV GL recently developed a Recommended Practice (RP) for LNG bunkering. This helps fill the regulatory gap between legislation/standards and local operational LNG bunkering procedures which may even not exist yet. Details of the RP are outlined below.

Reliable and safe concepts, established legislation, the regulatory framework and necessary competences, knowledge and skills are the main requirements to develop a LNG bunkering infrastructure - provided LNG is available, access to capital is given and the public is informed.

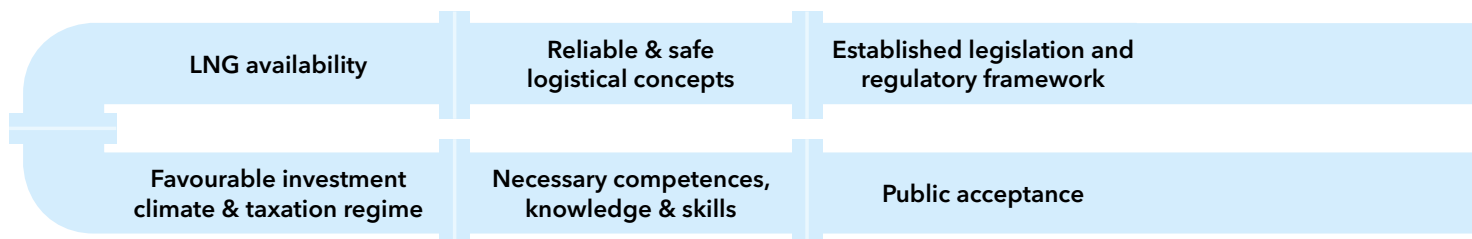


Figure 4 - Cornerstones for establishing small-scale LNG infrastructure



A bunker facility in this context is not only a supplying tank and a physical connection between supplying tank and the consumer. Bunker facilities in this context are all those installations that are needed in a port to provide bunkering. This may include every component of the value chain, as shown in the “System Boundaries” box in Figure 5.

The main elements to ensure the safety of bunker installations are:

- Planning, design and operation
- Safety management
- Risk assessments

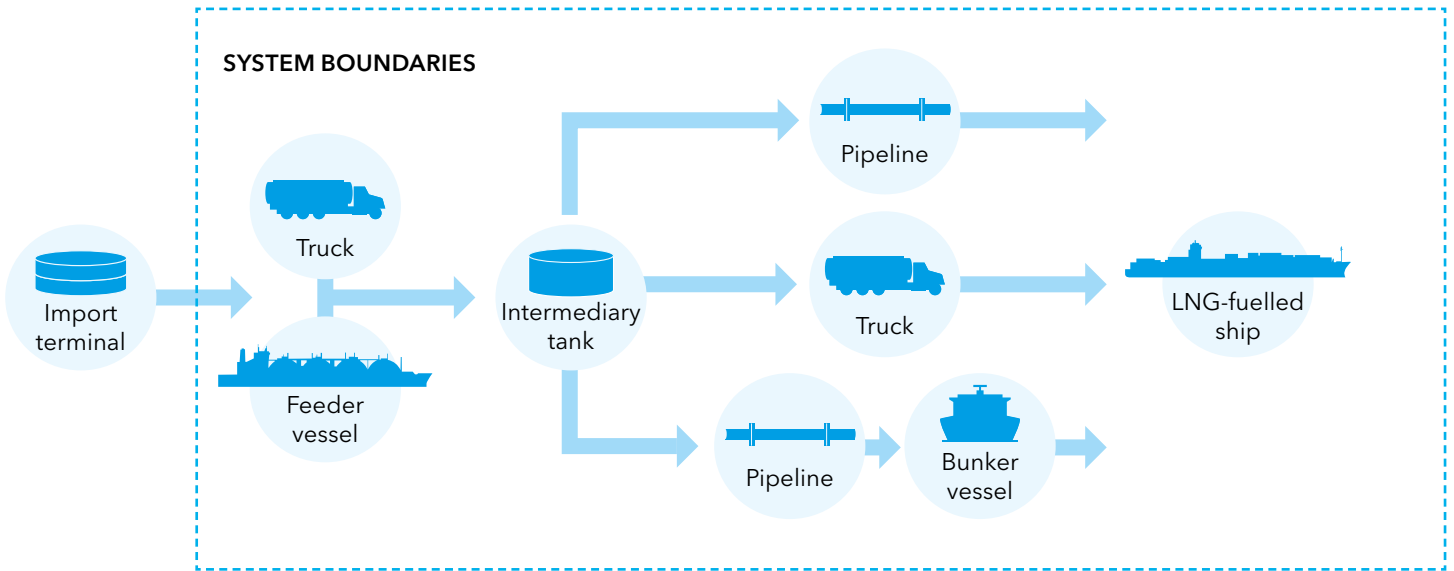


Figure 5 - local small scale LNG value chain

		Strategy	Feasibility	Design	Commissioning	Operation
Planning, design and operation of LNG bunkering facilities	Design or hardware (1st LOD)			(S)		
	Instrumentation and control (1st LOD)			(S)		
	Design of operational procedures (1st LOD)			(S)		
	Design of hardware and systems (2nd LOD)			(S)		
	Emergency response plan (3rd LOD)			(A) (S) (V)	(A) (S) (V)	(A) (S) (V)
	Use of operational procedures (1st LOD)					(S) (V)
Safety management	Establish safety philosophy and targets	(A) (S)				
	Agree upon organization		(A) (S)	(A) (S) (V)		
	Secure proper training of personnel			(S)	(S) (V)	(S) (V)
	Implement organisation and procedures				(A) (S) (V)	(S) (V)
Risk assessment	High level risk assessment for site location	(A) (S)	(A) (S)			
	Use the risk assessment as input to design			(S)		
	Determine the safety zone			(A) (S)		
	Determine the security zone			(A) (S)		
	Demonstrate acceptance of the facility			(A) (S)	(A) (S)	
	Perform a safe job analysis, new ships, etc.			(S)		(S) (V)

(A) Authority (S) Supplier (V) Vessel, who is receiving

Figure 6 - Overall process for developing LNG bunker infrastructure (source: DNV GL Recommended Practice for Developing and Operating LNG bunkering facilities)

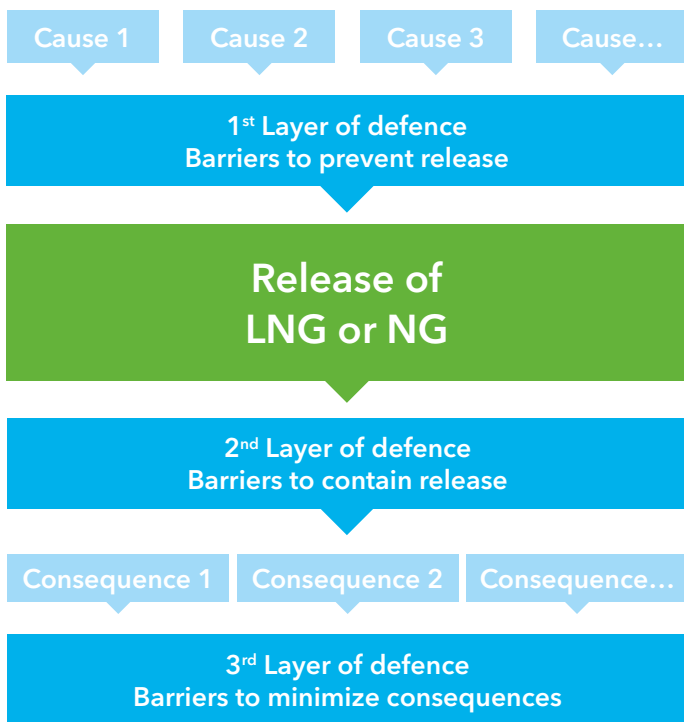


Figure 7 - Barriers, layers of defence (source: DNV GL Recommended Practice for Developing and Operating LNG bunkering facilities)

Figure 6 shows an overall process which ensures that an LNG bunker facility can be built safely. The process integrates the three main elements above to ensure the safety of a bunker installation.

The process identifies key activities within the main elements. The activities are linked to stages in the process, such as strategy, feasibility, etc. These are linked to key actors and they are linked to layers of defence (LOD). The key actors are the approving authority, bunker installation operator and receiver of the bunker. The layers of defence are illustrated in Figure 7.

As this process is independent of the actual regulatory regime, it is a robust process that can be used in any of the regions identified in Figures 2 and 3.

Measures that prevent the release of LNG or natural gas are considered as the first layer of defence. The second layer of defence is constituted by measures that ensure the containment of natural gas or LNG in the case of a leakage. Finally, the third layer of defence is emergency response. Figure 6 identifies the layers and links them to the actors and phases of development

Finally, the risks need to be assessed for any bunkering installation. Figure 8 shows how a risk assessment links up to the stages of the development of a bunker installation. The activities in the early phases are essential. They set the boundaries for risk acceptance, define the scope of the assessment (QRA) and lead either into a scenario-based assessment (grey) or to a full quantitative risk assessment (green). Whether to go “grey” or “green” is triggered by the complexity of the bunker installation. If the intended bunker installation and the planned activities are standard bunker scenarios (truck-to-ship, land-to-ship, ship-to-ship), and if no loading on/off operations are executed, and if no passengers are on board during bunkering, and if no other simultaneous operations are performed, a deterministic assessment based on a design scenario is acceptable. In all other cases a full QRA is required.

In summary, by having understood the implications of the six cornerstones (Figure 4) and having defined the system boundaries of his or her value chain (Figure 5), an LNG bunker installation developer can apply a process (Figure 6) that is applicable to any region on the globe and will thus define a robust set of barriers (Figure 7), the effectiveness of which can be assessed with a well-defined procedure (Figure 8). As a result, the developer will move gradually from the top to the bottom (Figure 1).

Further details and more guidance can be found in the DNV GL Recommended Practice for Development and Operation of LNG bunkering facilities, DNVGL-RP-0006:2014-01. ■

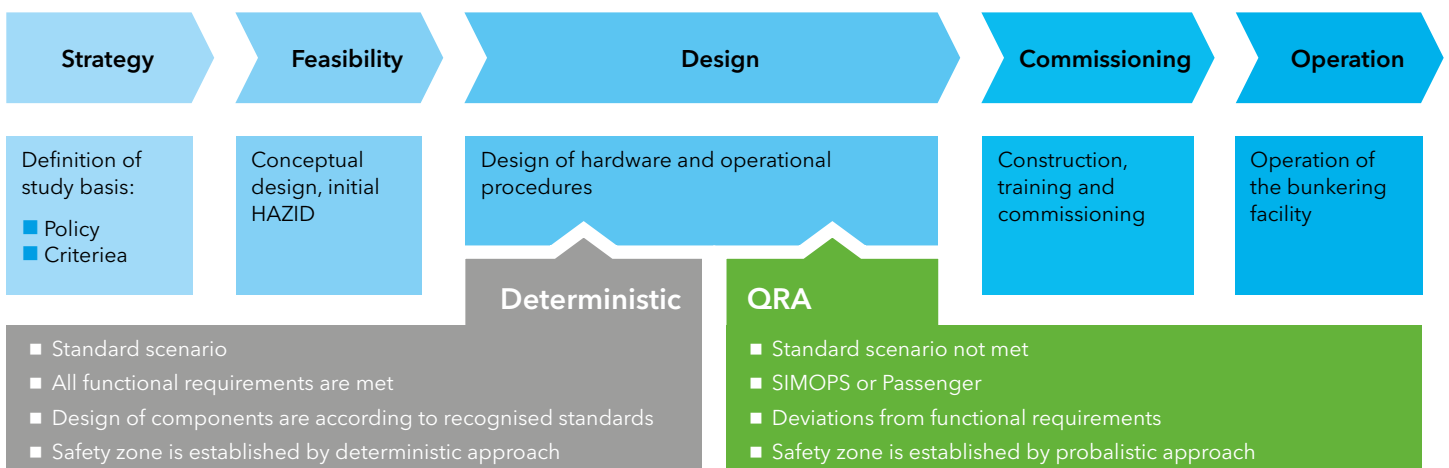


Figure 8 - Risk assessment in the context of LNG bunker installations (source: DNV GL Recommended Practice for Developing and Operating LNG bunkering facilities)

# VESSELS ON ORDER

**76 LNG-fuelled vessels currently on order\***  
as of May 2015

YEAR	TYPE OF VESSEL	OWNER	CLASS	YEAR	TYPE OF VESSEL	OWNER	CLASS
2015	Ro-Ro	Norlines	DNV GL	2016	Containership	GNS Shipping	
2015	Car/passenger ferry	Society of Quebec ferries		2016	Containership	GNS Shipping	
2015	Car/passenger ferry	Society of Quebec ferries		2016	Ro-Ro	SeaRoad Holdings	DNV GL
2015	Car/passenger ferry	Society of Quebec ferries		2016	Car/passenger ferry	BC Ferries	
2015	PSV	Harvey Gulf Int.		2016	Car/passenger ferry	BC Ferries	
2015**	Oil/chemical tanker	Bergen Tankers		2016	Gas carrier	Ocean Yield	DNV GL
2015	Car/passenger ferry	AG Ems	DNV GL	2016	Gas carrier	Ocean Yield	DNV GL
2015**	Car/passenger ferry	AG Ems	DNV GL	2016	Gas carrier	Ocean Yield	DNV GL
2015	Tug	CNOOC		2016	Car/passenger ferry	Seaspan Ferries	
2015	Tug	CNOOC		2016	Car/passenger ferry	Seaspan Ferries	
2015	Tug	Drydocks World		2016	Gas carrier	Navigator Gas	
2015	PSV	Harvey Gulf Int.		2016	Gas carrier	Navigator Gas	
2015	PSV	Harvey Gulf Int.		2016	Gas carrier	Navigator Gas	
2015	PSV	Harvey Gulf Int.		2016	Gas carrier	Navigator Gas	
2015	Tug	NYK		2016**	RoPax	Baleària	
2015	Gas carrier	Chemgas Shipping		2016	Dredger	DEME	
2015	Gas carrier	Evergas		2016	Dredger	DEME	
2015	Gas carrier	Evergas		2016	Cable layer	DEME Tideway	DNV GL
2015	Gas carrier	Evergas		2017	Tug	Østensjø Rederi	
2015	Bulk ship	Erik Thun		2017	Tug	Østensjø Rederi	
2015	Containership	Brodosplit	DNV GL	2017	Tug	Østensjø Rederi	
2015	Containership	Brodosplit	DNV GL	2017	RoPax	Rederi AB Gotland	DNV GL
2015	PSV	Siem Offshore	DNV GL	2017	Oil/chemical tanker	Groupe Desgagnés	
2015	PSV	Siem Offshore	DNV GL	2017	Oil/chemical tanker	Groupe Desgagnés	
2015**	Oil/chemical tanker	Furetank Rederi		2017	Containership	GNS Shipping	
2015	Containership	TOTE Shipholdings		2017	Containership	GNS Shipping	
2016	Containership	TOTE Shipholdings		2017	Car/passenger ferry	BC Ferries	
2016	PSV	Harvey Gulf Int.		2017	Oil/chemical tanker	Terntank	
2016	Icebreaker	Finnish Transport Agency		2017	Container ship	Crowley Maritime	DNV GL
2016	PSV	Siem Offshore	DNV GL	2017	Container ship	Crowley Maritime	DNV GL
2016	PSV	Siem Offshore	DNV GL	2017	Car/passenger ferry	Tallink	
2016	Gas carrier	Chemgas Shipping		2018	Containership	Matson Navigation	DNV GL
2016	Oil/chemical tanker	Terntank		2018	Containership	Matson Navigation	DNV GL
2016	Oil/chemical tanker	Terntank		2018	Containership	Containerships	
2016	Oil/chemical tanker	Terntank		2018	Containership	Containerships	
2016**	Ro-Ro	TOTE Shipholdings					
2016**	Ro-Ro	TOTE Shipholdings					
2016	Car carrier	UECC					
2016	Car carrier	UECC					
2016	Car/passenger ferry	Boreal	DNV GL				
2016	Car/passenger ferry	Boreal	DNV GL				

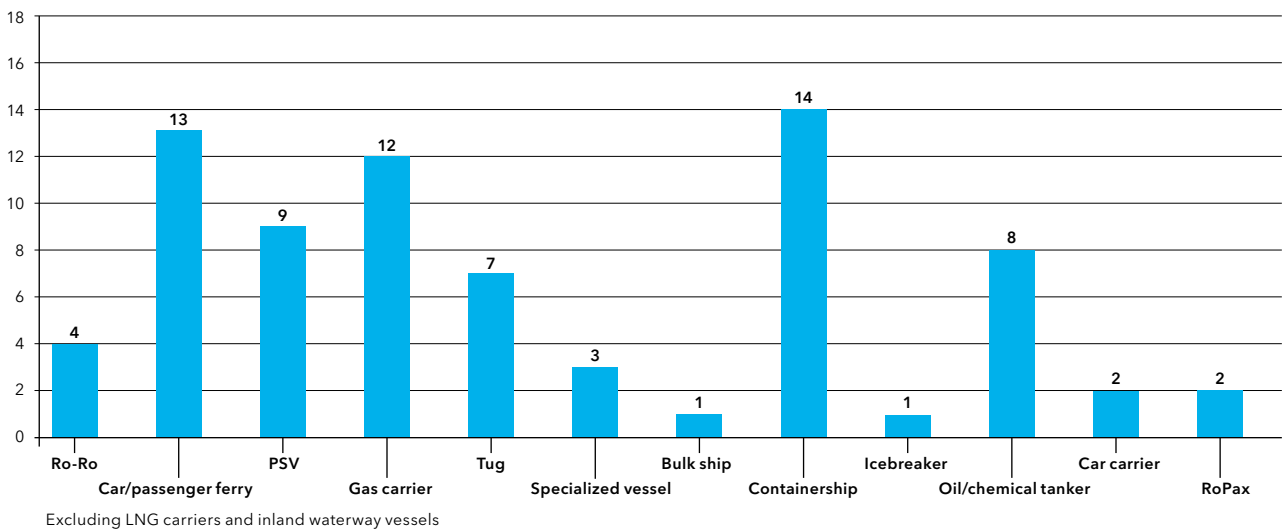
\*LNG carriers and inland waterway vessels are not included

\*\*Conversion project

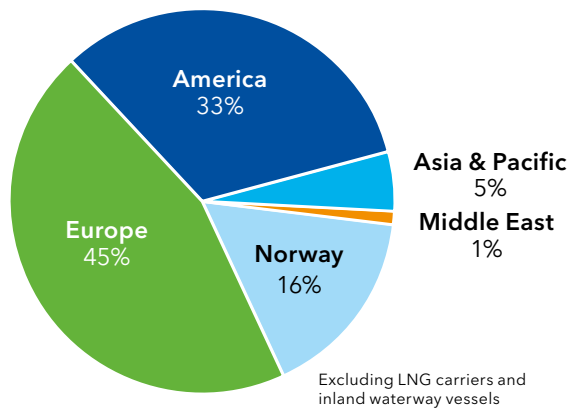




Number of vessels on order per vessel segment

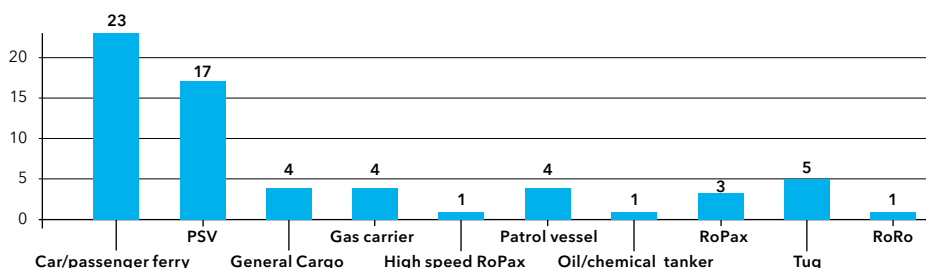


Confirmed orderbook - global development

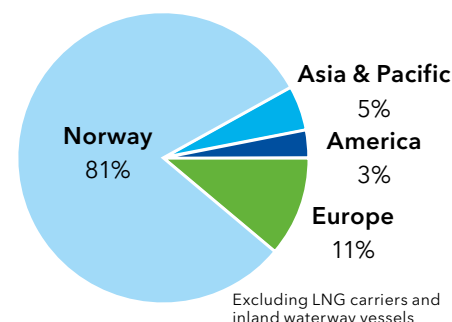


# VESSELS IN OPERATION

Number of vessels in operation per vessel segment



Vessels in operation - global development



**63 LNG-fuelled vessels worldwide\***  
currently in operation as of May 2015

YEAR	TYPE OF VESSEL	OWNER	CLASS
2000	Car/passenger ferry	Fjord1	DNV GL
2003	PSV	Simon Møkster	DNV GL
2003	PSV	Eidesvik Shipping	DNV GL
2006	Car/passenger ferry	Fjord1	DNV GL
2007	Car/passenger ferry	Fjord1	DNV GL
2007	Car/passenger ferry	Fjord1	DNV GL
2007	Car/passenger ferry	Fjord1	DNV GL
2008	PSV	Eidesvik Shipping	DNV GL
2009	PSV	Eidesvik Shipping	DNV GL
2009	Car/passenger ferry	Tide Sjø	DNV GL
2009	Car/passenger ferry	Tide Sjø	DNV GL
2009	Car/passenger ferry	Tide Sjø	DNV GL
2009	Patrol vessel	Remøy Management	DNV GL
2009	Car/passenger ferry	Fjord1	DNV GL
2010	Patrol vessel	Remøy Management	DNV GL
2010	Car/passenger ferry	Fjord1	DNV GL
2010	Patrol vessel	Remøy Management	DNV GL
2010	Car/passenger ferry	Fjord1	DNV GL
2010	Car/passenger ferry	Fjord1	DNV GL
2010	Car/passenger ferry	Fosen Namsos Sjø	DNV GL
2011	PSV	DOF	DNV GL
2011**	Oil/chemical tanker	Tarbit Shipping	DNV GL
2011	Car/passenger ferry	Fjord1	DNV GL
2011	PSV	Solstad Rederi	DNV GL
2012**	Car/passenger ferry	Fjord1	DNV GL
2012	PSV	Eidesvik Shipping	DNV GL
2012	PSV	Olympic Shipping	DNV GL
2012	PSV	Island Offshore	DNV GL
2012	General Cargo	Nordnorsk Shipping	DNV GL
2012	PSV	Eidesvik Shipping	DNV GL
2012	PSV	Island Offshore	DNV GL

YEAR	TYPE OF VESSEL	OWNER	CLASS
2012	Car/passenger ferry	Torghatten Nord	DNV GL
2012	Car/passenger ferry	Torghatten Nord	DNV GL
2012	Car/passenger ferry	Torghatten Nord	DNV GL
2013	PSV	REM	DNV GL
2013	RoPax	Viking Line	DNV GL
2013	Car/passenger ferry	Torghatten Nord	DNV GL
2013	Tug	Incheon Port Authority	DNV GL
2013	General Cargo	Eidsvaag	DNV GL
2013	RoPax	Fjordline	DNV GL
2013	High speed RoPax	Buquebus	DNV GL
2013	Tug	CNOOC	DNV GL
2013	Tug	CNOOC	DNV GL
2013	Car/passenger ferry	Norled	DNV GL
2014	Car/passenger ferry	Norled	DNV GL
2014	Tug	Buksér & Berging	DNV GL
2014	RoPax	Fjordline	DNV GL
2014	Patrol vessel	Finnish Border Guard	DNV GL
2014	Tug	Buksér & Berging	DNV GL
2014	Gas carrier	Veder Rederijzaken	DNV GL
2014	Gas carrier	Veder Rederijzaken	DNV GL
2014	Gas carrier	SABIC	DNV GL
2014	Gas carrier	SABIC	DNV GL
2014	PSV	Remøy Shipping	DNV GL
2014	General Cargo	Egil Ulvan Rederi	DNV GL
2014	General Cargo	Egil Ulvan Rederi	DNV GL
2014	PSV	Siem Offshore	DNV GL
2015	PSV	Harvey Gulf Int.	DNV GL
2015	Ro-Ro	Norlines	DNV GL
2015	Car/passenger ferry	Samsøe municipality	DNV GL
2015	PSV	Simon Møkster Shipping	DNV GL
2015	PSV	Siem Offshore	DNV GL

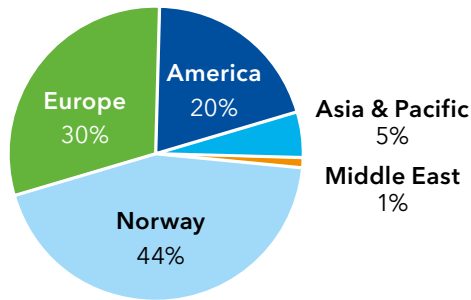
\*LNG carriers and inland waterway vessels are not included

\*\*Conversion project

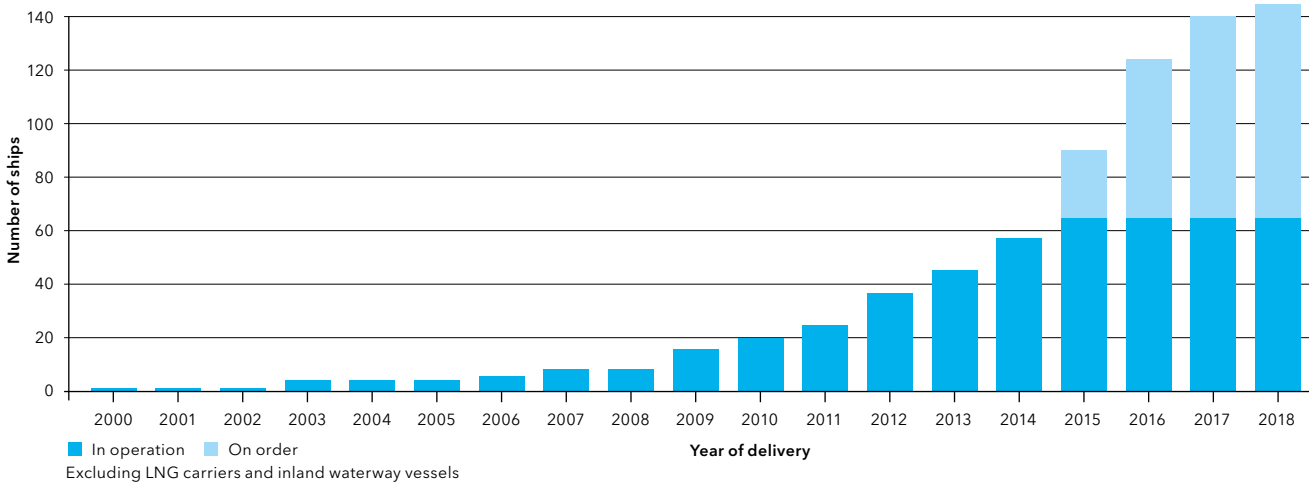
# SUMMARY

## ALL CONFIRMED PROJECTS

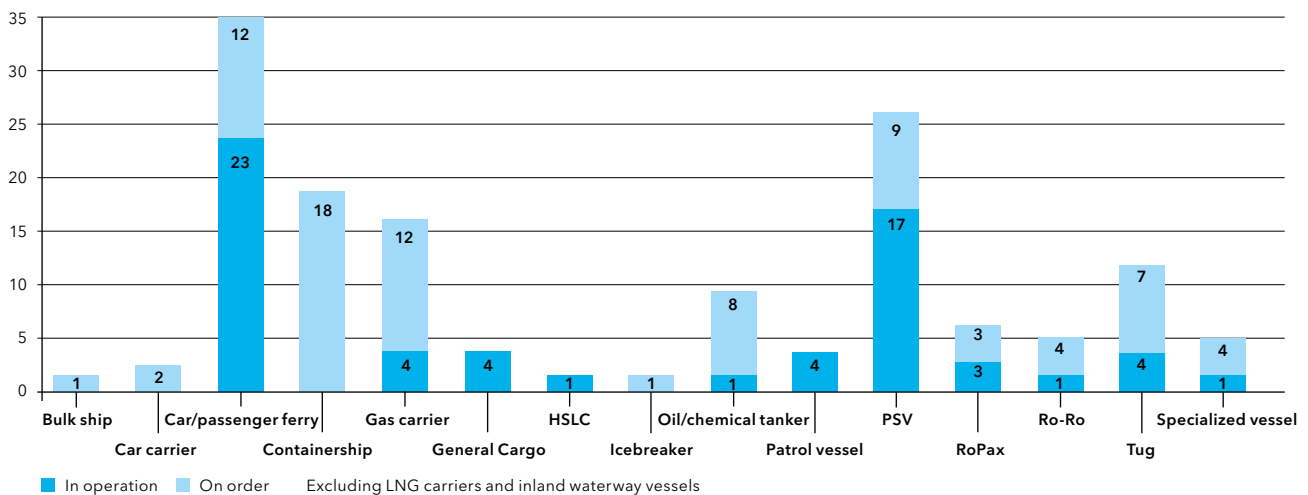
Global development - all confirmed projects (in operation & on order)



### Development of LNG-fuelled fleet



### LNG-fuelled fleet per segment







## MARITIME ACADEMY

# GAS AS SHIP FUEL

### Course objective

The course will give the participants an overview about the current developments in the field of gas as ship fuel.

### Focus points

- Properties of liquefied gases
- Applicable rules and regulations
- Tank and pipe systems and ventilation
- Safety-related aspects of a gas-fuelled propulsion system
- Ship type considerations

[www.dnvgl.com/maritime-academy](http://www.dnvgl.com/maritime-academy)

### Content

Increasing limitations on the use of conventional fuel and rising fuel prices demand new solutions for marine transport: Gas as fuel may be an alternative for some shipping companies.

This course provides an overview of gas as ship fuel with special focus on the components of a gas-fuelled propulsion system.

Drawing on different examples from research and industry the differences between gas-fuelled and other conventionally propelled vessels (HFO/MGO) are examined in an interactive workshop approach. The economic and environmental advantages of this fuel will be highlighted as well as the current status of rule development.

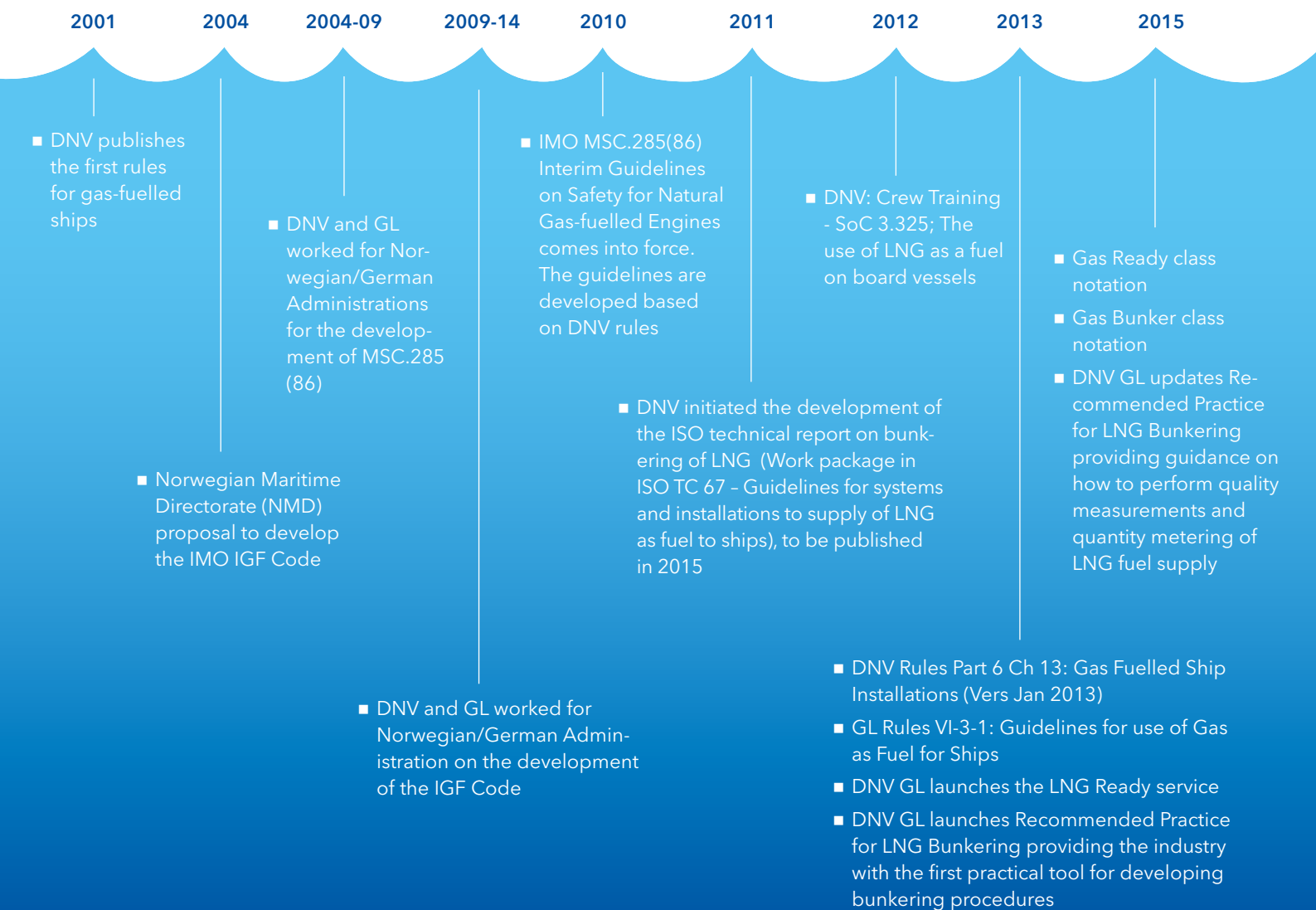
**Entry requirements** Basic maritime knowledge

**Duration** 1 day

**Who should attend** Shipping Companies: Management: Tech. Director (CTO), Managing Director (CEO); Inspection: Superintendent, Fleet Manager, Chief Operating Officer, CSO; Quality / ISM: Quality Manager, Designated Person; Commercial Dept.: Commercial Manager, Marketing and Sales Manager  
Yard: Management: Tech. Director (CTO), Managing Director (CEO), Design: Design Manager, Engineers (Naval Architects)  
Supplier (M&C): Management: Tech. Director (CTO), Engineers: Engineers  
Industry and Service Provider: Management: Managing Director (CEO), Plant Manager, Production Manager, Design Manager, Head of Department (HoD)

# DNV GL'S INVOLVEMENT IN LNG AS SHIP FUEL

Since the project to build GLUTRA was launched in the late 1990s, DNV GL has worked on LNG as ship fuel.



# DNV GL GAS READY NOTATION

## PREPARED FOR TOMORROW'S FUEL TODAY



With the IGF Code practically finalized, the introduction of sulphur limits and burgeoning infrastructure and production capability, LNG as a ship fuel is spreading rapidly through the maritime world. DNV GL's new GAS READY notation gives owners, who at the new building stage want to prepare their vessel for a potential conversion to LNG operation after delivery, a useful framework for contracting. It provides a clear picture of the level of LNG-fuelled preparedness of their vessel, as well as guidance on the scope of the contemplated work to all involved parties.

"We developed the new GAS READY notation based on the experience we have gained from our LNG Ready service as well as the 50 LNG-fuelled vessels we already have in class with our GAS FUELLED notation", says Torill Grimstad Osberg, DNV GL Head of Section for LNG Cargo Handling & Piping systems. "This new notation enables owners to ensure that a future LNG-fuelled version of the vessel complies with the relevant safety and opera-

tional requirements, while also being very useful in helping owners specify and quantify the level of investment they are making at the newbuilding stage."

The basic notation with nominators D and MEc - GAS READY (D, MEc) - verifies that the vessel is in compliance with the gas fuelled rules in terms of its overall design for future LNG fuel operations and that the main engine can be converted or operate on gas fuel. The owner can also choose to add extra optional levels to the newbuilding under the notation. These cover selections such as structural reinforcements and the choice of correct materials to support future LNG tanks (S), preparations for future gas fuel systems (P), certification and installation of LNG fuel tanks (T), and the installation of machinery, which can be converted gas fuel, or which is already capable of burning gas fuel - putting the vessel further along the LNG track and thereby speeding and simplifying a later conversion.

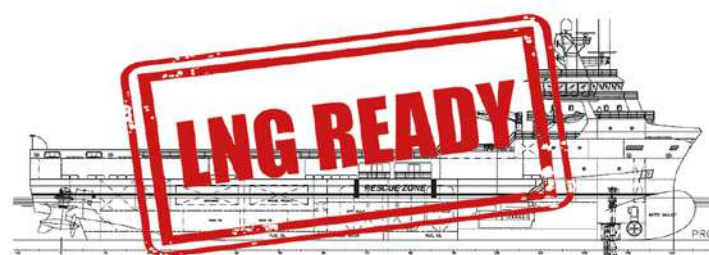


In 2014 the industry hit a significant milestone with over 120 LNG-fuelled ships in operation or on order worldwide (excluding LNG carriers). The vast majority of these ships already operate or will be built to DNV GL class, a result of the trust the industry places in DNV GL due to our long involvement in this technology and our continually evolving technical expertise.

“DNV GL’s unique LNG Ready service has been in place for over two years and has proven its value in assisting many shipowners, operators, yards and designers in identifying the most attractive compliance option for their ships. Through a detailed technical and financial feasibility study, the LNG Ready service investigates all the potential options for compliance and fuel cost reduction, uncovers any technical showstoppers, as well as calculating the financial attractiveness of each option”, says Dr Gerd-Michael Wuersig, DNV GL’s Segment Director for LNG-fuelled ships. “The new class notation GAS READY provides a formalised framework for documenting the compliance option and preparation level chosen, and thereby is a natural extension of the LNG Ready service.”

Over the past decades DNV GL has undertaken extensive research and has implemented many projects world-wide with industry partners covering the regulatory framework, infrastructure and

bunkering for LNG fuelled vessels. At DNV GL we have been helping companies and authorities to utilize LNG safely as a source of clean, reliable energy in the maritime industry through a complete set of services for nearly 20 years. With our breadth of services and global outreach delivered through our regional gas and LNG ready teams we have the capability to serve our customers wherever they might be. ■



#### Gas Ready - basic notation and extended options (as at 2.12.2014):

GAS READY	D	The design for the ship with LNG as fuel is found to be in compliance with the GAS FUELLED notation rules applicable for the new-building, ref. Pt.1 Ch.1 Sec.2 A300.
	S	Structural reinforcements to support the fuel containment system (LNG fuel tank(s)) are installed, and materials to support the relevant temperatures are used
	T	Fuel containment system (LNG fuel tank(s)) is installed
	P	The ship is prepared for future gas fuel system installations: Pipe routing, structural arrangements for bunkering station, gas valve unit space, fuel preparation space if relevant (optional)
	MEc	Main engine(s) installed can be converted to dual fuel
	MEi	Main engine(s) installed can be operated on gas fuel
	AEc	Auxiliary engines installed can be converted to dual fuel
	AEi	Auxiliary engines installed can be operated on gas fuel
	B	Boilers installed are capable of burning gas fuel
	Misc	Additional systems and equipment are installed on board from new building stage.

Table 1: DNV GL’s new GAS READY notation provides a clear picture of the level of LNG-fuelled preparedness of a vessel.

# LNG FUEL SERVICE PORTFOLIO

The topic of LNG as a marine fuel has strong roots in DNV GL and our newly merged company is the dominant ship classification society for LNG-fuelled ships. Some 50% of the LNG-fuelled orderbook is DNV GL classed vessels. DNV GL has, over the past 15 years, contributed significantly to the evolution of LNG as a ship fuel, both through the development of class rules for

gas-fuelled vessels and by advising authorities, gas majors, ship operators, tank manufacturers, engine makers, ports and yards with technical, financial and market assessments.

We have also been working closely with IMO and now also the Society for Gas as a Marine Fuel (SGMF) to promote the safe

DNV GL SERVICES IN THE LNG FUEL MARKET							
	Ship operator/owners	Port operator/owners	Gas providers	Designers, Yards	Authorities	Logistics provider	Engine/system provider
Qualitative and quantitative risk assessments for the use of LNG as fuel	✓	✓	✓	✓	✓	✓	✓
Barrier management	✓	✓	✓	✓	✓	✓	✓
Assessment of regulations, rules and standards affecting the use of LNG as fuel	✓	✓	✓	✓	✓		✓
Evaluation of LNG containment and distribution systems				✓			✓
Evaluation of LNG tank impact risk of dropped objects and collisions	✓			✓			
'LNG Ready' service, i.e. fuel decision support, concept review, approval in principle	✓		✓	✓			
DNV GL class serves the LNG industry by offering: <ul style="list-style-type: none"> <li>• Design review</li> <li>• Approval in Principle</li> <li>• Certification of materials and components</li> <li>• Plan approval</li> <li>• New build surveys</li> <li>• Fleet in Service surveys</li> </ul>	✓			✓	✓		✓
Analysis of market drivers and hindrances, regulations, emission inventories	✓	✓	✓		✓		
Forecast studies of LNG marine fuel uptake		✓	✓		✓	✓	✓
Financial implications and business landscape of choosing LNG as fuel	✓	✓	✓			✓	
LNG fuel supply chain and distribution assessments		✓	✓			✓	
Development of site specific LNG bunkering policies, practice procedures and recommendations	✓	✓			✓		
TQ of LNG fuel distribution systems and on board technology							✓
Development of functional requirements for components and systems		✓					✓
Design of LNG fuel awareness programs and campaigns to industry	✓	✓			✓		
Evaluation of necessary emergency preparedness in LNG bunkering ports		✓					
Initiatives for making shipowners and operators aware of the LNG fuel market dynamics (Pre-Class uptake services)	✓						



and efficient use of LNG as ship fuel. This long involvement has enabled us to develop a deep and well proven advisory service portfolio, as well as a preeminent role in classification of LNG-fuelled ships. Our success is based on technical and maritime understanding connected to risk-based approaches gained through our decades long engagement with the oil and gas industry. LNG fuel is ready to breakthrough, and we are here for the long run - ready to help our clients to succeed.

Some typical questions we answer in our projects include:

- Should I as a shipowner choose LNG fuel, or am I better off continuing using conventional fuels?
- How much money, if any, will I as an owner save by choosing LNG as fuel?
- Has a particular LNG-fuelled ship design been optimised for a given trade pattern and will it meet all safety standards?
- Where in my port should a LNG bunker station be located, and for which capacity and to which safety standard should it be built?
- What are the major safety risks with LNG bunkering, and which precautions should we take in our port and on board the vessel?
- How should we separate vessel traffic in my port after LNG-fuelled ships start bunkering here?
- I am developing a new LNG containment system; how can it be applied as a LNG fuel tank in the shipping industry, and how can I avoid the challenge of sloshing?

- How many LNG-fuelled ships will be sailing by 2020, what will the LNG consumption be, and what is the benefit to air emissions?
- How many, how large and what type of LNG bunker ships are required in order to supply the expected LNG fuel demand?
- What LNG bunkering policies should we develop in our jurisdiction, and what kind of bunkering practices should we implement in our major ports?
- Where should we establish LNG bunkering infrastructure to create a new revenue stream for our downstream gas business?
- How do we analyse the quality and quantity of the LNG sold as fuel?

These services are offered from our regional hubs in Oslo, Hamburg, Antwerp, Rotterdam, Piraeus, Houston, Dubai, Singapore and Shanghai.

In addition to the advisory services above, our ship classification services in support of the LNG-fuelled business have been strengthened. This portfolio includes the Gas Fuelled ship's Code, IMO Interim guidelines MSC .285(86) adopted 2009 and the DNV GL Class regulations for LNG-fuelled vessels. The figure to the left is a simplified illustration of the services we offer in various markets. Our reference list for advisory projects for small scale and LNG bunker projects contains more than 70 projects. In addition we have more than 70 LNG-fuelled ships in class.



# HIGHLIGHT PROJECTS LNG AS FUEL HISTORY



## Fjord1 (Ferry)

MF 'Glutra' is the world's first gas ferry to operate on LNG. The vessel is DNV GL class and marked the first development of rules for gas-fuelled vessels. The company started operating 'Glutra' in Møre og Romsdal County in 2000. The ferry route serving the coastal trunk road in Rogaland and Hordaland Counties has since 2007 been served by five such ferries from Fjord1. The magazine "Skipsrevyen" awarded the prize "Ship of the Year 2000" to Glutra's owner and operator Møre og Romsdals Fylkesbåtar and to the Langstein Yard of Tomrefjord, Norway for their newbuilding of M/F Glutra.



## Eidesvik Shipping AS (PSV/OSV)

Designed by Wärtsilä ship Design, classed by DNV GL and built by Kleven Verft AS in Norway, the 'Viking Energy' is the world's first LNG-powered supply vessel. The vessel was delivered in April 2003, and is chartered to Statoil for delivering supplies to oil and gas platforms in the North Sea. The vessel has dual-fuel engines installed and can operate both on LNG and liquid fuel.



## Simon Mækster Shipping AS (PSV/OSV)

"Stril Pioner" together with 'Viking Energy' are the first gas-fuelled supply (PSV) vessels in North Sea operation and has been operating for Statoil since delivery, July 2003. The vessel has dual-fuel engines installed and can operate both on LNG and liquid fuel.



## Crowley (ConRo vessels)

Crowley Maritime has ordered two LNG-fuelled ConRo vessels with DNV GL class at US Shipyard. These vessels are Jones Act and are intended for the USA - Puerto Rico trade



## United Arab Shipping Company (Container vessels)

United Arab Shipping Company (UASC) has ordered 17 LNG Ready container vessels - eleven 15,000 TEU and six 18,000 TEU containerships. Barzan, the first in the series of 18,800 TEU vessels, was recently named at Hyundai Samho Heavy Industries (HSHI) in Mokpo, South Korea. DNV GL has worked closely with UASC and the yards in order to make the first ultra large LNG Ready container vessels a reality. Barzan, her five sister ships and the eleven 15,000 TEU vessels of UASC's newest eco-ship generation, will be given the DNV GL's new GAS READY notation.



## Buquebus (High Speed Craft)

'Francisco', classed in DNV GL, entered service with Buquebus in South America in 2013. The vessel operates between Buenos Aires and Montevideo at 50 knots fully loaded (1,000 passengers and 150 cars). It is the first vessel to have been built under the HSC (High Speed Craft) Code with power by gas turbines using natural gas as the primary fuel.

# IN THE



### Matson (Container vessels)

Matson has signed a contract with a US shipyard for the construction of 2 vessels 3,600 TEU each equipped with dual-fuel engines. These vessels are Jones Act and are intended for trade between the US West Coast and Hawaii.



### Fjord Line (Cruise ferry)

MS Stavangerfjord (2013) and MS Bergenfjord (2014), both classed to DNV GL, are cruise ferries with a capacity of 1,500 people and 600 cars. Both vessels operate between Norway and Denmark and perform LNG bunkering operations in both ends.



### Tarbit Shipping AB (Tanker)

The 25,000 dwt product tanker Bit Viking was the first vessel ever to undergo a conversion from Heavy Fuel Oil (HFO) to Liquefied Natural Gas (LNG) operation. The vessel is DNV GL classed, has Wärtsilä engines two 500 m<sup>3</sup> LNG fuel tanks and is most environmentally friendly product tanker in the world.



### AGA (LNG bunker vessel)

Seagas, the first LNG bunker vessel in operation, is classed by DNV GL and supplies LNG to M/S Viking Grace, while she is berthing at Stockholm. Fiskerstrand Verft AS converted the former car ferry M/F 'Fjalir' (built in 1974) into an LNG bunkering vessel. The conversion was completed in March 2013 and the vessel, was named LNG/C 'Seagas',.



### SeaRoad (RoRo vessels)

SeaRoad's order for a new LNG-powered RoRo ferry under DNV GL class marks the first-ever order placed from Australia. This vessel will be used on the Melbourne - Devonport (Tasmania) route and is the world's first RoRo ferry designed to carry reefer containers and hazardous cargo side-by-side. The LNG bunkering process for this vessel will include mobile tanks which will be loaded upon arrival in port, and then secured in place aboard the ship as part of the fixed fuel supply system for the main engines. Delivery is expected in Q3 2016.



### EMS AG (Ferries)

The newbuild MS Helgoland and the retrofitted ferry MS Ostfriesland both with LNG powered main drive and auxiliary systems operate in German coastal waters since summer 2015. DNV GL has been working with the owner and the shipyards to realize these green shipping concepts every step of the way.

SAFER, SMARTER, GREENER



[www.dnvgl.com/LNG](http://www.dnvgl.com/LNG)

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**About DNV GL**

Driven by our purpose of safeguarding life, property and the environment, DNV GL enables organizations to advance the safety and sustainability of their business. Operating in more than 100 countries, our 16,000 professionals are dedicated to helping our customers in the maritime, oil & gas, energy and other industries to make the world safer, smarter and greener.

DNV GL is the world's leading classification society and a recognized advisor for the maritime industry. We enhance safety, quality, energy efficiency and environmental performance of the global shipping industry - across all vessel types and offshore structures. We invest heavily in research and development to find solutions, together with the industry, that address strategic, operational or regulatory challenges.