DNV·GL

LNG AS SHIP FUEL

No 01 2014

THE FUTURE – TODAY

LNG READY SERVICE

ENGINES FOR GAS-FUELLED SHIPS

RECOMMENDED PRACTICE ON BUNKERING

GLOBAL LNG SOLUTIONS

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EDITORIAL

In 2000 the first LNG-fuelled ferry based on DNV GL standards was launched. This ferry has been operating safely and successfully ever since.

Over the years that have followed, shipping has seen bunker prices rise sharply and environmental regulations tighten, while in the LNG sector there has been a surge in production and deployment of infrastructure. Combined, these trends have set the stage for LNG to emerge as a viable fuel choice on a much larger scale.

In 2014 the industry hit a significant milestone with over 120 LNG-fuelled ships in operation or on order worldwide. They range from passenger ferries, Coast Guard ships, containerships and Con-Ro vessels to tankers and platform supply vessels. The vast majority of these ships is in operation or will be built to DNV GL class, reflecting the trust our customers have in our long involvement in this technology and our continually evolving technical expertise.

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_x 80%, almost eliminating SO_x and particulate matter, and reducing CO_2) also cannot be understated.

Over the past decades we have undertaken extensive research on LNG as a fuel and have implemented an unmatched number of projects with industry partners. With this magazine we would like to offer some insight into the state of the industry, its current status and the future prospects we see emerging.

At DNV GL we believe that the ground work has been laid for LNG to thrive in the shipping and transport sectors – and we invite you to come and take the next steps together with us.

LNG AS SHIP FUEL

Published by DNV GL
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Design and layout: DNV GL
Printing: ID 801156 2014-11

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RESCUE ZONE

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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. 50 LNG-fuelled ships (excluding LNG carriers) already operate worldwide, while another 69 newbuildings are confirmed (as of September 2014). 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_X and NO_X to carbon dioxide, particulates (PM) and black carbon. The complete removal of SO_X and particle PM emissions and a reduction of NO_X 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_2 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 32.

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 22.

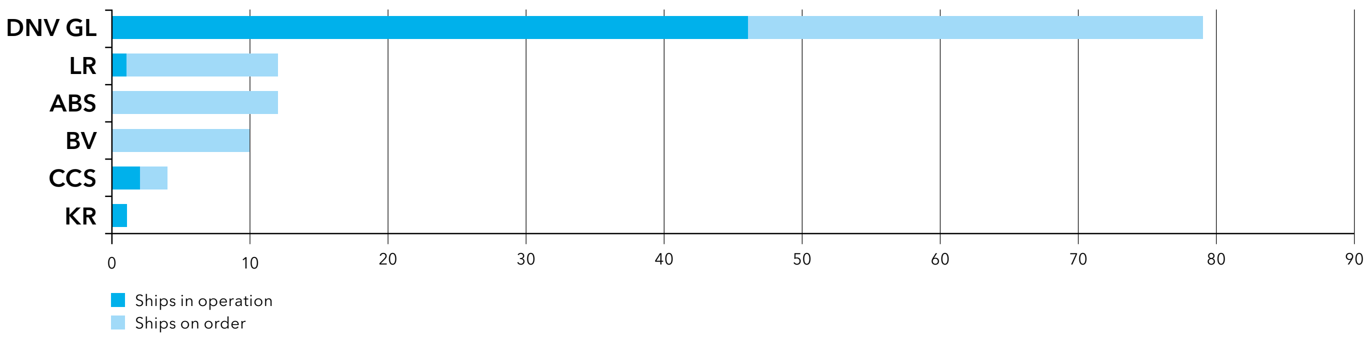
The infrastructure, which will enable the growing wave of LNG new builds and conversions to operate, is on the way. From Norway to the Netherlands, Singapore to Sri Lanka, new projects are springing up every week. DNV GL expert Jan Tellkamp assesses the bunkering and infrastructure picture on page 40 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 50, we look at our approach to helping customers choose the best fuel option and implement it successfully.

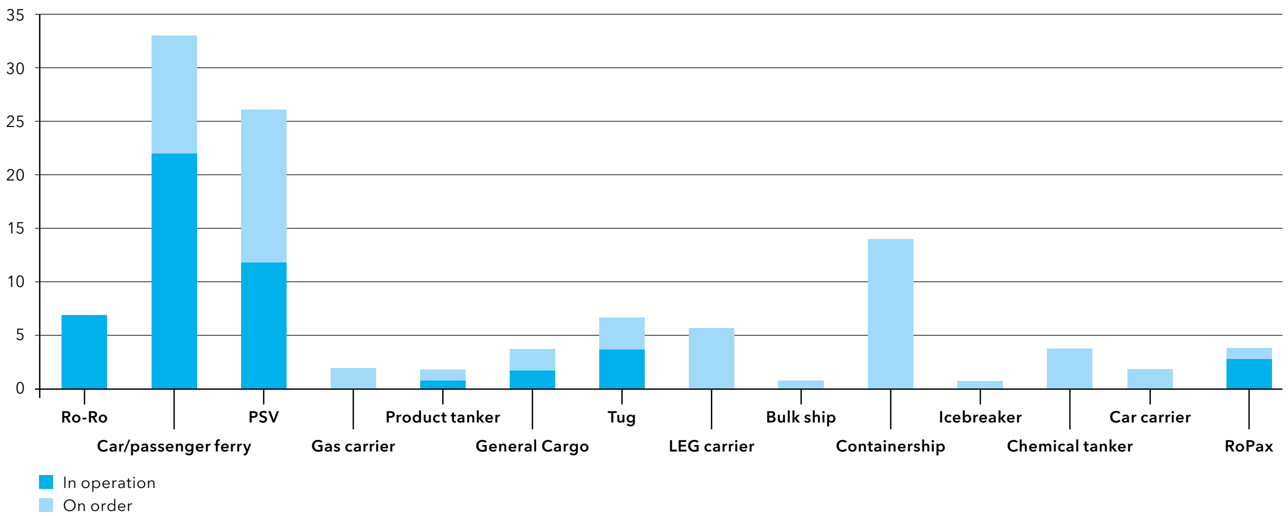
Many market players still have the perception that the commercial risk of choosing LNG as ship fuel is still high. But, on the other hand, what might the risks be of not considering LNG? A vessel ordered today will still be operating in the 2030s, in a world with unknown fuel availability, fuel prices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



LNG-fuelled fleet per segment



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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_x scrubbers and urea-based catalysts for NO_x 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.

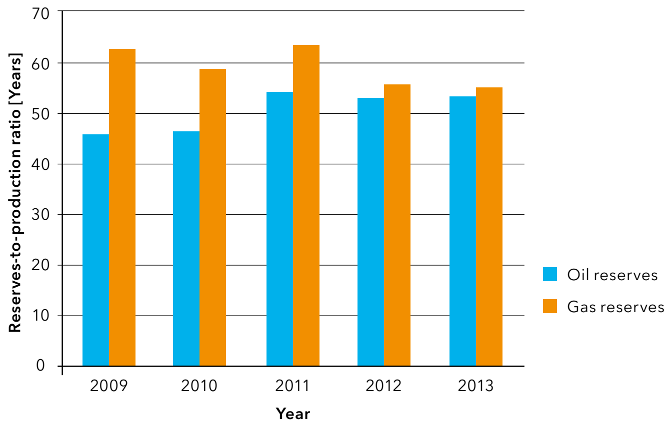


Figure 1: World oil and gas reserves

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_2.

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_x emissions, significant reduction of NO_x 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).

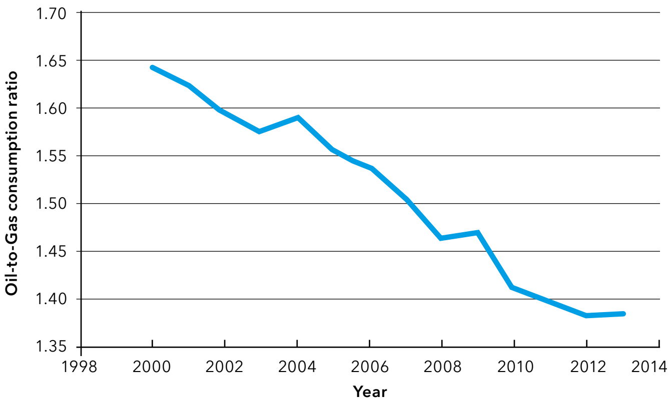


Figure 2: Oil-to-gas consumption ratio, in terms of energy content. Consumption in all sectors and industries is included.

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.

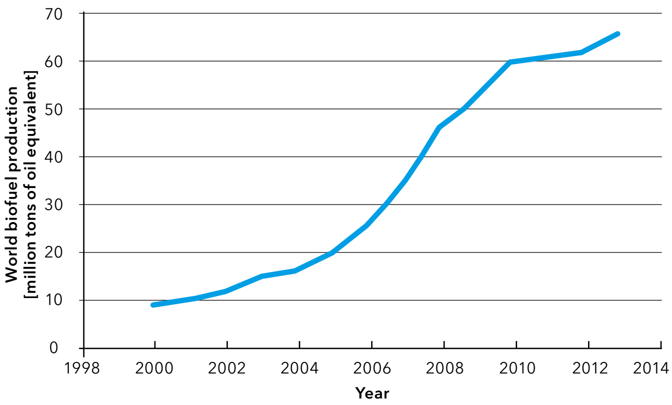
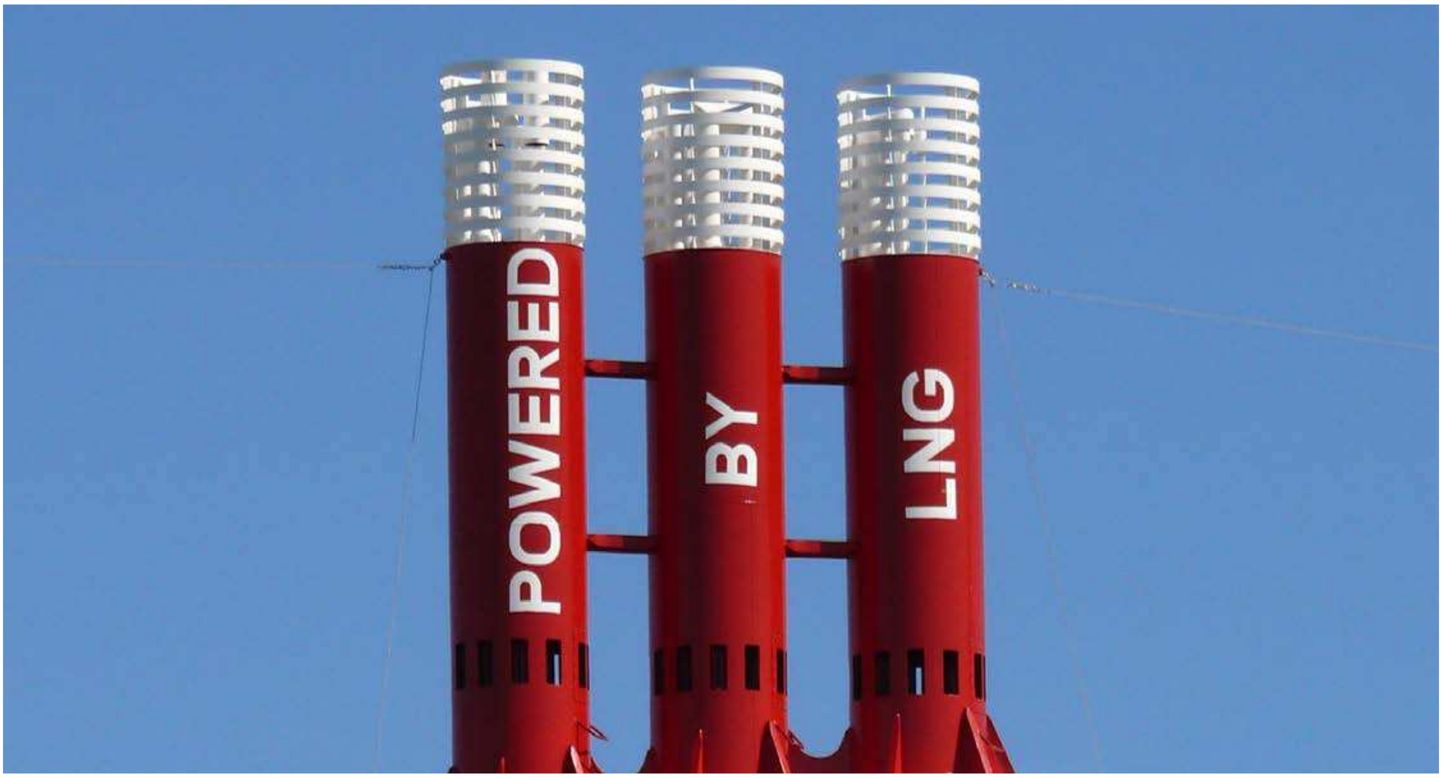


Figure 3: World biofuel production, in million tons of oil equivalent.



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_x 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_x and SO_x 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. ▮

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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.

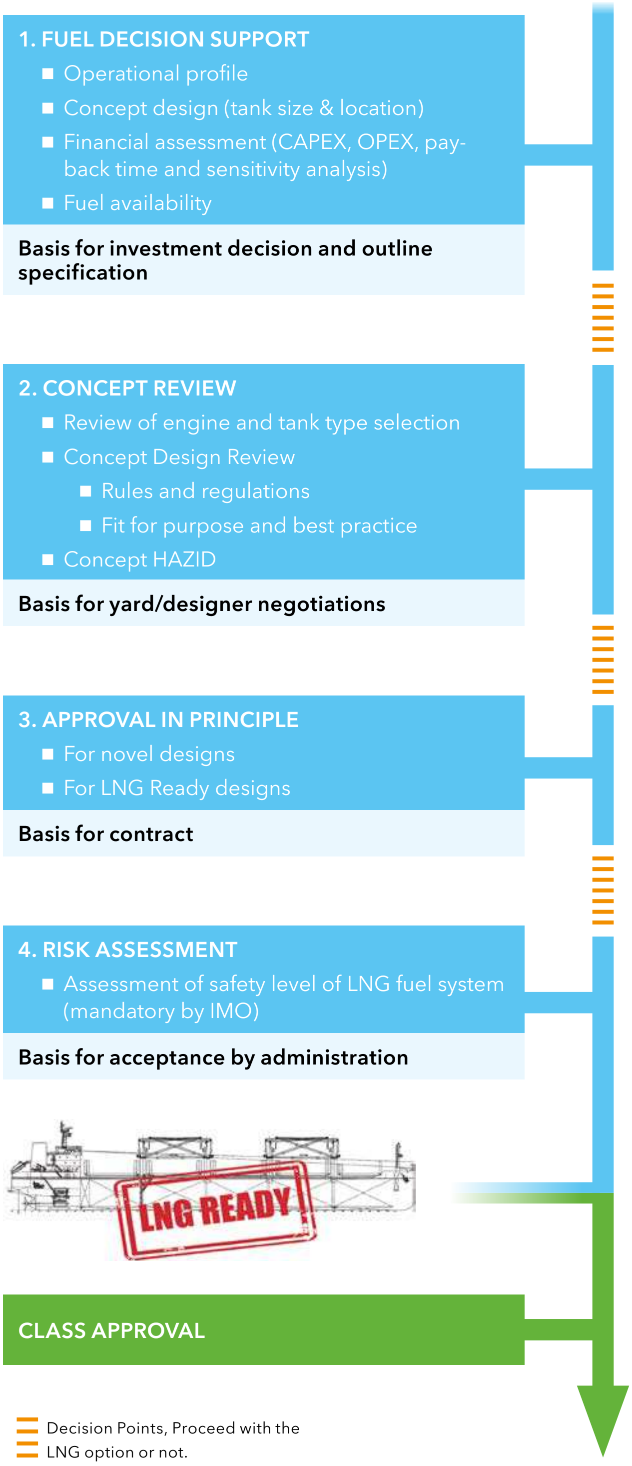

Figure 1: the 4 steps to become LNG Ready

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 containerships (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. 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. ▮

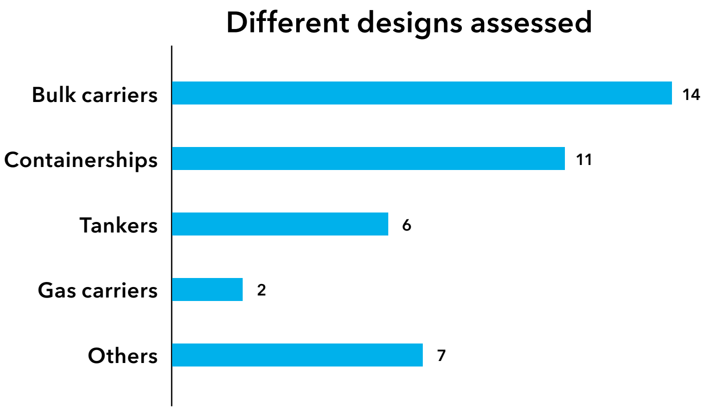

Figure 2: Different designs assessed as of September 2014

Global LNG Ready Service network

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

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THE NEW REFERENCE FOR LNG PROPULSION

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

Fuel consumption is the major cost driver in shipping. Only the most fuel efficient ships will survive in tomorrows' markets! This thesis has become the challenge for UASC – the United Arab Shipping Company with their German Consultant and Ship Designer TECHNOLOG Services GmbH from Hamburg. The TECHNOLOG Consultants have been engaged by UASC to optimise the design of their earlier UASC new-building series from1997 onwards. These have grown steadily in capacity over the years from the initial Panmax size of 4,100 TEU (A4) to 7,200 TEU (A7) and on to 13,500 TEU (A13) ships in 2010, with the last ship delivery of the series in 2012. UASC will now double its fleet capacity with eleven 15,000 TEU (A15) and six 18,800 TEU (A18) new super-efficient and environmentally friendly container vessels. 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.

The ships will come into service between the end of 2014 and autumn 2016. This article will demonstrate the efficiency gains and reductions in emissions by UASC over recent years up to 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 commercial feasible, if it can be offered below the HFO price, or if the 0.5% S regulations come into force in 2020. UASC is the major Middle East liner company serving AEC8 ports between Shanghai and Hamburg with their Asia to Europe service. A string of 10 number 4,100 TEU (A4 class) ships operated on this route between 1999 and 2008.

In 2008, these A4 class vessels on this route were replaced by the new larger 8 (+1) number 7,100 TEU (A7 Class) vessels. These ships were propelled by Wärtsilä 11 RT-flex 96C engines with an NCR power of 56,628 kW.

The new standard – UASC's A15 and A18 class

The previous vessels were all standard shipyard designs that only underwent limited optimisation and were trimmed for the common high operational speeds at that time. However, the new vessels of 15,000 TEU (A15 class) and 18,800 TEU (A18 class) were developed for economy and best fuel consumption by UASC with their consultant TECHNOLOG and the tendering shipyards, later the selected builders HHI, in successful partnership. These newbuilds have the following particulars:

Main Particulars A15 A18

Both vessel types follow an identical design and outfitting strategy. All of them have been designed and equipped for fuel economy with hull form optimisation. As all the vessels have their keel laying dates before the end of 2015, they are IMO Tier II compliant regardinging NO_x emissions. The CO_2 output of the 11 number A15 class ships will be 0.80 million tons per year, while the CO_2 output per TEU/nm is 63.2 grams. This is again a reduction in CO_2 footprint of 22% compared to the A13 vessels.

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		

The 6 new number A18s will operate in alliance with 5 new CSCL vessels in partnership; therefore only the 6 UASC vessels have been evaluated. The yearly CO_2 output of these 6 ships will be 0.50 million tons. The CO_2 output per TEU/nm is 52.3 grams, which is 36% below the CO_2 footprint of the A13 vessels. When the ships are eventually retro-fitted to LNG as fuel, there will be a CO_2 reduction of 25%, a NO_x reduction for these IMO Tier II vessels of 25%, a SO_x reduction of 97% and a Diesel particle reduction of 95%. The use of LNG as fuel will significantly reduce all emissions to the atmosphere, which may cause harm to people or contribute to the global warming effect.

Challenges related to the application of LNG as fuel compared to existing applications

These new vessels must not only be the most competitive when put into service compared to (still) conventional ships but, moreover, the most competitive in the years to come, while complying with the increasing environmental demands of IMO MARPOL VI regarding emissions of SO_x, NO_x, diesel particles, and CO_2. With coastal countries increasing their environmental consciousness of global warming by, Emission Controlled Areas will certainly be extended. 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.

The 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 retro-fitting and 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. The further development of efficient bunkering logistics along the trading routes with the availability of adequate LNG bunker quantities and refuelling without lost idle time is a further demand.

Technical concept of UASC for A15 and A18 Class vessels

From the retro-fit perspective, it became evident 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 has the greatest stowage density compared to several smaller cylindrical type 'C' tanks, and thus require 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 of 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 commercially the most attractive 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 pay-back times once the fuel price differences become visible.

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LNG AS FUEL ON A NEW BUILD MR TANKER

A COMMERCIALLY ATTRACTIVE OPTION?

In this article, we present the business case for building a dual-fuel medium range (MR) tanker from our LNG Ready Service. We examine the commercial attractiveness of LNG compared to the other main options for emission control area (ECA) compliance - fuel switch to MGO and HFO plus a scrubber - and discuss whether a LNG Ready or LNG-fuelled ship is ideal for this case.

Case – building a MR tanker to run on LNG
This case examines the commercial attractiveness of building a dual-fuel 50,000 DWT medium range oil tanker. MR tankers are usually engaged in spot trade, meaning the vessels have an unpredictable trading pattern. This has so far been one of the main arguments for not investing in LNG as fuel – industry actors consider it as too big of a risk before it is certain that LNG can be bunkered globally.

However, as charterers look for the cheapest overall cost of transportation, a dual-fuel MR tanker will be an attractive choice for trades with high ECA exposure. Especially for vessels trading to the US, charterers will realise that LNG-fuelled vessels may have a lower total cost of transportation. For shipowners with a Dual Fuel MR tanker, this would mean that their vessels would be an attractive choice in the spot pool.

Operational profile

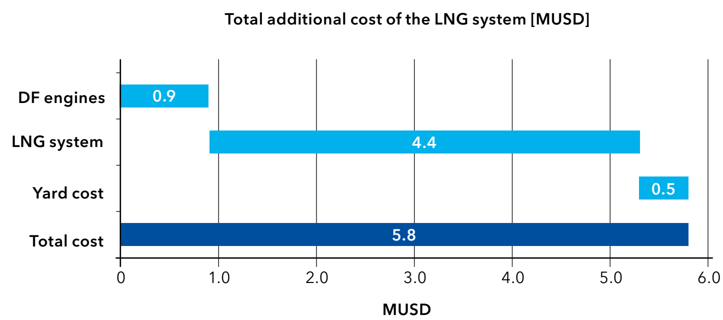


Figure 1: Total additional cost of the LNG system (MUSD)

In this case, we have therefore looked at a cross-Atlantic trade with a high ECA exposure. The vessel will trade from Rotterdam via New York to Houston, as illustrated on the map above. This means that the vessel will operate in the North Sea SO_x ECA and the North American SO_x and NO_x ECA. From 1 January 2015, all vessels operating in designated SO_x ECAs will need to comply with the 0.1% sulphur regulation. If the vessel is built after 1 January 2016, it will also have to comply with NO_x Tier III regulations when operating in NO_x ECAs. If the vessel runs on conventional fuels, it will then have to install additional emission abatement technologies on board.

TOTAL DISTANCE (ROUND-TRIP)	10,300 NM
Total sailing time	32 days
Speed	13.5 knots
Sailing time in ECA	38%

We assume that the vessel will use LNG for the complete voyage. If the vessel bunkers twice per roundtrip, for example in Rotterdam and in Houston/New Orleans, the vessel will need a tank capacity of 1500 m^3. For only one bunkering operation during the roundtrip, the vessel requires a 3000 m^3 tank. The latter case will allow the vessel to bunker all of its fuel in the US, where LNG prices are considerably lower than in Europe. LNG is expected to be available on the trade route within the next two years.

There are no technical barriers for using LNG as fuel on an MR tanker; there are now several dual-fuel engines available to choose from for these vessels (both main and auxiliary), and one or more LNG fuel tanks can easily be located on board.

Financial analysis

In order to examine the commercial attractiveness of LNG on the case vessel, we have performed a high-level inancial analysis comparing LNG to fuel switch to MGO and to HFO with a scrubber:

1. LNG case: The vessel will use LNG for the whole roundtrip
2. MGO: The vessel will use MGO in the ECAs, and HFO outside the ECAs
3. HFO with a scrubber: The vessel will use HFO for the whole trip, and use the scrubber in the ECAs

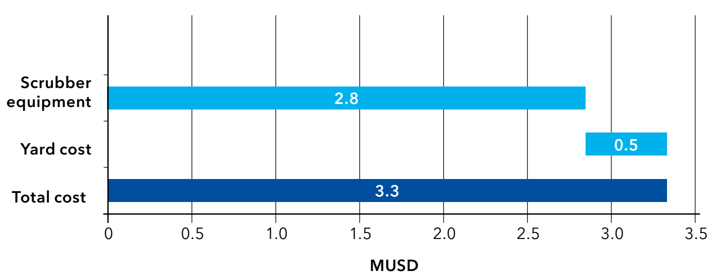


Figure 2: Total additional cost of the hybrid scrubber system (MUSD)

In the analysis, we include both capital and operational expenditure. The figure below presents an estimate of the total additional capital cost of the LNG system, meaning the delta cost of installing dual-fuel engines and the LNG system compared to a regular, diesel-fuelled vessel. The cost of the LNG system is based on a 1500 m^3 tank capacity. Doubling the tank capacity would mean a moderate increase in the costs. An estimate for a hybrid scrubber system is also shown in Figure 2.

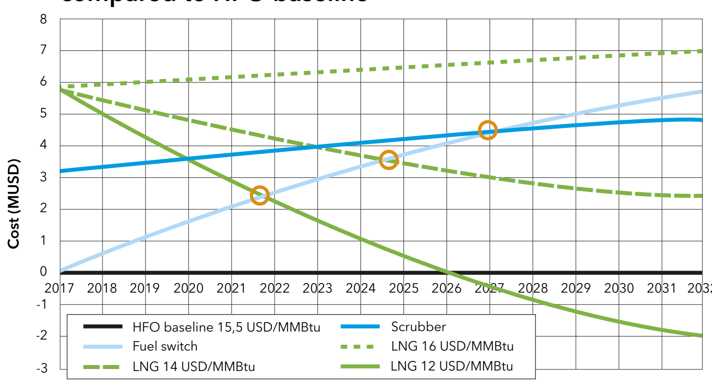
Figure 3 above presents the cumulative cost of the different fuel options for the new build MR tanker, compared to a HFO baseline. Although LNG has a high investment cost, operational savings can be significant, depending on the fuel price. In this case, we have applied a LNG price spread ranging from 12 USD/MMBtu (600 USD/tonne) to 16 USD/MMBtu (900 USD/ton). In the case of a LNG price of 12 USD/MMBtu, the payback time compared to HFO with a scrubber is 2.6 years, and 4.5 years compared to fuel switch to MGO.

Conclusion

Our analysis shows that LNG can be an attractive fuel option for an MR tanker, depending on the LNG price. This is particularly promising for LNG-fuelled vessels trading in the North American ECA, where access to attractively priced LNG in several relevant ports and areas is being developed. These vessels would have a competitive advantage over vessels with other, potentially more costly, ECA compliance options. Could these vessels become the preferred option by cost-conscious charterers with spot cargos and short term time charters for routes with high ECA exposure? Judging by the interest, the first orders are likely not far away.

The high-level analysis performed and presented in this article is part of the DNV GL LNG Ready service, where more than 40 business cases for shipowners across all segments have been evaluated. The LNG Ready service has been developed in order to assist shipowners, operators, yards and designers in identifying the most attractive compliance option for their ships. For more information regarding the service, please see pages 12 and 13. ▮

Cumulative total cost (MUSD) for LNG and scrubber compared to HFO baseline



Payback time and value of the investment over the lifetime of the ship, taking into account all relevant options for future emission compliance

Figure 3: Cumulated discounted cost difference for different compliance options compared to HFO baseline (MUSD)

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RETROFITTING CRUISE SHIPS TO LNG BY ELONGATION

A CRAZY IDEA?

A large number of cruise ships currently sailing to popular destinations will soon need to comply with stricter environmental regulations - requiring the installation of scrubbers, the use of LNG as fuel, or a changeover from heavy fuel oil (HFO) to marine gas oil (MGO) or a combination of these two. Compliance with regulations and the strongly fluctuating fuel prices have made cruise operators sceptical about the success of their future business.

The difference in price between MGO and the HFO currently used can increase operational expenses by up to 40%. Making ships more energy efficient and using distillate fuels in order to comply with the forthcoming regulations is an option, but the financial attractiveness needs to be investigated for every ship on a case-by-case basis. A conversion to LNG might, under certain circumstances, be an attractive alternative solution that eliminates the complexities of fitting scrubbers and the high cost of burning distillate fuel.

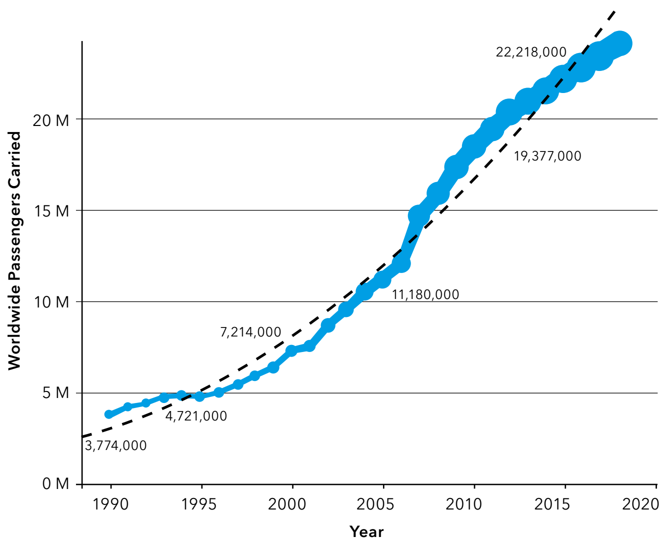


Figure 1: Growth of worldwide passengers carried. Source: cruisemarketwatch.com

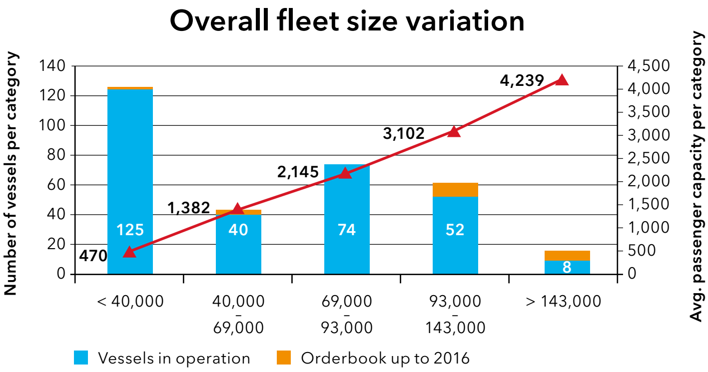


Figure 2: Fleet size variation

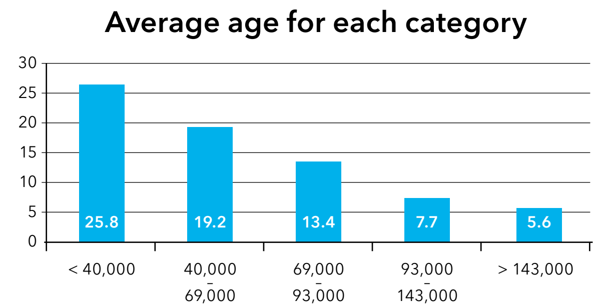


Figure 3: Average age variation

Statistics show that the cruise industry has experienced is expected to continue to experience annual passenger growth of 7% from 1990 up to 2017 (Figure 1). This trend is reflected by the current order book for larger ships and ongoing revitalisation projects in which balconies, new on-board facilities, etc., are being retrofitted (Figures 2 and 3). The Asian, European and North American markets are expected to continue to grow strongly.

The future of cruising continues to look promising and the industry has a large growth potential, provided it continues to compete price-wise with the alternative options.

Currently, 299 cruise ships are in operation. Figures 2 and 3 show that there is a large number of ships below 40,000 GT with an age of almost 26 years. Moving up to larger ships, a clear drop in age can be seen, with the average age falling almost to six years for ships larger than 143,000 GT. In addition, the current order book also supports the fact that the industry is continuing to move towards larger ships (Figure 2).

Converting an existing ship to run on LNG can in principle be done by:

1. Taking the ship out of operation and installing the LNG tanks and fuel handling systems in the existing hull. Such a retrofit will reduce the number of cabins and will involve technical complications as the LNG tanks require more space than HFO or MGO fuel tanks and such free space is not available on the ship. In addition, this is time-consuming and thus represents a loss of revenue due to the lengthy off-hire.

2. Inserting a new "LNG Ready" prefabricated mid-body section containing all the LNG systems, additional cabins and public spaces into the ship. Such a retrofit can be done in a few weeks, the ship does not need to go on a lengthy off-hire and the passenger capacity will increase by approximately 10%. The investment is limited to approx. 10% to 12% of newbuilding costs.

In this study, we focus on the second option, which is proven to be the most feasible solution from a technical and financial perspective.

The potentially strongest candidates for conversion comprise 8-19-year-old ships between 40,000 GT and 143,000 GT which represent almost 55% of the fleet. Ships over 143,000 GT have been excluded as their length is already at the limit of present port capacities.

Ships below 40,000 GT are not considered favourable for lengthening due to the limitations of the ports they visit. Cruise ships of this size are usually in the luxury segment, typically visiting smaller and less busy ports without the infrastructure and ability to receive the bigger ships. Another reason is the lack of financial attractiveness; the payback time of the investment is increased due to the lower passenger capacity. However, because these are high-end ships, the investment cost could be absorbed by the higher premiums.

Generally, every ship has unique characteristics and whether or not it is a good candidate for conversion needs to be investigated on a case-by-case basis and in close cooperation with the respective flag state administrations.

Technical considerations

The 'crazy idea' outlined in the title involves the conversion of a cruise ship to run on LNG by lengthening it (Figure 4). A new prefabricated part, containing LNG tanks and all the required LNG systems, is added to the ship.

As mentioned earlier, every ship is different – so whether or not it can be converted must be extensively assessed. In the following part, all the required technical modifications are outlined and presented from a hull and structural perspective, the machinery point of view and finally the operational side.

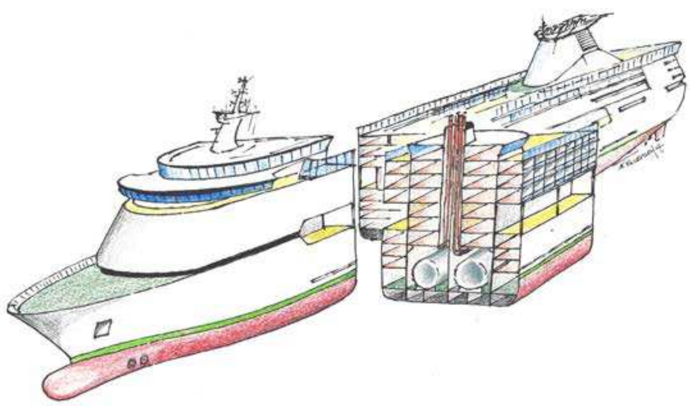


Figure 4: Elongation concept with prefabricated LNG tanks

A real life example is the ENCHANTMENT OF THE SEAS (figures below), lengthened in 2005 by adding a 22m-long mid-body section in order to increase the number of cabins. The conversion itself was completed in one month.

ENCHANTMENT OF THE SEAS LENGTHENING

Royal Caribbean International's Enchantment of the Seas received a new 73 feet mid-body section in May 2005 built by Aker Finnyards of Finland. The lengthening took just 31 days to complete, using a new procedure in which the ship pieces were manipulated and aligned with jacks and skids in dry dock at the Kepel Verolme Shipyard in Rotterdam, The Netherlands.

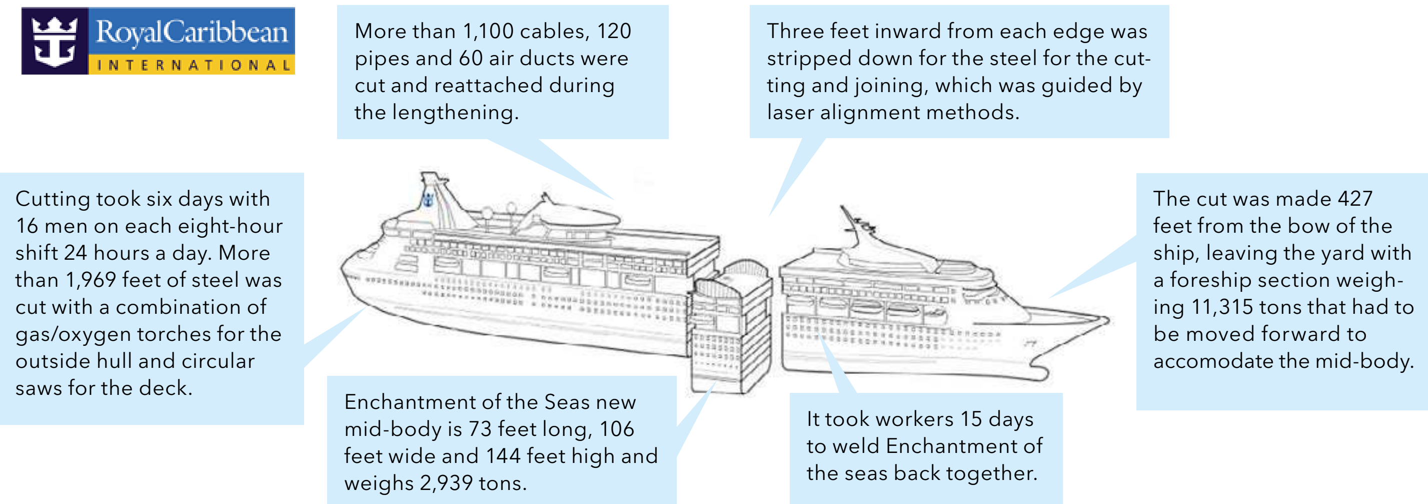


Figure 5: Enchantment of the Seas concept

Figure 6: Enchantment of the Seas

Figure 7: Enchantment of the Seas completed

Benefits and current challenges of elongation and use of LNG as a fuel

Benefits

- Most likely improved revenue
- Increased number of passenger and crew cabins
- Improved environmental footprint
- Energy efficiency may be increased by installing flow-improving appendages during dry-docking
- Additional public space and retail capacity
- Additional open deck spaces
- Reduction of main engine maintenance hours
- Less engine crew required
- Cheaper lubricants
- Cleaner engine room
- No soot on decks – less cleaning and wash water needed
- No need for exhaust cleaning devices or catalytic reactors
- Slightly lower noise level in engine room

Current challenges

- Design & retrofit cost compared to switching to distillates
- Time required for ship to be taken out of service for the retrofit operations
- Elongation may reduce the range of ports of call
- Bunkering challenges
- Statutory challenges
- LNG fuel cost pricing challenges
- LNG infrastructure challenges
- More tank space required to accommodate enough LNG to cover all the itineraries
- Onshore bunkering logistics are still under development
- Rules still under development
- More sophisticated fuel equipment is required
- Public perception not fully known

Lengthening characteristics
The minimum elongation limit is half a main vertical fire zone (approximately 22m); and the maximum could be a complete fire zone (approximately 43m). The longitudinal strength limits of the hull girder determine the elongation size. The increase in the longitudinal bending moment will require a corresponding amount of additional steel in order to maintain the required section modulus - deemed too costly to be seriously considered. Thus, the most feasible option for a potential candidate ship will be a new part that is half a fire zone in length.

Our technical feasibility study has shown that, in a 23m compartment, the maximum possible volume of LNG is approximately 1500m^3 due to design and structural constraints. The addition of new cabins will increase the total number of cabins by approximately 10%.

For this study, cylindrical pressure type C tanks were used as these are currently considered to be the most feasible option. A prismatic low-pressure tank, type B, is an alternative, increasing the LNG capacity by about 30%. However, for a type B tank, it has to be assumed that a controllable fatigue crack may occur as the worst-case leakage scenario. The leak rate is defined and the released LNG has to be controlled in a safe manner - which would be a challenge, especially on a cruise ship. In addition, the low max tank pressure of 0.7 bars for a type B tank results in limited flexibility for the tank operation and bunkering.

A high-level study showed that, with 1,500m^3 of LNG, approximately 70%-80% of all existing cruise itineraries can be operated. In order to cover the remaining routes, which are longer and require more fuel, the operator can either use the ship's dual-fuel capabilities and burn MGO/HFO, depending on the location, or perform a second bunkering operation to fill up with LNG half way through the voyage. A potential new mid-body section of 43m will be able to accommodate approximately 3,000m^3 of LNG in total and this will enable the ship to carry out all the current itineraries.

Flag engagement
Before deciding on a conversion, it is of the utmost importance to involve the Flag State Administration at an early stage, since a lengthening is defined as a major conversion. The new part of the ship must comply with the SOLAS regulation that is applicable when the conversion starts. According to SOLAS II-2/1.3.2, "Repairs, alterations and modifications which substantially alter the dimensions of a ship …shall meet the requirements for ships constructed on or after 1 July 2012 in so far as the Administration deems reasonable and practicable".

Although the term 'substantially' is not defined, a ship elongation operation is considered to be a major conversion as it alters the ship's initial dimensions. Therefore, the involvement of the Flag is even more important. Finally, the damage stability regulations to be applied need to be clarified at an early stage.

Current SOLAS requirements include the Safe Return to Port (SRtP) requirements, which should be complied with as well. However, as SRtP is a design requirement and applies to the whole ship, achieving compliance with a pre-2012 ship is a significant challenge. The Flag should therefore be contacted in order to obtain an exemption from the SRtP requirements.

Hull and structure
The following steps are required for the hull and structural part of the conversion:

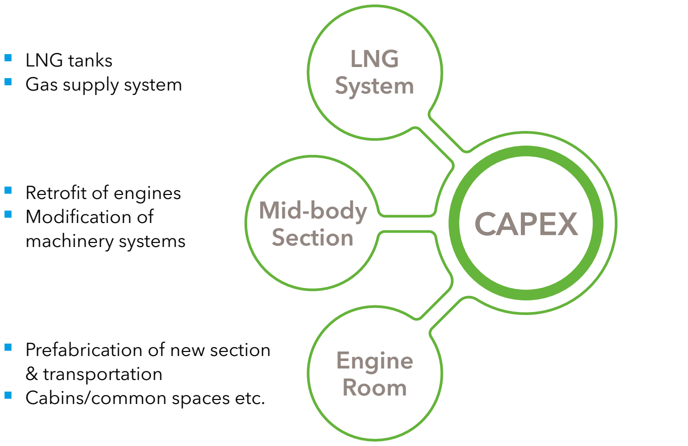
- The longitudinal strength of the candidate ship has to be evaluated. The maximum allowable bending moment can become a showstopper if the hull is already designed to its optimum and cannot sustain any additional length
- A damage stability study needs to be performed in order to determine the location of the new part
- Fire boundaries and the evacuation arrangements need to be sorted out when planning the inserted arrangement
- Machinery spaces need to be appraised and re-arranged as necessary
- The location of the bunker station might create some challenges as balconies, openings and lifeboats cannot be within a safety distance of the bunker station
- The location of the vent mast needs to be considered in order to avoid disruptions on the upper decks

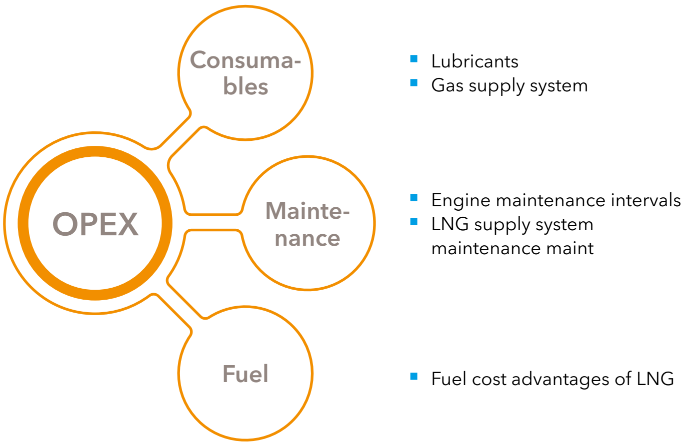
Operational requirements
- A major nautical aspect that needs to be investigated is the slow speed manoeuvring capability in port of the now longer ship
- The addition of new cabins requires an increase in potable, black and grey water capacity

Machinery requirements
- The possibility of converting the main engines to dual-fuel needs to be investigated. Engine suppliers are continuously developing retrofit packages for different engine types
- A longer ship will also require an increased thruster capacity New bow and stern thrusters might be necessary
- The ship's power supply will need to be recalculated due to the increased hotel load. On the plus-side, exploiting the properties of LNG such as utilising LNG cold recovery for cooling and a higher waste heat recovery potential, both of which make the engine room more energy efficient, might balance out the need for additional hotel power
- Removing the ship's entire HFO capability, including fuel treatment systems and tanks, could also be investigated. This will free up space in the engine rooms for new LNG tanks. However, this will leave the ship with MGO as its second fuel and thus have a slight effect on the fuel cost if MGO is consumed instead of HFO
- Cutting the ship in half involves severing and splicing all the coordination systems, including cables, pipes and ducts. This is a job not to be underestimated

Financial assessment

The investment cost required for such a conversion can be broken down into different categories. In addition to the cost of the systems outlined below, the cost of having the ship off-hire needs to be taken into consideration. On the other hand, there is a reduction in the yearly operational expenses outlined below and an additional increase in revenue and profit from the larger number of cabins.





High-level cost-estimate exercise

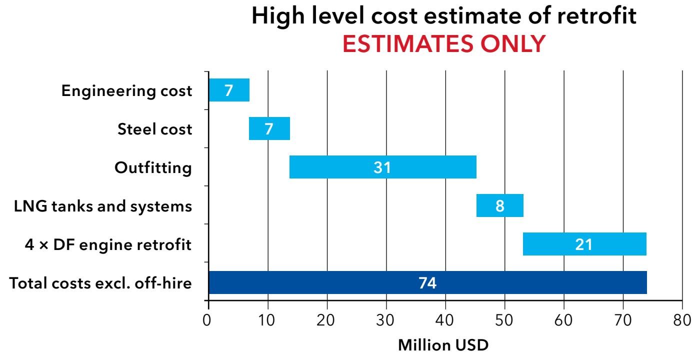
In order to examine the financial attractiveness of our "crazy idea", we performed a high-level study and mapped the required investment for the LNG system. We then compared the LNG system to MGO propulsion and to HFO with a scrubber, which is considered to be the next best alternative. A complete, in detail study can be performed by DNV GL within the scope of our LNG Ready service.

For the high-level simulation exercise, a ship with the following characteristics was assumed:

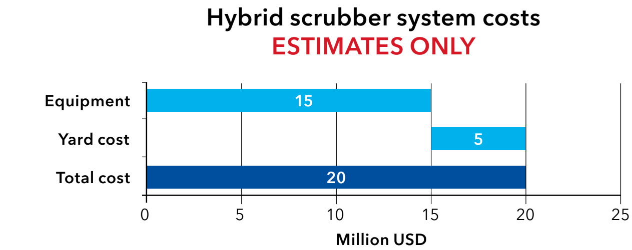
New mid-body section length:	23 m
New LOA of ship:	300 m
Beam of ship:	32 m
Ship GT:	75,000
Added staterooms with new mid-body section:	120
Total staterooms after elongation:	1,120
Engines before retrofit:	4 x MAN 12V48/60 at 12,600 kW
Engines after retrofit:	4 x MAN 12V51/60 DF at 11,700 kW

The high-level cost estimate was based on the following assumptions:

- The total weight was assumed to be 5,000 mt and the required steel was assumed to be 3,000 mt, which includes the outfitting, hull structure and required reinforcement
- The LNG system includes all the necessary equipment from the bunker station to the engine



For the scrubber system cost estimate, a hybrid system with 4 scrubbers, one per engine, has been used.

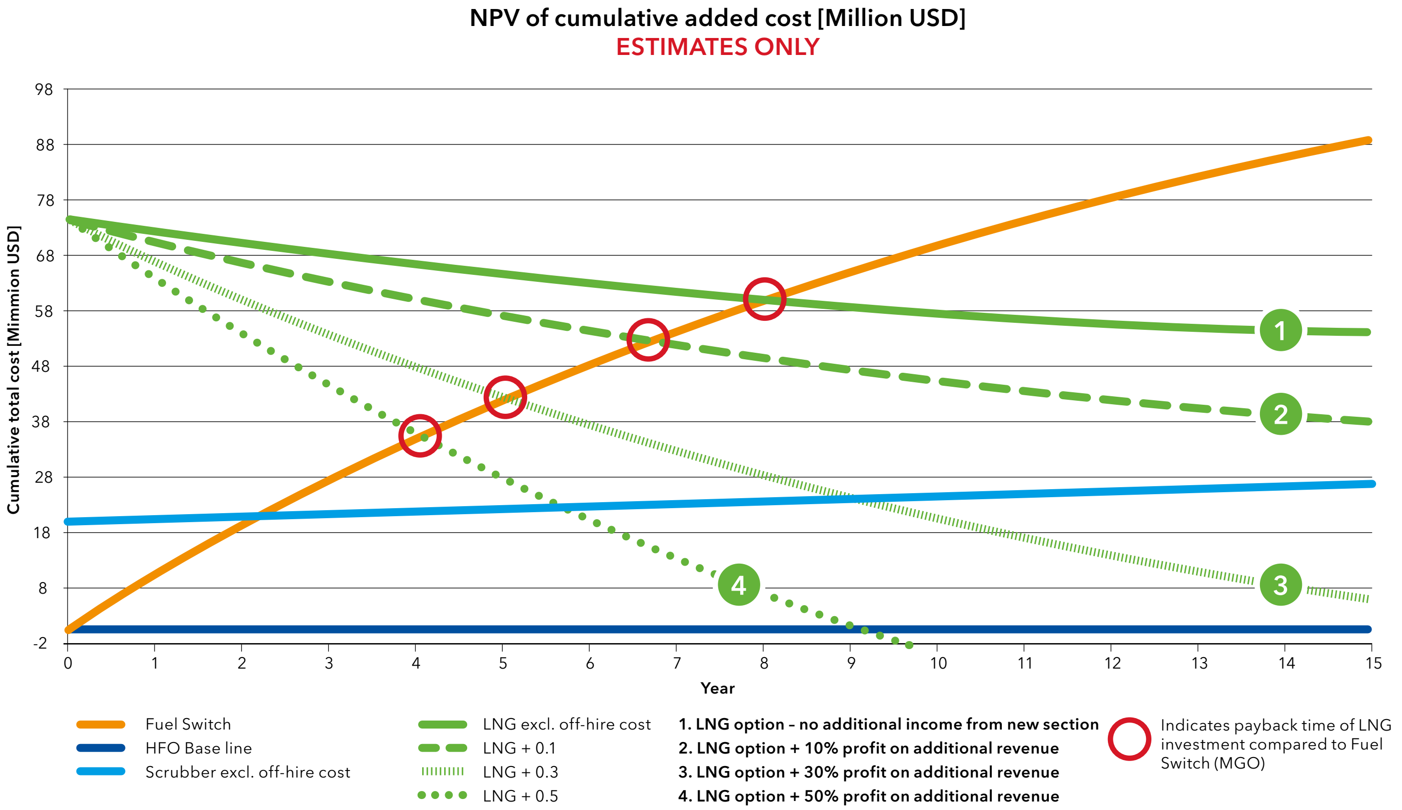


The parameters that have not been included in the cost estimate above are:

- The cost of having the ship off-hire as the daily income per passenger is a very case-specific parameter and depends upon each company's business strategy
- For simplicity, the operational cost of the LNG system has been assumed to be equal to that of the diesel equivalent version of the ship
- The transportation cost of the equipment (LNG tanks and systems and scrubber system)
- It is assumed that refit is used for energy optimisation. Therefore the energy consumption is reduced to a level which can be covered by the DF engines

The financial result for the business case is presented below. The additional income generated from the new cabins for the LNG case has been taken into consideration when calculating the payback time based on the following assumptions:

The scrubber and fuel switch case do not provide additional cabins and therefore no additional revenue from increased number of passengers. Four scenarios have been developed to calculate the payback time for the LNG option. The difference in the scenarios is the percentage of profit on the yearly revenue generated from the new mid-body section. A spread of 0% - 50% profit on the revenue



has been applied to represent the potential economic gains of the elongation. The additional running costs generated by the passengers on-board the new mid-body section are covered by the extra revenue. By switching to MGO or installing a scrubber system there are no additional cabins and therefore no additional income.

When calculating the financial attractiveness of the LNG option, the following assumptions were used:

- LNG Price: $ 14/MMBtu (12.5% below HFO price)
- MDO Price: $ 25/MMBtu ($1,000/ton)
- HFO Price: $ 16/MMBtu ($614/ton)
- Discount rate applied: 8%
- No price increase over time is assumed
- 100% gas mode operation when operating
- The thermal efficiencies of diesel and gas engines are assumed to be identical
- All engines running at the same load point (assumed average load of 50% MCR)

The pricing of the LNG used above is based on the following rationale:

US Henry Hub price:	$ 3-4/MMBtu
US liquefaction cost:	$ 5/MMBtu
Distribution cost:	$ 3-6/MMBtu
Total final price spread of LNG:	$ 11–15/MMBtu

As is illustrated in the graph, the payback time of LNG compared to MGO is between 4 and 8 years, depending on the profit percentage of the revenue, as outlined above. For the upper profit margins of 30% and 50%, LNG is favourable compared to the scrubber option after 5.5 and 9 years, respectively.

Conclusion

In the authors' view, retrofitting an existing cruise ship so that it can use LNG fuel is a feasible option for a number of existing cruise ships. The study presented above shows that every ship needs to be considered separately as each ship has unique design characteristics and limitations for the integration of a new section. The retrofit potential depends on the design and structural characteristics of each cruise ship and, based on that, technical showstoppers might arise. Another challenge the industry is facing at the moment is the size and location of the LNG tank due to the ship's structural limitations and the rules and regulations currently governing the specific topic. The IMO rules have not yet been confirmed. The strictest set of rules currently under discussion limits the maximum allowable tanks size. The fuel that can be stored in the new mid-body section of a typical cruise ship is approximately 1,500 m^3 which is equal to the energy of about 800 m^3 of MGO.

This study has shown that retrofitting cruise ships to run on LNG – our crazy idea – is not only technically but also financially feasible if an attractive LNG price can be achieved. The calculated payback time is 4-8 years compared to MGO. LNG propulsion is a unique solution in that the ship achieves compliance, saves money on fuel, and generates extra revenue from additional passenger capacity. Certain ships now have a window of opportunity to take advantage of the potential financial benefits of LNG propulsion. ▮

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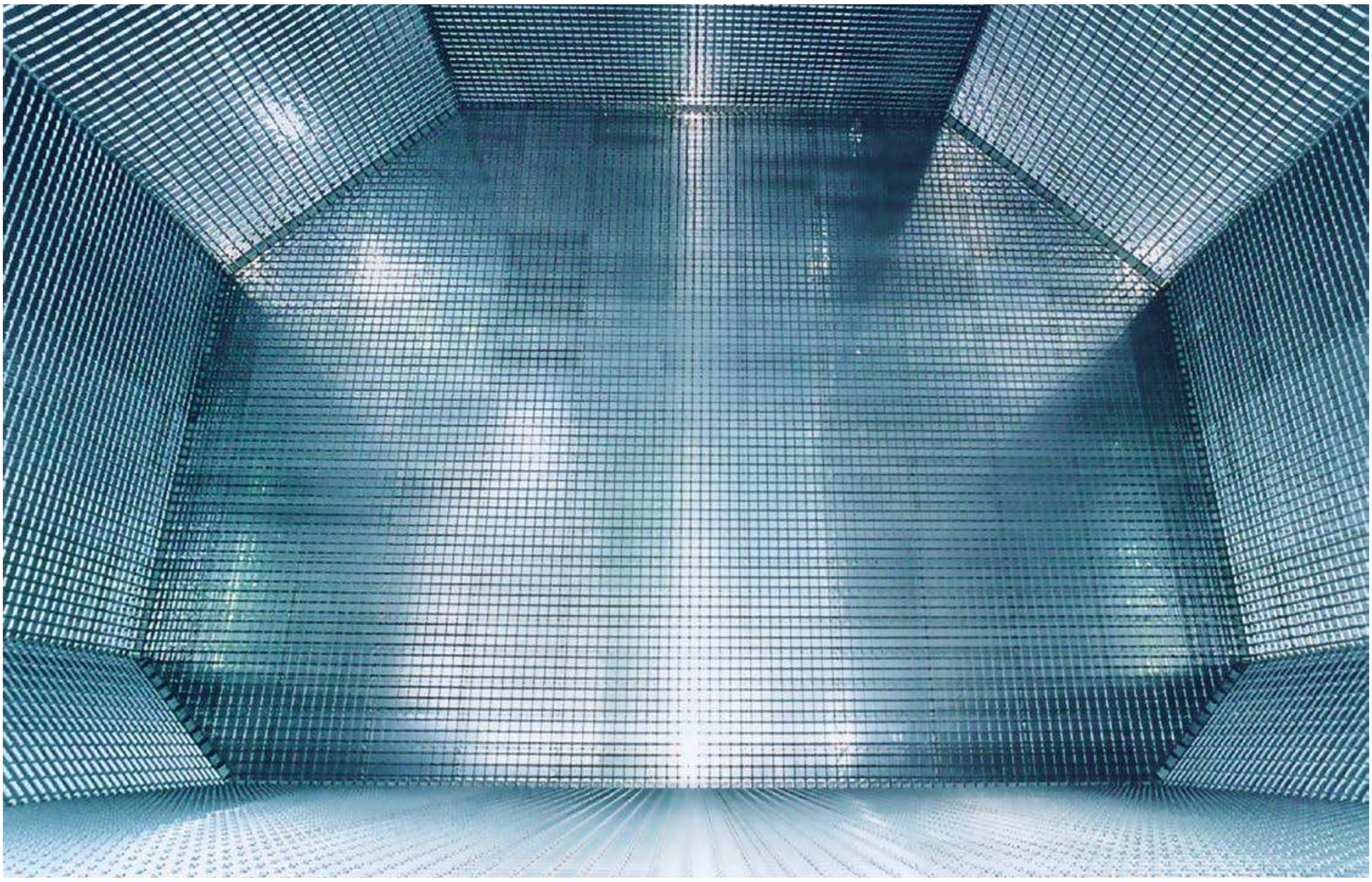


Membrane tanks make efficient use of the available on board space

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.

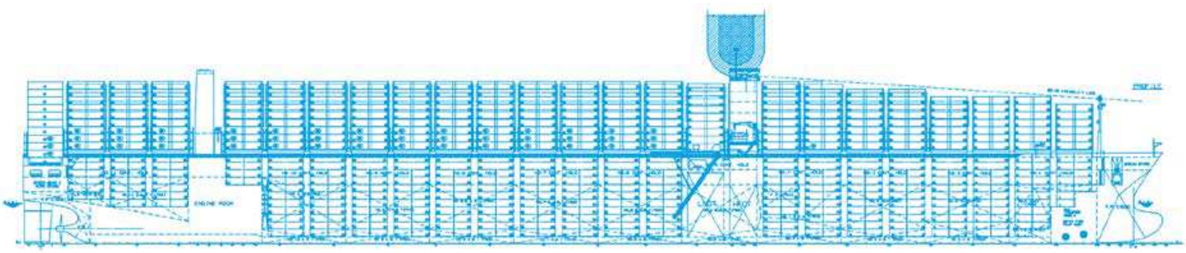
The boil-off challenge

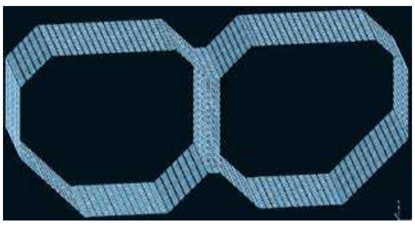
One key issue has been the treatment of boil-oil gas from the LNG tanks. The pressure increase inside the membrane tank system, which is designed for a maximum of 700 mbarg, must be limited without releasing gas to the atmosphere. This can be achieved by using the boil-off gas to power the auxiliary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

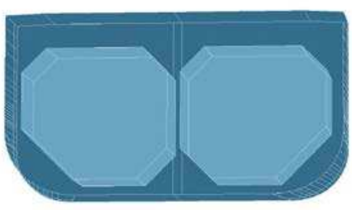
Today 50 LNG-fuelled ships are in service and the milestone of 100 confirmed LNG projects worldwide was achieved this year. There is no longer any doubt that LNG will be a major ship fuel in the future. Yards and component manufacturers have developed fuel-efficient and eco-friendly LNG propulsion systems 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. ∎

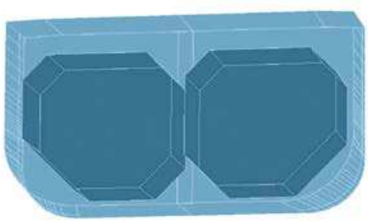
Main particulars of the ship concept

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









Photos: Hanjin – GTT - DNV GL

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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.

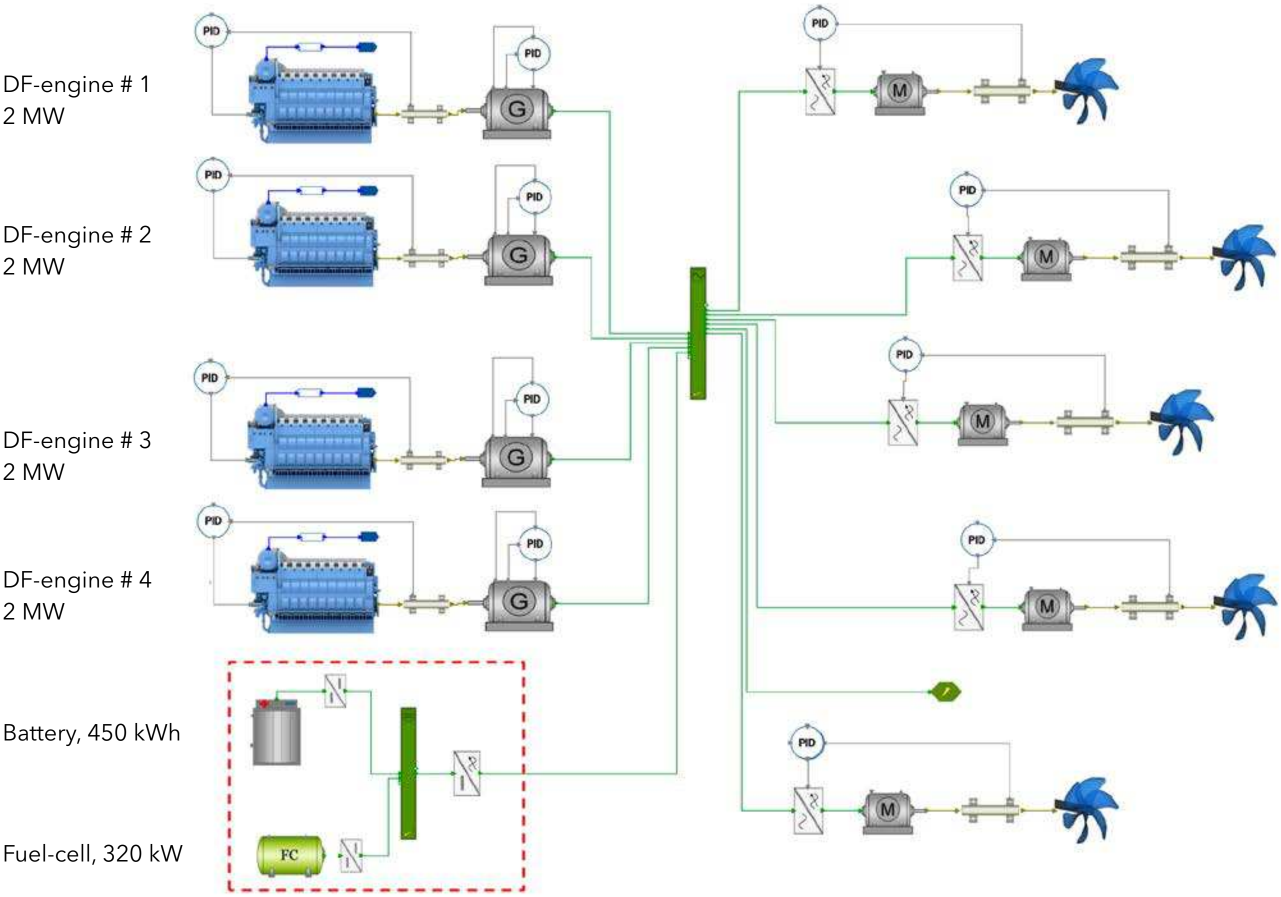

Figure 2. COSSMOS model of the Viking Lady hybrid propulsion system.

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 that a 15% reduction in fuel consumption, 25% reduction in NO_x 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. ▮

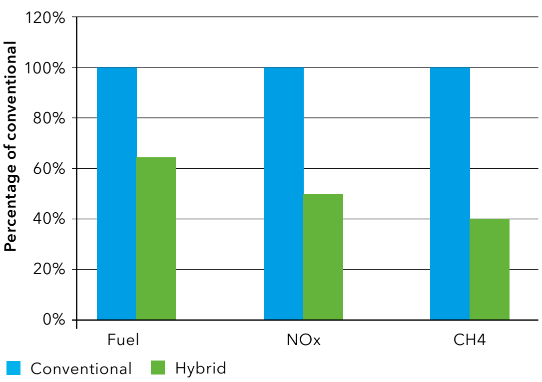

Figure 3. Sea trials: Hybrid system performance in DP mode in calm weather.

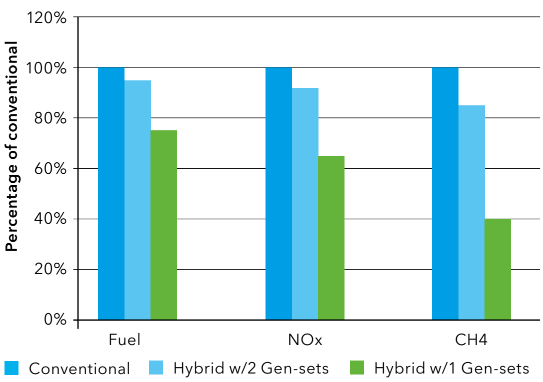

Figure 4. Sea trials: Hybrid system performance in DP mode in bad weather.

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RULES FOR GAS-FUELLED SHIPS

IGF Code
Due to the lack of international safety requirements for gas as fuel for non-LNG tankers, the development of an International Code for Gas as Ship Fuel (IGF Code) was proposed to the Marine Safety Committee (MSC) of IMO in 2004. The goal of the guideline is to provide an international standard for ships with natural gas-fuelled engine installations.

The Interim Guideline MSC.285(86) was adopted in 2009 and 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.

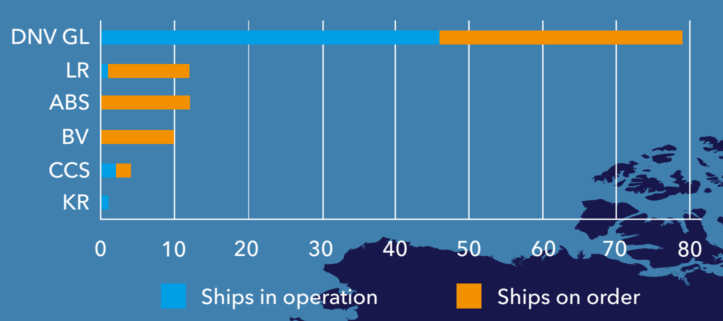
Hence, the uncertainties for the owners and yards are reduced, both when looking into standard solutions and more innovative designs. The main outcome is however to more efficiently lower the risks for gas-fuelled ship designs.

The new DNV GL Rules for Gas Fuelled Ship Installations will be consistent with the IGF Code and are planned to be published July 2015 and to enter into force January 2016. ∎


THE INFOGRAPHIC CAN BE REMOVED
AND USED AS A POSTER.

2014 STATUS FOR LNG AS SHIP FUEL

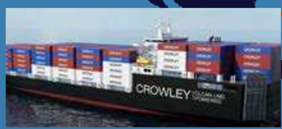
DNV GL takes LNG ship fuel global



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 v
to be converted to LN
fuel.

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

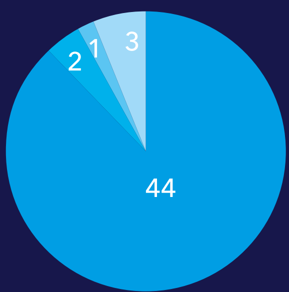


2017
Crowley's 2 ConRo vessels will join TOTE's container vessels on the U.S. – Puerto Rico trade.

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

50 LNG-fuelled ships in operation

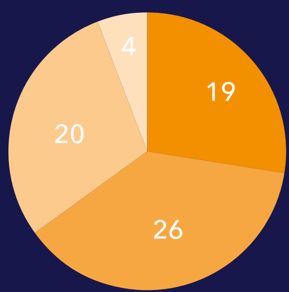
- Norway
- Europe
- America
- Asia & Pacific

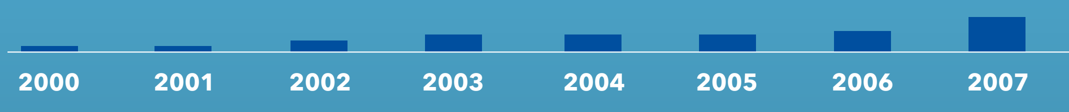


Per 01.09.2014

69 LNG-fuelled ships on order

- Norway
- Europe
- America
- Asia & Pacific





Important events

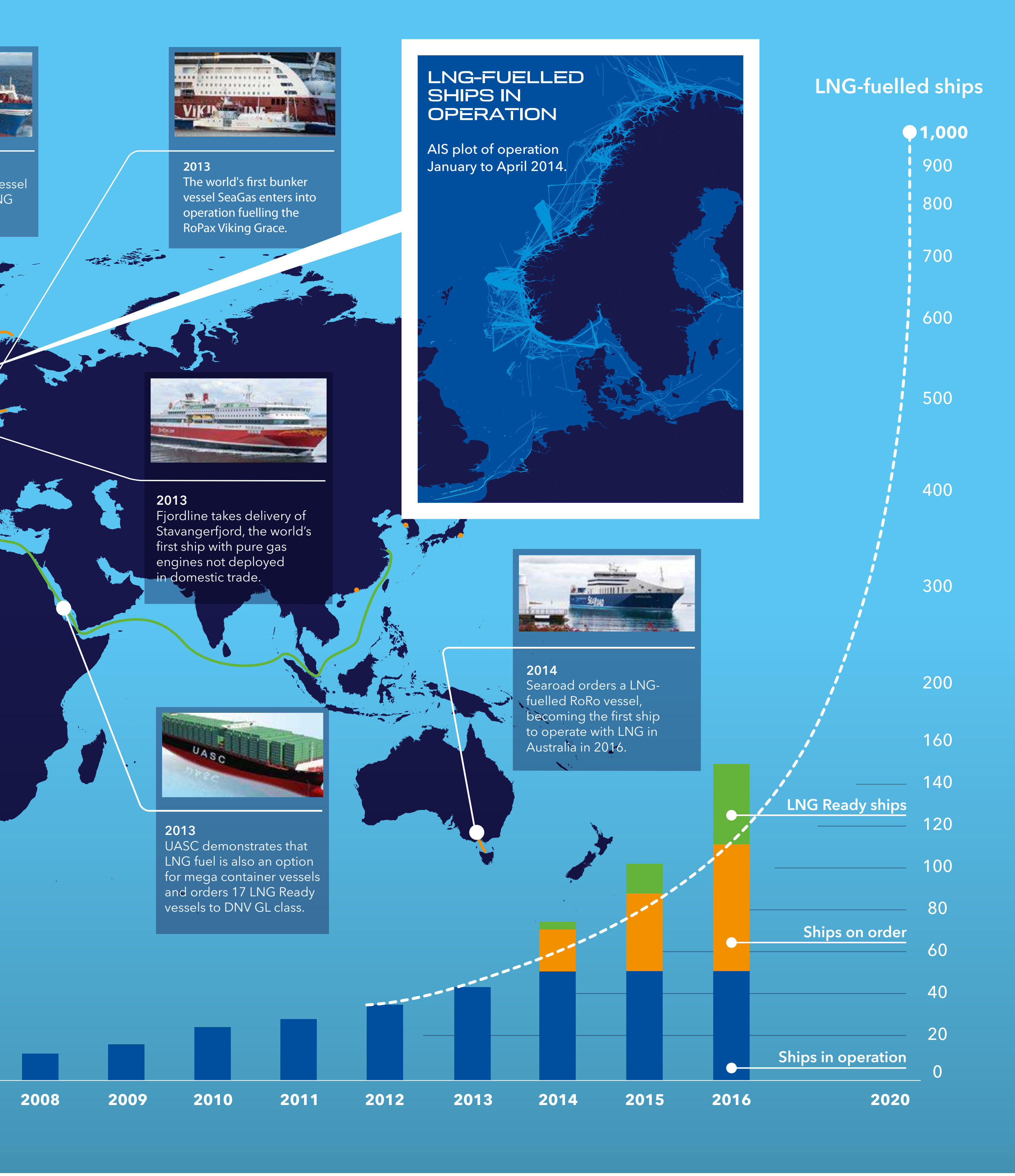
2000
The first LNG-fuelled ship Glutra enters into operation.

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



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.

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MAKING SENSE OF LNG CONTAINMENT SYSTEM INNOVATIONS

Over the past five years, dynamic market forces have generated improvements of existing and new technical solutions for LNG containment systems. DNV GL is working with a number of suppliers to get new systems approved.

Owners active in LNG transportation of large volumes are practically limited to two choices for LNG containment systems: Membrane or type B (spherical). These systems met the needs of segment characterised by stable, long-term point-to-point trades. But according to Magnus Lindgren, Principle Surveyor, Tankers & Dry Cargo for DNV GL, the LNG business is in a period of rapid change.

"Increased concerns about security, the development of floating LNG solutions, new emissions regulations and ship types using LNG as fuel and the development toward reduced boil of rates have helped create demand for new containment systems," he says.

Innovation drivers

Lindgren notes that developments of floating LNG solutions (such as LNG Floating Production, Storage and Offloading (FPSO) units and Floating Storage, Regas Units (FSRUs) have created the need for containment systems that can manage any filling level, while implementation of Environmental Control Areas (ECAs) has led to an increase in dual-fuel propulsion and LNG-fuelled coastal vessels, requiring smaller LNG containment tanks. "These changes have created a growing market not only for suppliers already active in the shipping industry, but companies active in land-based containment systems," he says. "Our primary goal is to ensure that these new systems are safe and effective and for companies with no experience in the maritime industry, ensure that they have the technical support to help them manage the unique challenges of operating systems at sea."

Approvals process

DNV GL is working closely with suppliers to help guide them through the approvals process and compliance with IMO's International Code for the Construction and Equipment of Ships Carrying Liquefied Gases (IGC) and the Corresponding DNV GL Rules. First, suppliers submit designs to DNV GL to review for potential design flaws. Once the designs have been amended to comply with existing standards, DNV GL awards the company an Approval in Principal (AiP) certification. The second phase (GASA) requires full documentation, with comments from DNV GL linked to more detailed engineering.

For example, DNV GL has awarded the Korean Shipyard, DSME an AiP for their new membrane-type containment system, Solidus, which features double stainless-steel barriers and reinforced polyurethane insulation foam, with a secondary barrier secured to the hull with load bearing mastic. In addition, DNV GL has awarded a Norwegian supplier, Torgy with an GASA for a Type A containment system, featuring a stainless steel tank held in position within a space by stainless steel supports. Further, we are working with a large number of other suppliers at various stages of development.

Lightweight composites

One trend in containment systems is the use of technologies and materials already in use in other industries aerospace and land-based industry. "The development of new, lightweight composites has enabled the development of innovative tank designs that are now being further developed for the application to the maritime industry," he says. "While we welcome these developments, we are mindful that the LNG segment is notable for its excellent safety record and our primary goal is to ensure that these systems not only function effectively, but also do not represent a risk to crew, cargo or the environment."

Lindgren acknowledges that the development and the approval process often include several design iterations and therefore takes time – about 18 months and more – but says that owners will soon have access to many different designs that match the operating profile of their vessel – from an FSRU to a coastal ferry. "We are in the middle of an exciting shift in technology for containment systems which will help transform the maritime LNG," he says. " Our role is to ensure that we help suppliers and owners alike manage this shift safely." ▮

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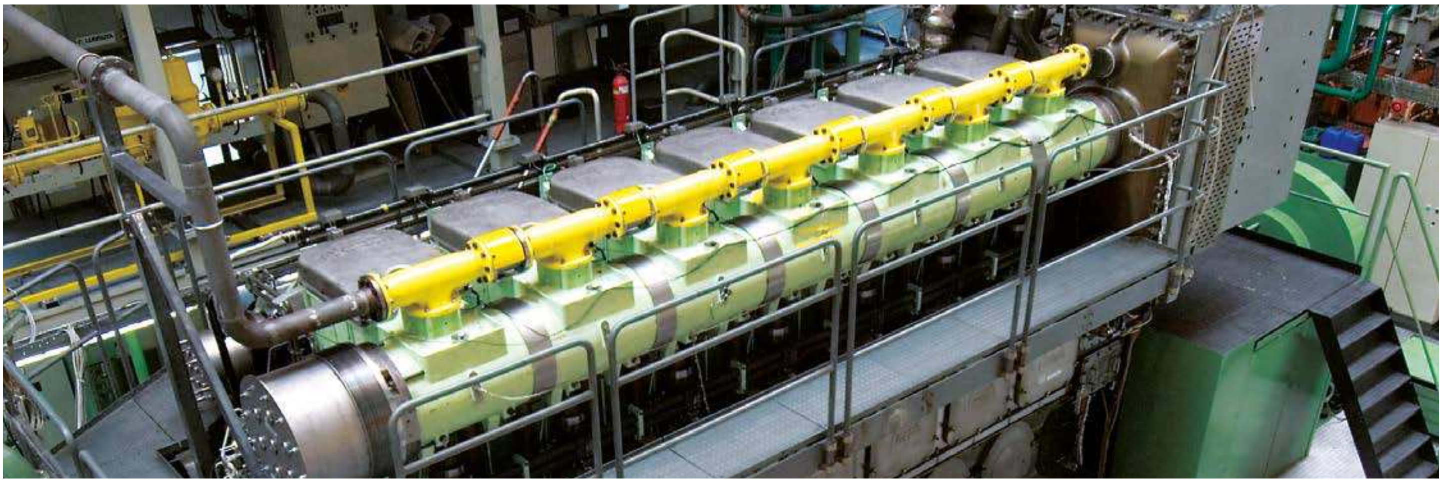
ENGINES FOR GAS-FUELLED SHIPS

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

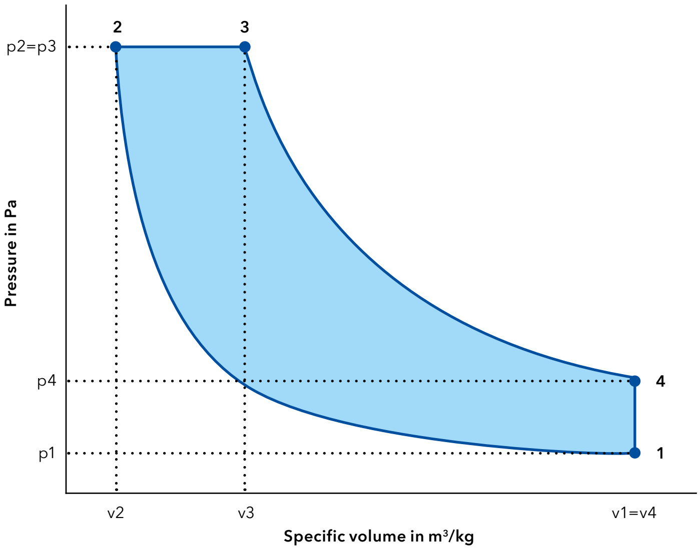


Figure 1: Diesel-Process: const. pressure during combustion (2→3)

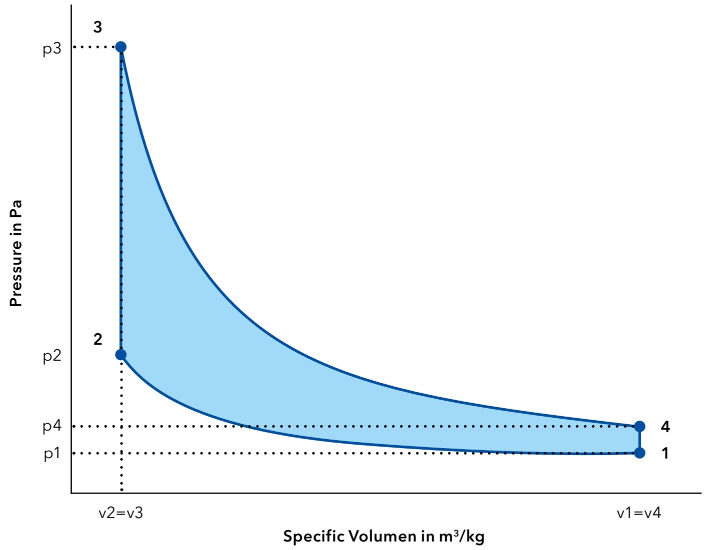


Figure 2: Otto-Process: const. volume during combustion (2→3)

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 (Hu), 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 Hu (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

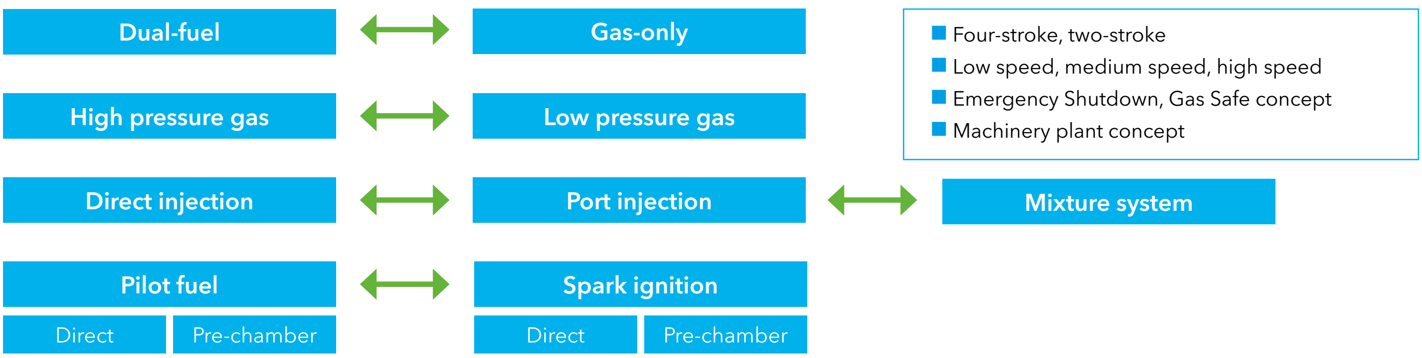
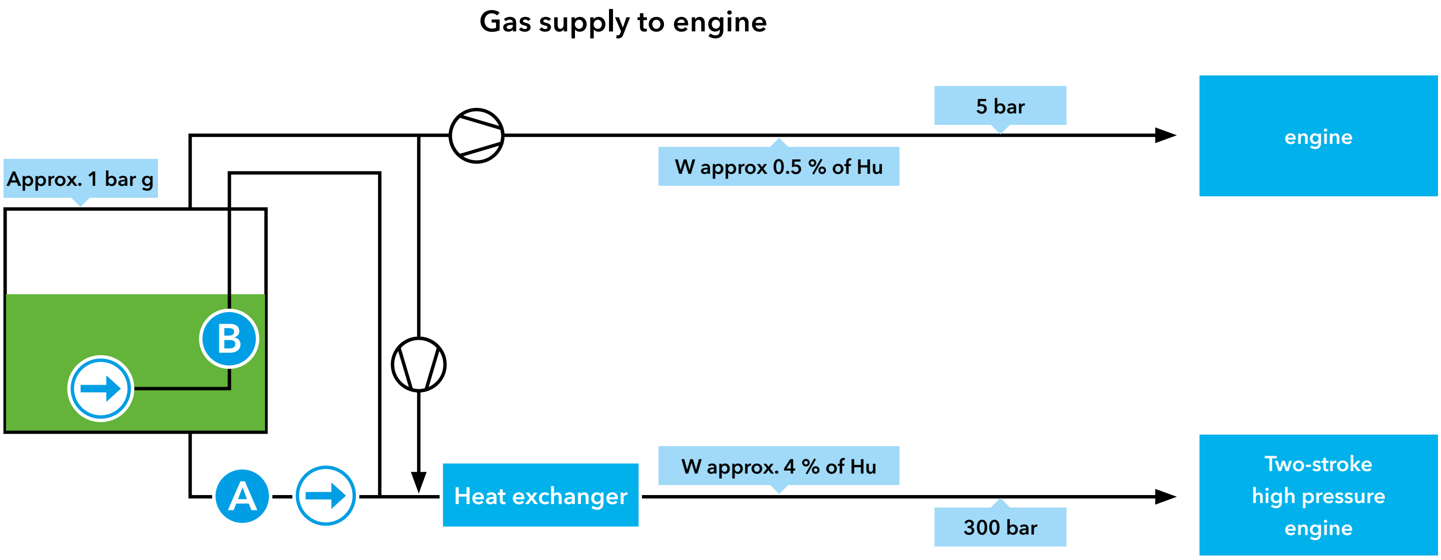


Figure 3



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_x 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_x 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_x	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_2	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					
	CO_2 equivalent [g/MJ] (Tab 3, DNV-2012-0719)			**% CO_2 (HFO=100 %)**	
Data from DNV No 2011-1449, rev 1 (Tab 16 mainly); DNV NO 2012-0719	**Well To Tank CO_2 emissions (WTT)**	**Tank To Propeller CO_2 emissions (TTP)**	**Total CO_2 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_2 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_2. The Kyoto protocol gives Methane a value that is 21 times the global warming potential (GWP) of CO_2. This means that an unburned methane molecule has 21 times the GWP of one molecule of CO_2.

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_2 effect by 26% compared to HFO, compare article on page 14. ∎

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LNG IN THE US

For a long time DNV GL has been looking to LNG as a cost-effective solution to the challenges faced by the maritime industry – particularly challenges related to fuel cost and emissions. This pro-LNG approach, combined with the abundance of inexpensive natural gas in North America, has led to a surge in LNG-related activities. Shipowners in the US are already feeling the effects of tightened Emission Control Area (ECA) regulations. Next year, an increasingly strict sulphur emissions regulation will go into effect. LNG is an attractive fuel choice for many vessels, because it exceeds the air quality standards set forth in the North American Emission Control Area (ECA), and the price of LNG is significantly lower than ECA-compliant fuel.

Several owners have committed to switching to LNG, in anticipation of the strictly limited emissions to air allowed under the North American Emission Control Area (ECA) requirements and Phase II of California's Ocean Going Vessel (OGV) Clean Fuel Regulation. Two owners have already decided to work with DNV GL as they make their first forays into this new chapter of shipping.

DNV GL has been asked by Crowley Maritime to provide classification services for its two new LNG-powered ConRo ships to be built at VT Halter Marine in Pascagoula, Mississippi. The ConRos will transport vehicles and containers between the US and Puerto Rico. The 219.5 meter long vessels will have space for 2400 TEU and 400 vehicles, and will meet the DNV GL Green Passport and CLEAN class notation environmental standards.

Tucker Gilliam, Crowley's Vice President of Special Projects, says the company was pleased with DNV GL's expertise and professionalism during the project. "Over the past year and a half VT Halter Marine, Wärtsilä Ship Design, Crowley, and DNV GL have worked very hard to develop an evolutionary ship design that will yield a higher level of safety and environmental responsibility," he says.

"The name 'Commitment Class' was chosen to represent Crowley's commitment to the Puerto Trade, but it is also a fitting tribute to the commitment from firms such as DNV GL, who helped us design and deliver a safer, smarter, greener class of ships."

Bill Skinner, CEO of VT Halter Marine added: "DNV GL has demonstrated that they have the knowledge and experience to ensure that our first LNG-powered vessel construction program will be a successful one," he said. "DNV GL's outstanding support during the construction of VT Halter Marine's prior RO/RO and ConRo vessels ensured that they were the surveyors of choice for this programme."

Another shipowner, Matson, has also decided to construct two new Aloha class 3600TEU containerships at Aker Philadelphia Shipyard with DNV GL as its partner for classification. Designed for service between Hawaii and the West Coast, the 260.3 meter long vessels will be the largest containership constructed in the US and feature dual-fuel engines and hull forms optimised for energy efficient operations.

"We are proud to have been chosen to support Matson and Crowley on these ground-breaking projects," says Paal Johansen, Vice President and Regional Director Americas at DNV GL. "Their vision in taking this step forward will not only enhance their own competitiveness, but will prove valuable for the US shipping industry as a whole. This will also give the yards the opportunity to develop and showcase new competencies, while spurring infrastructure development around the country. Their customers will benefit from access to the latest generation of highly efficient ship designs."

DNV GL forms LNG solutions group in the Americas

DNV GL has also established a Houston-based LNG Solutions Group – Americas. It offers deep LNG expertise, as well as extensive experience in business, risk and regulatory matters specific to the North American market. The LNG Ready service is also part of the service portfolio, offered by the DNV GL Advisory Service in Houston (see LNG Ready, page 12).

"By drawing on our expertise from oil and gas we can offer an unrivalled set of capabilities, from major export or liquefaction projects to small-scale bunkering and everything in between," says Bjørn-Harald Bangstein, Director of Operations Maritime Advisory for DNV GL Americas. "We are happy to see shipowners, yards, ports, bunkering operators, and LNG proponents well-positioned for LNG," he says.

Study for IMO MEPC 66

DNV GL was engaged by the International Maritime Organization (IMO) to study the feasibility of using LNG as a ship fuel for international shipping in the North American ECA. The study identified the necessary conditions for the successful implementation of LNG as a fuel source for shipping in the region.

MARAD

The US Department of Transportation's Maritime Administration (MARAD) awarded DNV GL a contract to analyse the issues and challenges associated with LNG bunkering, and the landside infrastructure needed to store and distribute LNG. The study was delivered in spring 2014. Because the development of infrastructure is acutely dependent on the needs of specific ports and stakeholders, there is no one size fits all bunkering option for the USA.

To address the key factors for the development of infrastructure at a port, four potential bunkering options were identified and evaluated: truck to ship, shore to ship, ship to ship, and portable tank transfer. The report concluded that the development and implementation of a regulatory approval process for LNG bunkering operations and associated facilities should include a Quantitative Risk Assessment (QRA) that utilizes probabilistic risk acceptance criteria to assess the acceptability of the risk posed. To promote safe LNG bunkering operations, the approval should also include completion of a port risk assessment at each port where LNG bunkering will likely take place. The development of a methodology for, and completion of a quantitative port-wide navigational risk assessment that determines how changes in traffic character and frequency/ density affect the safety and security of the public, workers, critical infrastructure, and commercial operations is essential. Effective security and safety zone enforcement procedures to promote a safe environment for the port population, is also necessary.

Regulatory gaps were identified for LNG metrology, local vs. federal jurisdiction over bunkering operations, and a lack of framework for the review of potential risks related to LNG

bunkering from non-self-propelled barges. There is a need for greater clarity in regulations addressing simultaneous operations (SIMOPS). Proper training for crew and operators involved with LNG bunkering operations is critical for the establishment and maintenance of safe practices. The report provides a training scheme for crew and first responders that addresses basic, advanced, and site-specific recommended practices.

The Houston-based group of LNG experts has been communicating frequently with regulatory bodies, including the US Coast Guard, in an effort to understand and help ensure compliance with new US regulations.

"Through our interfaces with the US Coast Guard, we know that they are now finalizing the remaining regulatory requirements on a detailed level," Bangstein says. "They are doing so in an open and consultative manner that involves the industry and prevents surprises and misunderstandings. Naturally, there could be additional state, county, and municipal regulations.

But with a national regulatory framework designed to prevent major hazards using a risk-based approach, local variations can be addressed through risk assessments, allowing for a consistent and predictable national regulatory framework." ∎

THE US COAST GUARD:

Working with the industry for a safe and secure introduction of LNG as a fuel

With the stricter regulation of sulphur emissions in force next year and the already tightened Emission Control Area regulation for the US, shipowners are likely to feel more pain with the rising fuel prices for ECA compliant fuel. For instance, Marine Gas Oil (MGO), will likely see a price jump in January, possibly as high as 30% in the short term, and a minimum of 20% in the long run. This, combined with the abundance of cheaper natural gas in North America, is contributing to a surge in LNG activities.

Normally, the industry is grumbling that there are too many regulations. When it comes to LNG, there are those who also complain that there is too little regulation.

The US Coast Guard's LNG expert responds: "We understand and appreciate the situation. LNG as a fuel is new technology, presenting important safety and security concerns that need to be addressed. The public is used to seeing us fill this role and the industry would like us to establish minimum safety standards. So we are already working with the industry in a structured way to determine how best practices, experiences and needs should shape our regulations."

"We apply existing regulations with regard to safety. Currently, existing regulations in force specifically written to cover LNG are applicable to LNG as cargo, and the transfer of LNG cargo. So there are gaps, and we cover them through our policy letters, some of which are completed and some of which are currently being studied and commented upon by the industry in draft form. Topics covered by policy letters include operations like bunkering, training of crew, transfer of personnel and infrastructure for transfers," he says.

The USCG has an effective collaboration internally to prepare and share knowledge within its organization: "We have an internal LNG as fuel network that includes personnel from Coast Guard units around the country who are actively working on LNG projects in their local areas. Conference calls are held which allow us to discuss unique matters concerning various LNG projects and provides a forum for sharing information related to standards, studies, reports, technologies, and new projects which may be on the horizon," Ken Smith explains.

Commenting on how DNV GL can be of assistance to the USCG, he says "DNV GL is already doing everything the USCG could hope for and more, and we recognize and appreciate the vast experience and in-depth expertise that DNV GL has when it comes to LNG as fuel, both here in the US and internationally. The recommended practices and standards that you issue and the work you have done in other technical committees are helping to shape our policies and regulations in this area."

Interview with the USCG's LNG experts:

Ken Smith
Office of Vessels' and Facilities' Operating Standards, General Engineer

Text: Kevin Gallagher, Blue-C

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 com- pleted 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. ∎

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SMALL-SCALE LNG INFRASTRUCTURE DEVELOPMENT

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

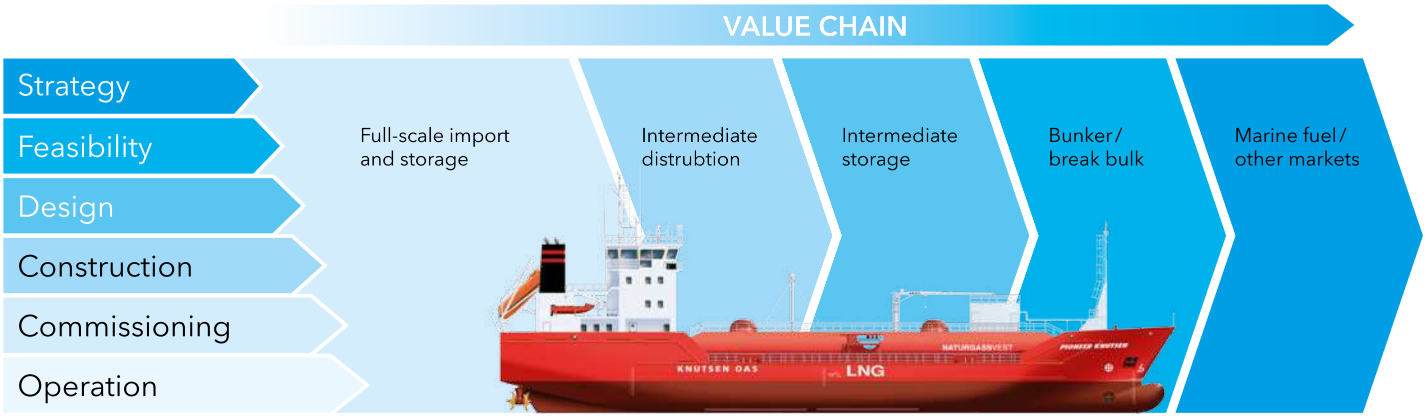


Figure 1 – Small scale LNG: an emerging industry in its infancy

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 m³ to the current largest carriers with 266,000 m³. 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.

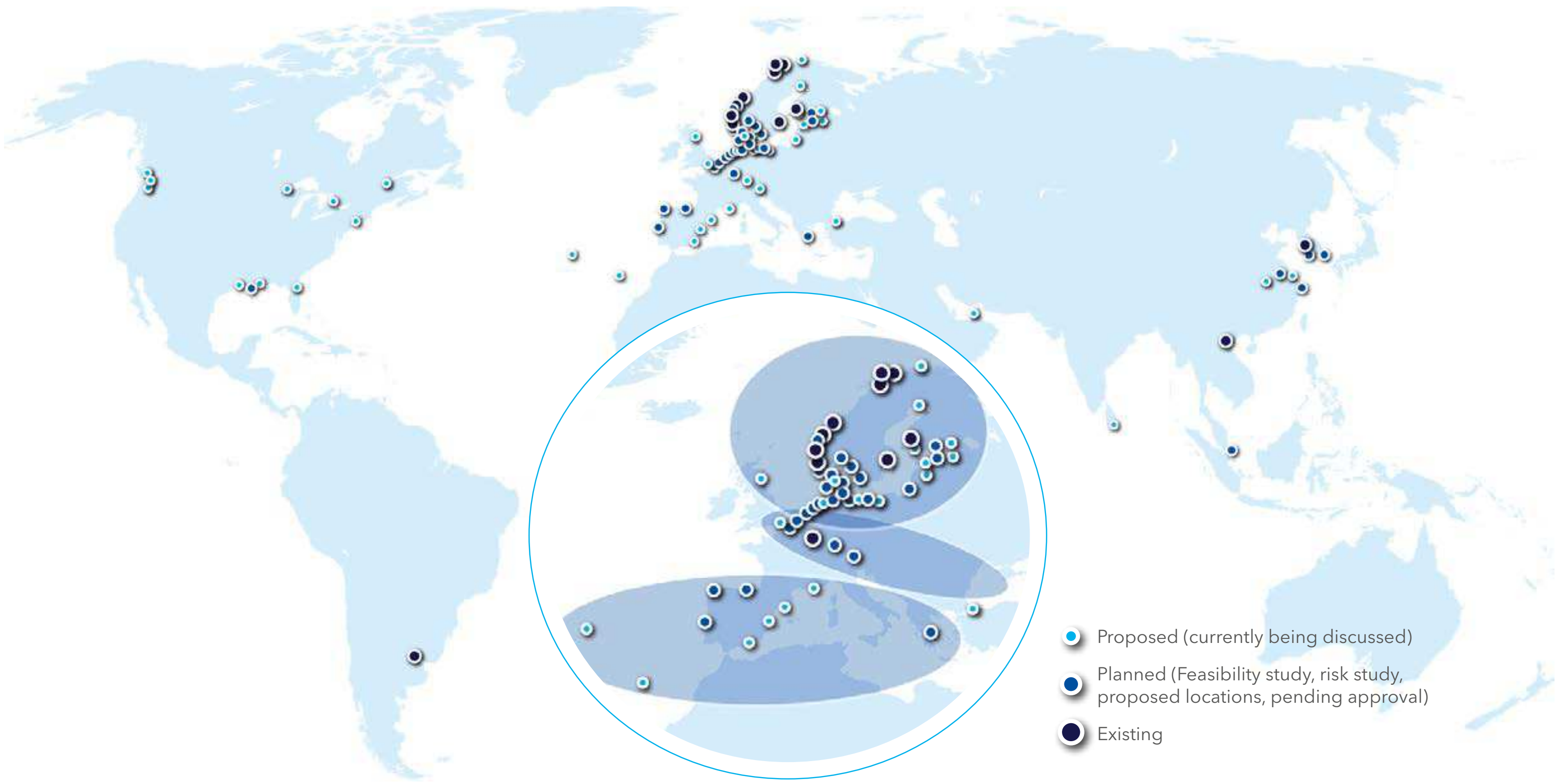


Figure 2 – Global LNG cluster

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 southernmost 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_x 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.

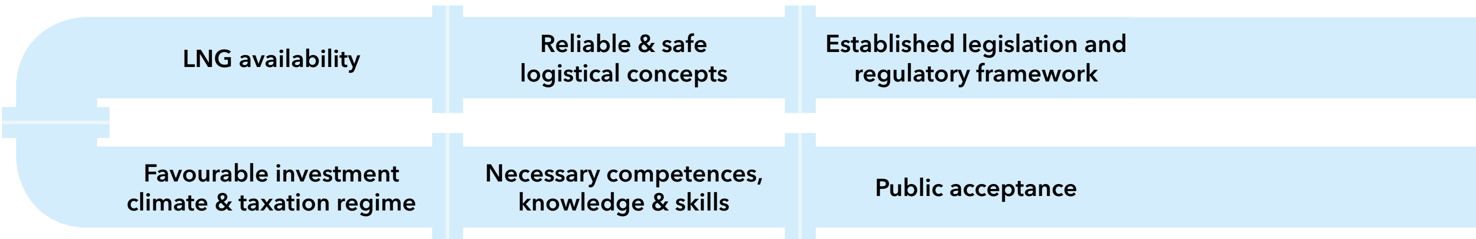


Figure 4 – Cornerstones for establishing small-scale LNG infrastructure

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

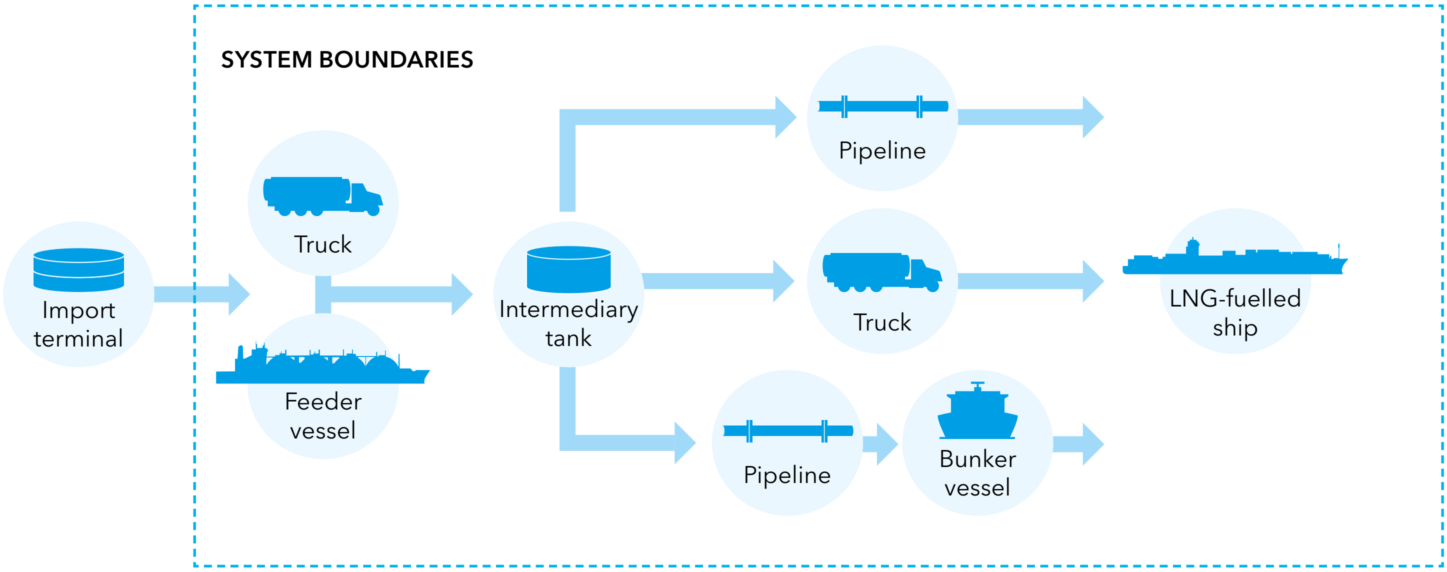


Figure 5 – local small scale LNG value chain

		Strategy	Feasability	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 Suplier 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)

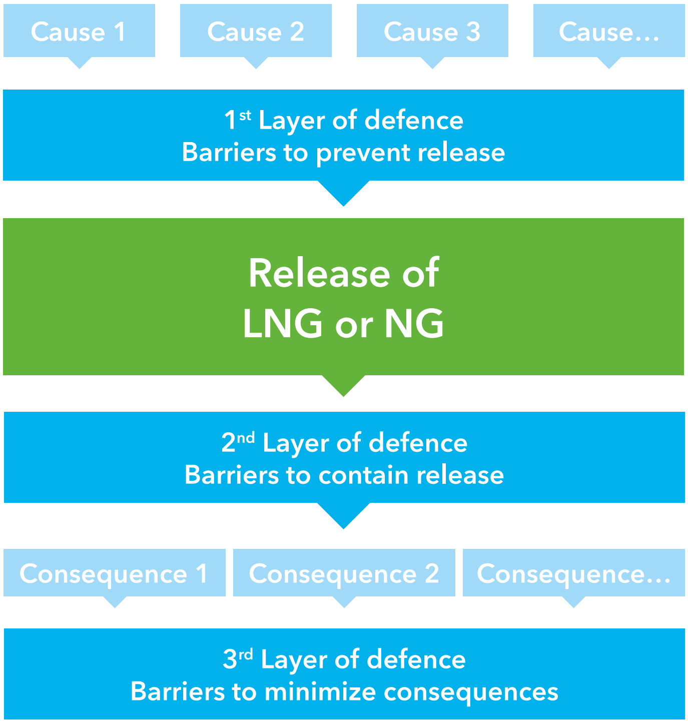


Figure 7 – Barriers, layers of defence (source: DNV GL Recommended Practice for Developing and Operating LNG bunkering facilities)

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. ▮

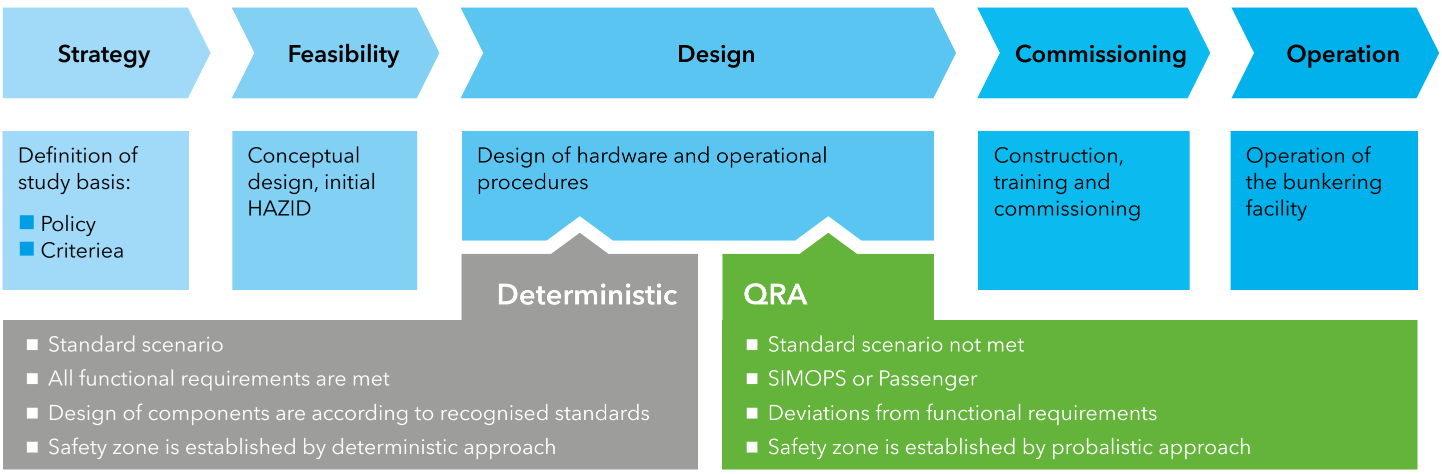


Figure 8 – Risk assessment in the context of LNG bunker installations (source: DNV GL Recommended Practice for Developing and Operating LNG bunkering facilities)

VESSELS ON ORDER

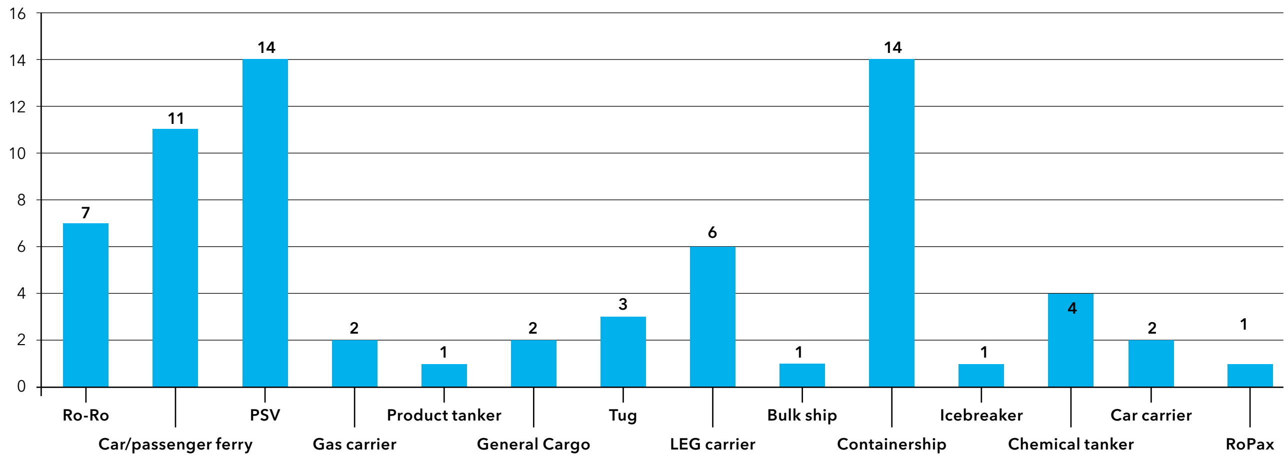
69 LNG-fuelled vessels currently on order*
as of September 2014

YEAR	TYPE OF VESSEL	OWNER	CLASS
2014	Ro-Ro	Norlines	DNV GL
2014	Ro-Ro	Norlines	DNV GL
2014	Car/passenger ferry	Society of Quebec ferries	
2014	Car/passenger ferry	Society of Quebec ferries	
2014	Car/passenger ferry	Society of Quebec ferries	
2014	PSV	Harvey Gulf International Marine	
2014	PSV	Harvey Gulf International Marine	
2014	PSV	Harvey Gulf International Marine	
2014	PSV	Harvey Gulf International Marine	
2014	Gas carrier	SABIC	
2014	Gas carrier	SABIC	
2014	Product tanker	Bergen Tankers	
2014	General Cargo	Egil Ulvan Rederi	DNV GL
2014	General Cargo	Egil Ulvan Rederi	DNV GL
2014	PSV	Remøy Shipping	DNV GL
2014	Car/passenger ferry	AG Ems	DNV GL
2014	Car/passenger ferry	AG Ems	DNV GL
2014	Car/passenger ferry	Samsoe municipality	DNV GL
2014	Ro-Ro	Sea-Cargo	DNV GL
2014	Ro-Ro	Sea-Cargo	DNV GL
2014	Tug	CNOOC	
2015	Tug	CNOOC	
2015	PSV	Siem Offshore	DNV GL
2015	PSV	Siem Offshore	DNV GL
2015	PSV	Simon Møkster Shipping	DNV GL
2015	PSV	Harvey Gulf International Marine	
2015	PSV	Harvey Gulf International Marine	
2015	Tug	NYK	
2015	LEG carrier	Evergas	
2015	LEG carrier	Evergas	
2015	LEG carrier	Evergas	
2015	Bulk ship	Erik Thun	
2015	Containership	Brodosplit	DNV GL
2015	Containership	Brodosplit	DNV GL

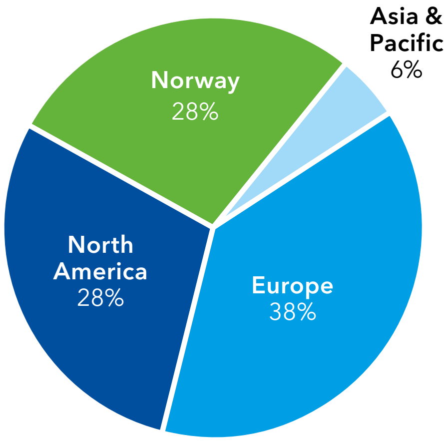
YEAR	TYPE OF VESSEL	OWNER	CLASS
2015	PSV	Siem Offshore	DNV GL
2015	PSV	Siem Offshore	DNV GL
2015	Containership	TOTE Shipholdings	
2016	Containership	TOTE Shipholdings	
2016	Icebreaker	Finnish Transport Agency	
2016	PSV	Siem Offshore	DNV GL
2016	PSV	Siem Offshore	DNV GL
2016	Chemical tanker	Terntank	
2016	Chemical tanker	Terntank	
2016	Chemical tanker	Terntank	
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
2016	Containership	GNS Shipping	
2016	Containership	GNS Shipping	
2016	Ro-Ro	SeaRoad Holdings	DNV GL
2016	Car/passenger ferry	BC Ferries	
2016	Car/passenger ferry	BC Ferries	
2016	LEG carrier	Ocean Yield	DNV GL
2016	LEG carrier	Ocean Yield	DNV GL
2016	LEG carrier	Ocean Yield	DNV GL
2016	Containership	Universal Marine	DNV GL
2016	Containership	Universal Marine	DNV GL
2017	Containership	Universal Marine	DNV GL
2017	Containership	Universal Marine	DNV GL
2017	Car/passenger ferry	BC Ferries	
2017	Chemical tanker	Terntank	
2017	RoPax	Brittany Ferries	
2017	Containership	Crowley Maritime Corporation	DNV GL
2017	Containership	Crowley Maritime Corporation	DNV GL
2018	Containership	Matson Navigation Company	DNV GL
2018	Containership	Matson Navigation Company	DNV GL

*LNG carriers and inland waterway vessels are not included.

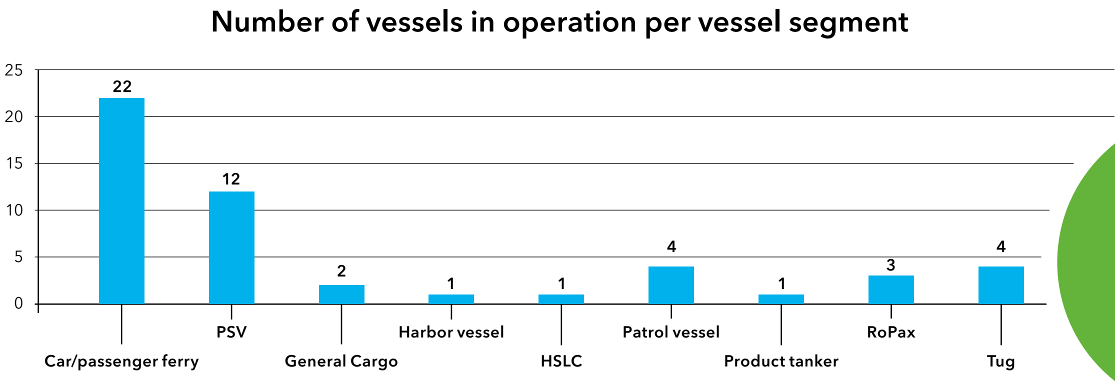
Number of vessels on order per vessel segment

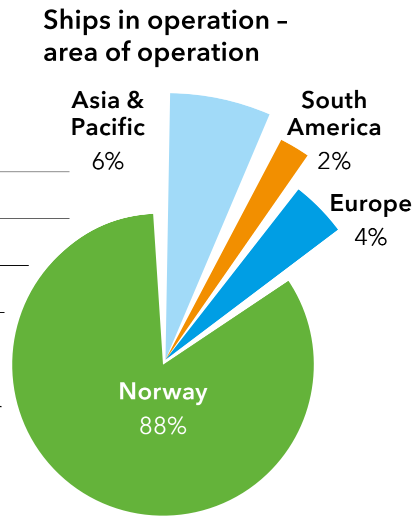


Confirmed orderbook – area of operation



VESSELS IN OPERATION





50 LNG-fuelled vessels worldwide*
currently in operation as of September 2014

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
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	Product tanker	Tarbit Shipping	DNV GL
2011	Car/passenger ferry	Fjord1	DNV GL
2011	PSV	Solstad Rederi	DNV GL

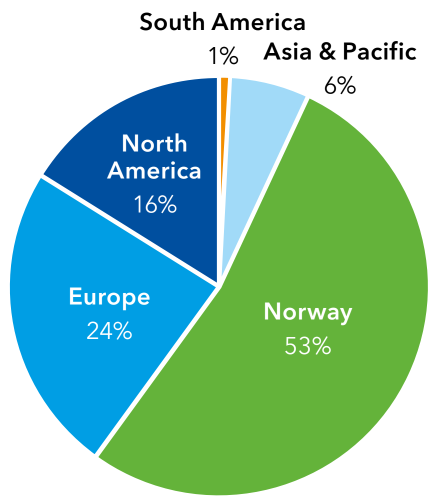
YEAR	TYPE OF VESSEL	OWNER	CLASS
2012	Car/passenger ferry	Fjord1	DNV GL
2012	PSV	Eidesvik Shipping	DNV GL
2012	PSV	Olympic Shipping	DNV GL
2012	PSV	Island Offshore	DNV GL
2012	General Cargo	Nordnorsk Shipping	DNV GL
2012	PSV	Eidesvik Shipping	DNV GL
2012	PSV	Island Offshore	DNV GL
2012	Car/passenger ferry	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	
2013	Car/passenger ferry	Torghatten Nord	DNV GL
2013	Harbor vessel	Incheon Port Authority	
2013	General Cargo	Eidsvaag	DNV GL
2013	RoPax	Fjordline	DNV GL
2013	HSLC	Buquebus	DNV GL
2013	Tug	CNOOC	
2013	Tug	CNOOC	
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

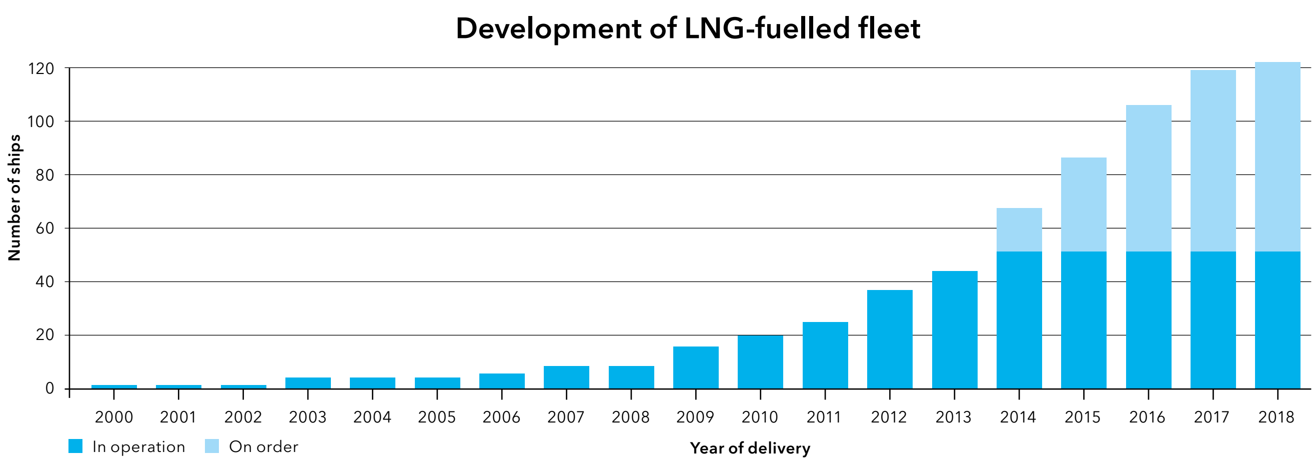
*LNG carriers and inland waterway vessels are not included.

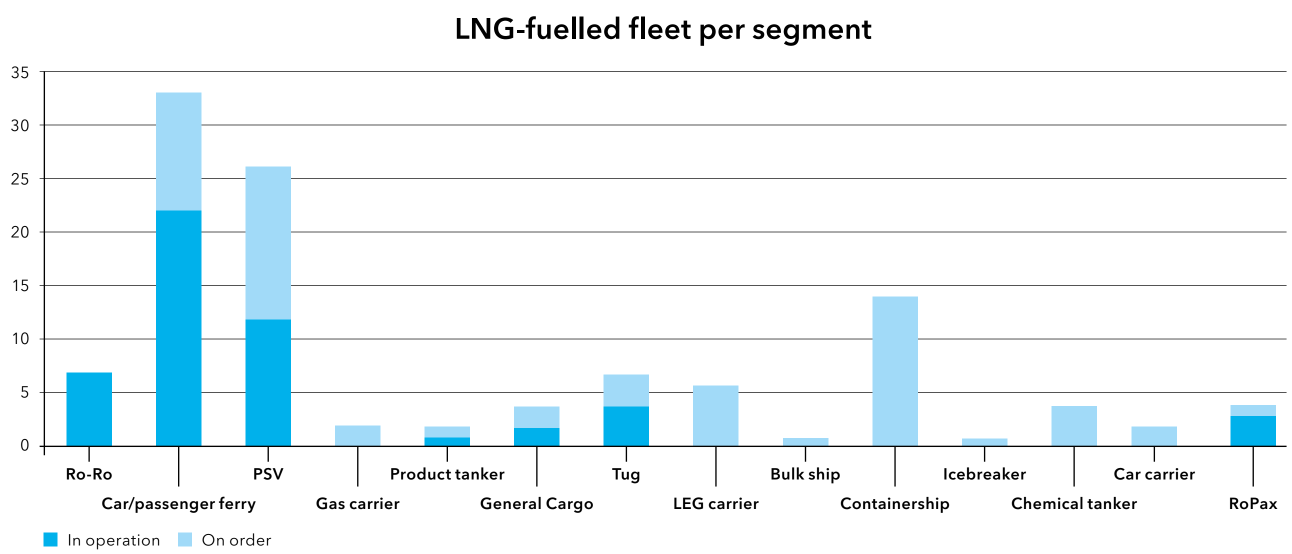
SUMMARY

ALL CONFIRMED PROJECTS

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







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

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.

2001

- DNV publishes the first rules for gas-fuelled ships

2004

- Norwegian Maritime Directorate (NMD) proposal to develop the IMO IGF Code

2004-09

- DNV and GL worked for Norwegian/German Administrations for the development of MSC.285 (86)

2009-14

- DNV and GL worked for Norwegian/German Administration on the development of the IGF Code

2010

- IMO MSC.285(86) Interim Guidelines on Safety for Natural Gas-fuelled Engines comes into force. The guidelines are developed based on DNV rules

2011

- DNV initiated the development of the ISO technical report on bunkering of LNG (Work package in ISO TC 67 – Guidelines for systems and installations to supply of LNG as fuel to ships), to be published in 2015

2012

- DNV: Crew Training - SoC 3.325; The use of LNG as a fuel on board vessels

2013

- DNV Rules Part 6 Ch 13: Gas Fuelled Ship Installations (Vers Jan 2013)
- GL Rules VI-3-1: Guidelines for use of Gas as Fuel for Ships
- DNV GL launches the LNG Ready service
- DNV GL launches Recommended Practice for LNG Bunkering providing the industry with the first practical tool for developing bunkering procedures

2015

- "GAS READY" class notation

Text: Simon Adams
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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 operational 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.

Henning Mohn and Anders Mikkelesen
Henning.Mohn@dnvgl.com and Anders.Mikkelsesen@dnvgl.com

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: • Design review • Approval in Principle • Certification of materials and components • Plan approval • New build surveys • Fleet in Service surveys	✓			✓	✓		✓
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 chose 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 worlds 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 Møkster 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 vessels of 14,000 TEU and six of 18,000 TEU. The first LNG Ready vessel is already scheduled for delivery in November 2014. DNV GL has worked closely with UASC and the yards in order to make the first ultra large LNG Ready container vessels reality.

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^3 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' (build 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.

GLOBAL COMPETENCE ON LNG AS FUEL

DNV GL's global presence is complemented by our local networks – giving you a point of contact in your region who can rapidly respond with a targeted solution to best meet your individual needs.

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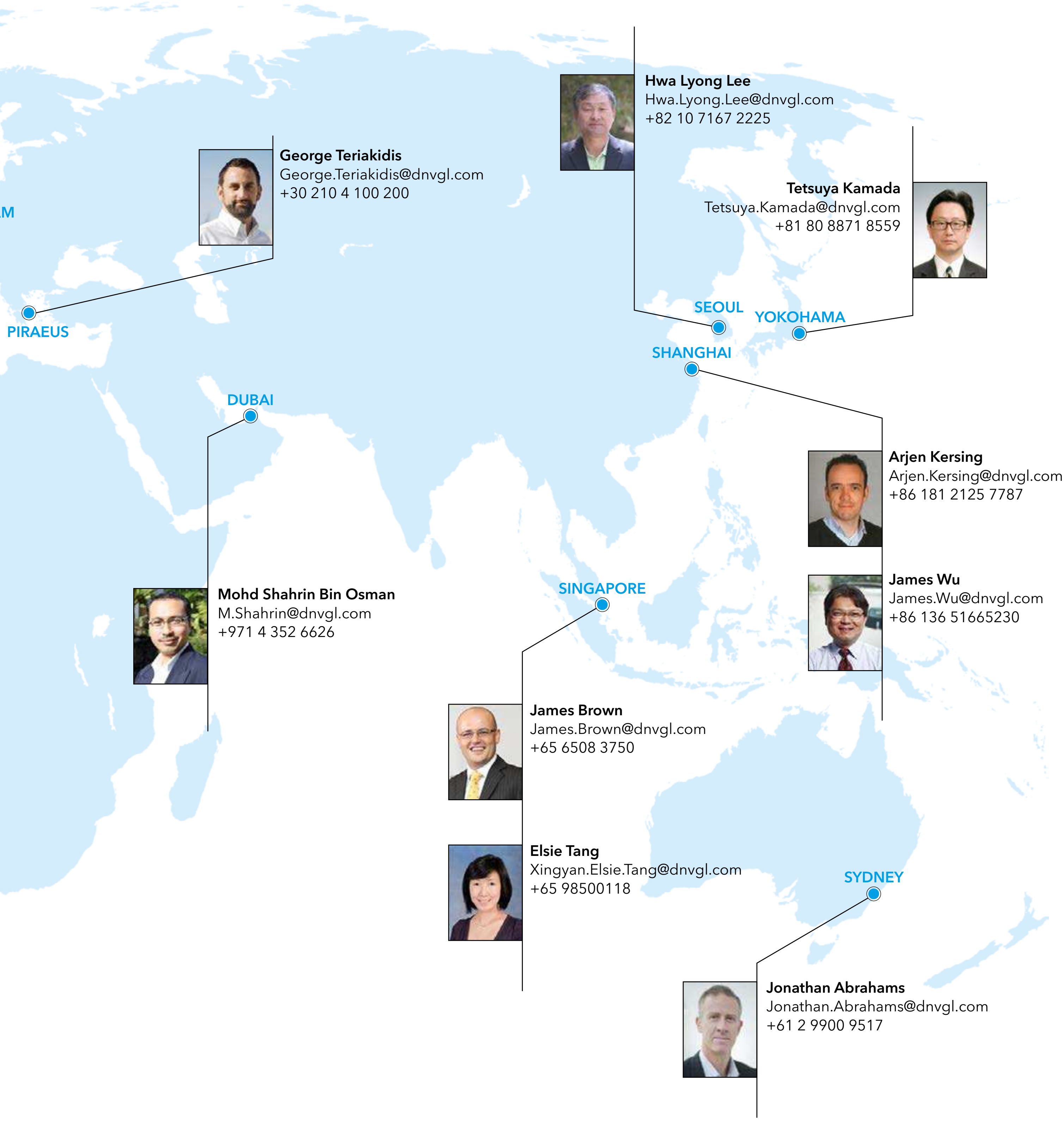

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