WÄRTSILÄ

LNG Shipping Solutions

Gas bunkering doesn't usually affect the normal operations of LNG fuelled ships. All commercial activities while in port can be performed as usual.

Dual-fuel Installation Advantages

Gas: a green solution

In an era characterised by ever more stringent emission regulations and volatile fuel prices, ship owners and operators are faced with serious challenges.

Different authorities are setting environmental requirements aimed at respecting international standards. Nevertheless, at the same time they stress the importance of a localised approach.

So, how to comply with new environmental rules and yet maintain cost-efficient operations? A complete range of diversified alternatives could be proposed but only one seems to fulfil all the requirements – switching to natural gas.

Natural gas (NG) is a mixture of different gases consisting primarily of methane. It is usually found in association with fossil fuels and in the past represented a by-product of oil production. Unwanted natural gas was burned off at the well site or pumped back into the oil reservoir with an "injection well".

Today, natural gas is traded around the world by pipeline (in its gaseous form) or by sea in its liquid form (liquefied natural gas, LNG).

The advantage of transporting LNG is clear: a defined volume of LNG contains approximately 600 times more energy than the same volume of NG. The transformation from gaseous to liquid form implies that cryogenic temperatures have been reached.

Liquefied natural gas is the most advantageous means of transporting and storing gas onboard. However, all equipment related to gas storage, handling and utilisation should be designed so that the cryogenic conditions are continuously maintained, thereby ensuring the safety and reliability of the installation.

Gas is the most affordable liquid fuel

Liquid fossil fuels and natural gas are normally priced by using two different measuring units.

- Heavy fuel oil (HFO), marine diesel oil (MDO) and marine gas oil (MGO) are quoted based on a price-per-mass quantity, the common unit being "United States Dollars per ton of liquid fuel – USD/ton"
- Natural gas prices, on the other hand, are usually set by the traded energy content, the commonly utilised unit being "United States Dollars per million British Thermal Units – USD/MMBTU"

This difference is derived from the fact that liquid fuels have fairly standardised and constant energy contents, while the energy content for natural gas varies depending on its composition.

In order to be able to compare the price of liquid fuels with that of natural gas, they should all be harmonised according to a common energy unit (MMBTU, for example).

Results show that natural gas has always been cost competitive against other marine fossil fuels, and its price has consistently been lower than any other single liquid fuel alternative.

Fuel flexibility

Fuel flexibility gives owners and operators the chance to select the most suitable fuel depending on such factors as local environmental restrictions, fuel price variations, and fuel bunkering availability.

Fuel flexibility also represents a safety feature of particular interest for marine applications. For example, should the gas supply be interrupted for any reason, dual-

The world's first LNG powered PSV, the 'Viking Energy', designed and powered by Wärtsilä, has been in operation since 2003.

fuel (DF) engines automatically and instantly change to diesel operation without any loss in speed or power. This feature ensures an additional level of operational safety, not present in a single-fuel installation.

A unique feature of Wärtsilä dual-fuel engines is their ability to run on natural gas, marine diesel oil, heavy fuel oil and bio fuels, thus providing maximum flexibility in fuel choice.

Outstanding emissions compliancy

By switching the main source of power from liquid residual fuels to natural gas, the challenges imposed by increasingly stringent emission regulations can be met and overcome.

When a medium-speed DF engine runs in "gas mode" (natural gas as the primary source of energy), the following targets are achieved:

- CO_2 emissions are reduced by approximately 30%, thanks to a lower carbon content in natural gas compared to liquid fuels.
- NO_X emissions are reduced by approximately 85%, thanks to the lean burn combustion process implemented in DF engines.
- SO_X emissions are almost completely eliminated, since natural gas does not contain any sulphur.
- Particle production is practically non-existent, due to the efficient combustion of natural gas, a fuel with almost no residuals.

In gas mode, Wärtsilä medium-speed DF engines are already compliant with the IMO's Tier III regulations without the need of any secondary exhaust gas purification systems. Furthermore, in liquid fuel oil mode, all Wärtsilä DF engines are fully compliant with the IMO's Tier II exhaust emission regulations set out in Annex VI of the MARPOL 73/78 convention.

Availability of gas

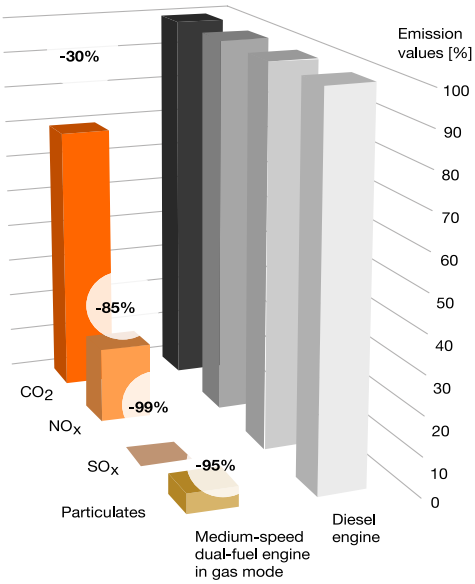
Natural gas in its liquid form is transported by sea. Liquefied natural gas carriers move massive quantities of natural gas from liquefaction terminals to regasification terminals, all around the globe. Liquefied natural gas is available at all these on-shore facilities.

Marine LNG import and export terminals are to be found virtually everywhere, meaning that LNG is basically available anywhere in the world. A number of new additional terminals are planned to come on stream during the next few years.

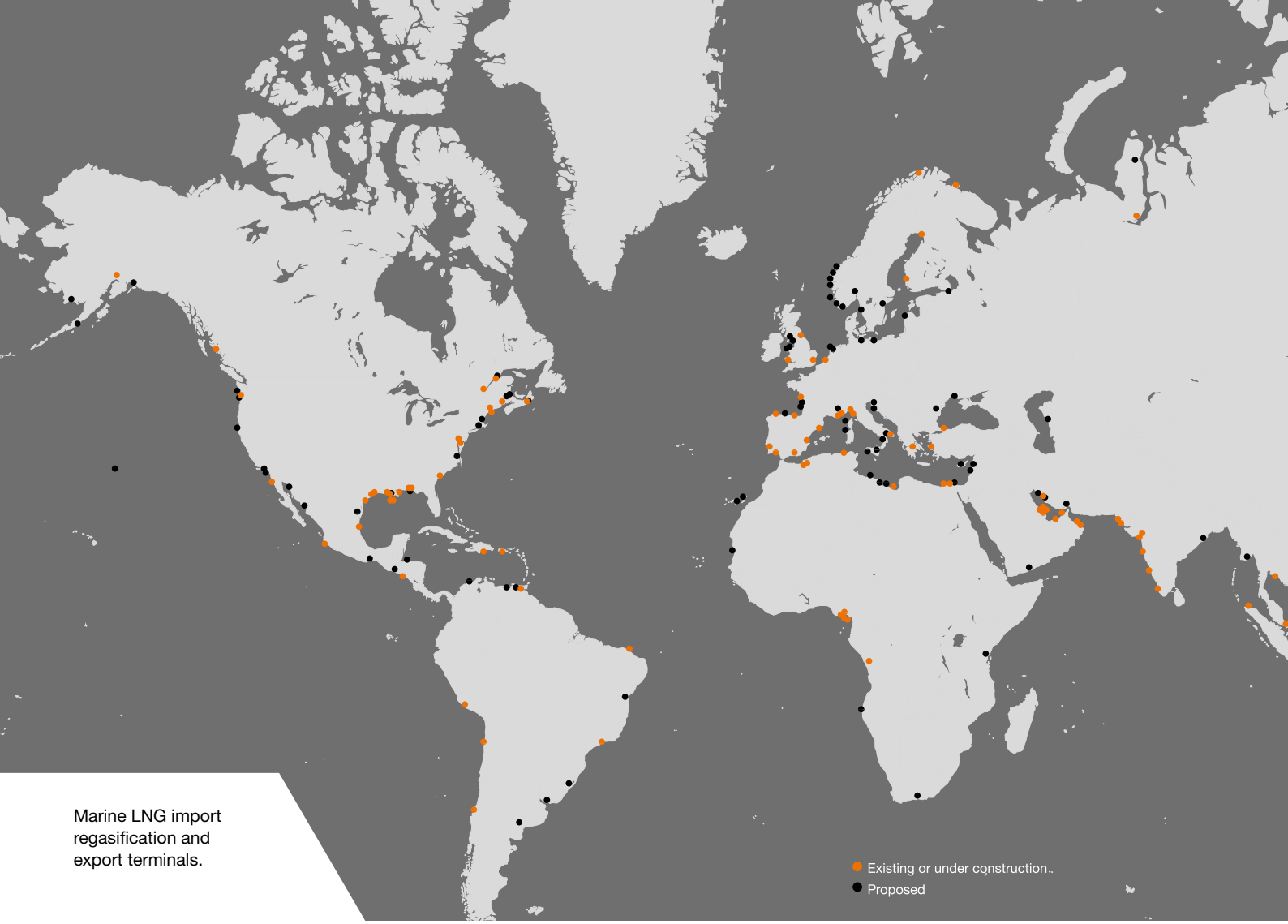
The Wärtsilä LNG bunker carrier

However, as the current gas market is focused mainly on large-scale production and distribution, very few operators are ready to deliver LNG to vessels for use as fuel.

In order to overcome this problem, Wärtsilä has developed its 6,500 cbm LNG



Example of emission reductions obtained by switching to gas.



Marine LNG import regasification and export terminals.

bunker carrier, the WSD59 6.5K, a self-propelled bunkering vessel able to transport LNG from standard large-scale facilities directly to the mooring sites.

When a vessel is powered by Wärtsilä DF engines utilising LNG as the primary marine fuel, gas bunkering has no impact on the time spent in port. All commercial activities during the port call can be performed as normal while the LNG tank is, at the same time, being refilled by the LNG carrier.

The Wärtsilä LNG bunker carrier is designed with a diesel-electric/mechanical application based on the Wärtsilä 20DF engine.

The LNG bunker carrier uses gas as its main source of energy, thus contributing to a reduction in the environmental impact of the total chain.

This consideration is particularly important since these vessels operate entirely within harbours or along coastal areas.

The complete bunker system

Wärtsilä provides all the necessary elements for marine LNG bunkering operations, for which the fuel transfer pump plays an important role.

For more than 50 years, Wärtsilä Svanehøj has been the market leader in cryogenic cargo pumps for liquid gas, and more than 1.000 ships are utilising our pumps.

When selecting a pump for bunkering operations, it is important to consider the quality of the LNG and the type of receiving tank system. The flexibility of our variable speed pumps enables bunker vessels to supply any fuel tank system, regardless of the design pressure and flow.

Cost-efficient shaft generators

Wärtsilä provides shaft generators with PWM technology for PTO and PTI solutions, including take home drives (PTH). They are cost-effective to operate and in compliance with environmental legislation. The high level of flexibility allows the systems to be applied in combination with exhaust gas and steam turbine generators, as well as in shore connection applications. The system configuration can be adapted to the owner's needs and ship types with LV and MV power distribution.

In particular, LNG carrier vessels benefit from the Wärtsilä shaft generator system since it enables the ship to use this environmental friendly power to keep the valuable cargo cooled down to below -100°C without the use of auxiliary engines.

Dual-fuel applications in the marine industry

The marine applications that benefit the most from gas operation, are those vessels whose operations incur a potential risk of non-compliance with environmental regulations.

Dual-fuel technology is elegantly solving the challenges set by present and upcoming emissions legislation without the need for installing any exhaust abatement equipment in the exhaust pipe.

Short-sea routers, as well as ferries constantly operating between defined ports, are the main applications where a propulsion train based on gas-propulsion offers the biggest advantages. This

Examples of LNG-fuelled vessel typologies

Low Emission Container Feeder: WSD80 3800 TEU.

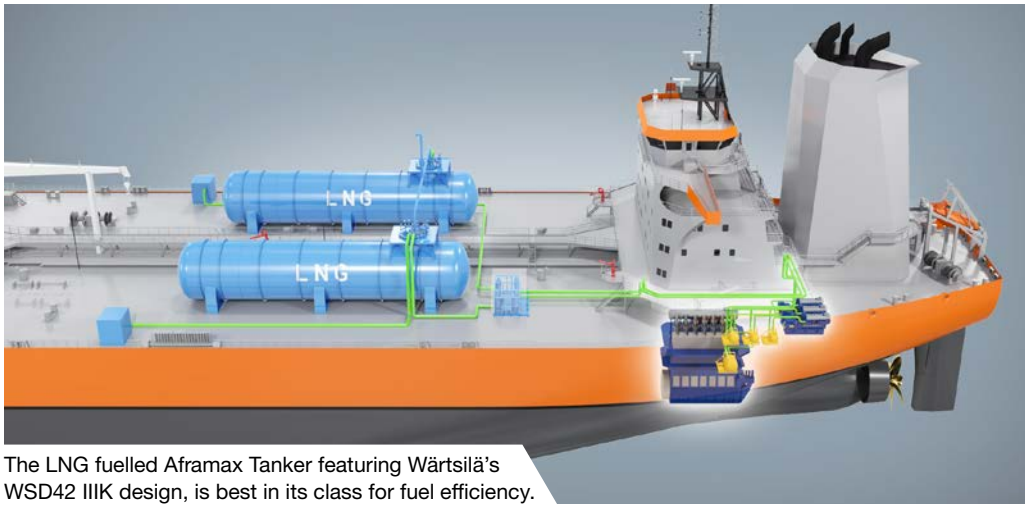
Costal/Deep-Sea Multigas Carrier: WSD 55 12K.

The Middle East's very first LNG fuelled tug, currently under construction at Drydocks World, Dubai.

The VS 485 MKIII LNG PSV continues more than a decade of success for Wärtsilä designs.

consideration becomes even stronger when the operation is influenced by sailing periods spent in Emission Control Areas.

In particular, container feeders, ferries and ro-ros represent typical vessel fleets that could be converted to gas operation. Gas offers a simpler solution for new built ships and for retrofitting vessels for a greener tomorrow.



The LNG fuelled Aframax Tanker featuring Wärtsilä's WSD42 IIIK design, is best in its class for fuel efficiency.

Marine Installation Features

To operate on gas fuel, in addition to the appropriate engines, vessels require onboard gas storage and supply system capabilities. Wärtsilä can efficiently meet all these needs for gas fuelled propulsion, thus providing a single-interface partnership to ship owners, ship operators and shipyards.

Wärtsilä LNGPac

The Wärtsilä LNGPac™ is a complete fuel gas handling system for LNG fuelled ships. It includes the bunkering station, LNG tank and related process equipment, as well as the control and monitoring system.

We offer the LNG fuel system as a stand alone product or as part of a complete propulsion system package.

Wärtsilä can deliver LNG systems for propulsion and power generation for any applicable types of ship or engine.

Our upgraded version of the LNGPac, offers a simple plug and play solution to fuel gas handling by placing the airlock and control cabinet inside the tank connection space. The functional components of the gas valve unit (GVU) can also be installed inside the tank connection space.

Additionally, the heating media skid is replaced by an intermediate heating media circuit in the tank connection space. The new circuit requires no pumps and is able to directly utilise the engines' cooling water. Therefore fewer interfaces and less installation work is required.

The LNGPac can be equipped with either vacuum insulation or PUR insulation for installation either on or below deck depending on the requirements of the fuel gas handling system.

The new, upgraded LNGPac includes the following customer benefits:

- Efficient space utilisation
- Fewer interfaces
- Reduced CAPEX & OPEX
- Increased reliability
- Maximised LNG storage volume.

Always the optimal solution

The ultimate function of a fuel gas system is to store the LNG, convert it to gas, and supply it to the engine under perfect and stable conditions.

Wärtsilä uses two principles for transferring LNG fuel, namely the pressure build up system and the cryogenic Wärtsilä Svanehøj ECA fuel pumps.

The ECA fuel pump is a highly flexible solution, providing stable and constant pressure in all weather conditions. The solution is based on the well proven deepwell technology used in our cryogenic cargo pumps for liquid gas.

All sensitive components, including the electric motor, are placed outside the fuel tank, thereby easing maintenance and avoiding the transfer of heat to the LNG. This has a very positive influence on operational expenditures (OPEX).

By using a pump to pressurise the LNG, the tank design pressure can be lowered. This reduces the initial investment cost (CAPEX).

All operations of the LNGPac™ are controlled by the automation system to provide excellent safety and control of the LNG system with the HMI adapted to actual customer needs. The control system can be integrated with the vessel's Wärtsilä NACOS Platinum automation system. This innovation results in a dramatic reduction in the number of interfaces since the electrical cabling from the LNGPac™ to the external switchboards can be limited to just a few cables. The LNGPac automation can be connected to the Wärtsilä engine digital ecosystem for global maintenance support during the complete life cycle of the vessel. As a single supplier for the automation design, project execution, commissioning work and and services, Wärtsilä can reduce project risks and minimise communication delays.

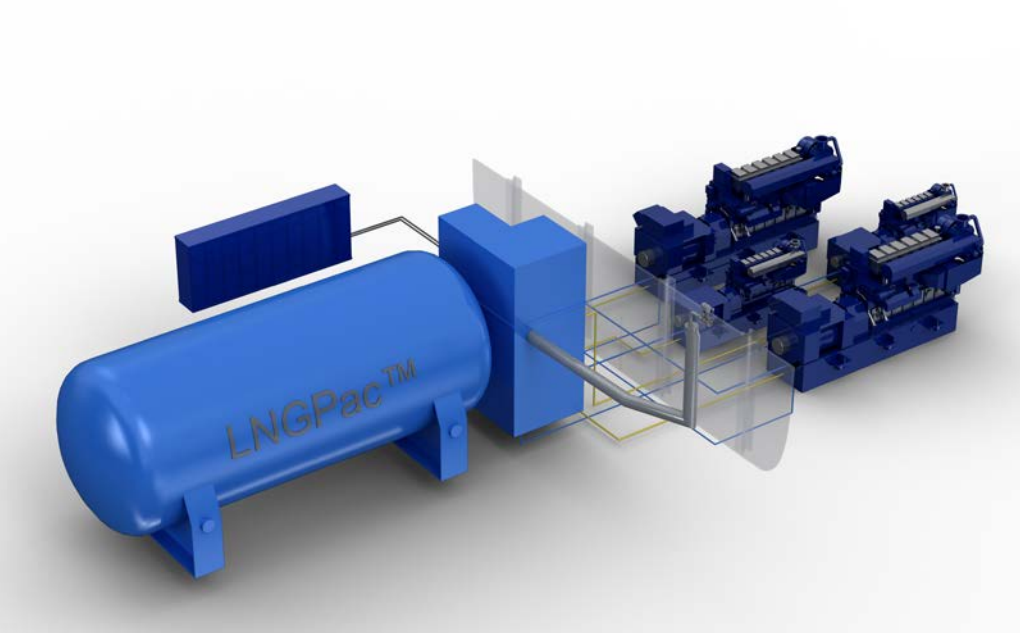
Wärtsilä's team of Fuel Gas Handling experts can customise the LNGPac gas supply system to the requirements of each project on a case-by-case basis. We offer dedicated engineering to fulfil specific operational requirements and safety regulations, while conforming to the rules of each classification society.

Gas can be burnt in Wärtsilä's four-stroke and two-stroke dual-fuel engines, which are capable of operating on both gas and conventional liquid fuels.

Wärtsilä LNGPac system references

Since 2000, Wärtsilä engines have been selected for more than 200 LNG fuelled vessels either in operation or under construction. As at the end of 2016, the Wärtsilä LNGPac was in operation in 18 vessels, with 5 years being the oldest installation. Altogether, 70 orders had been received for this system.

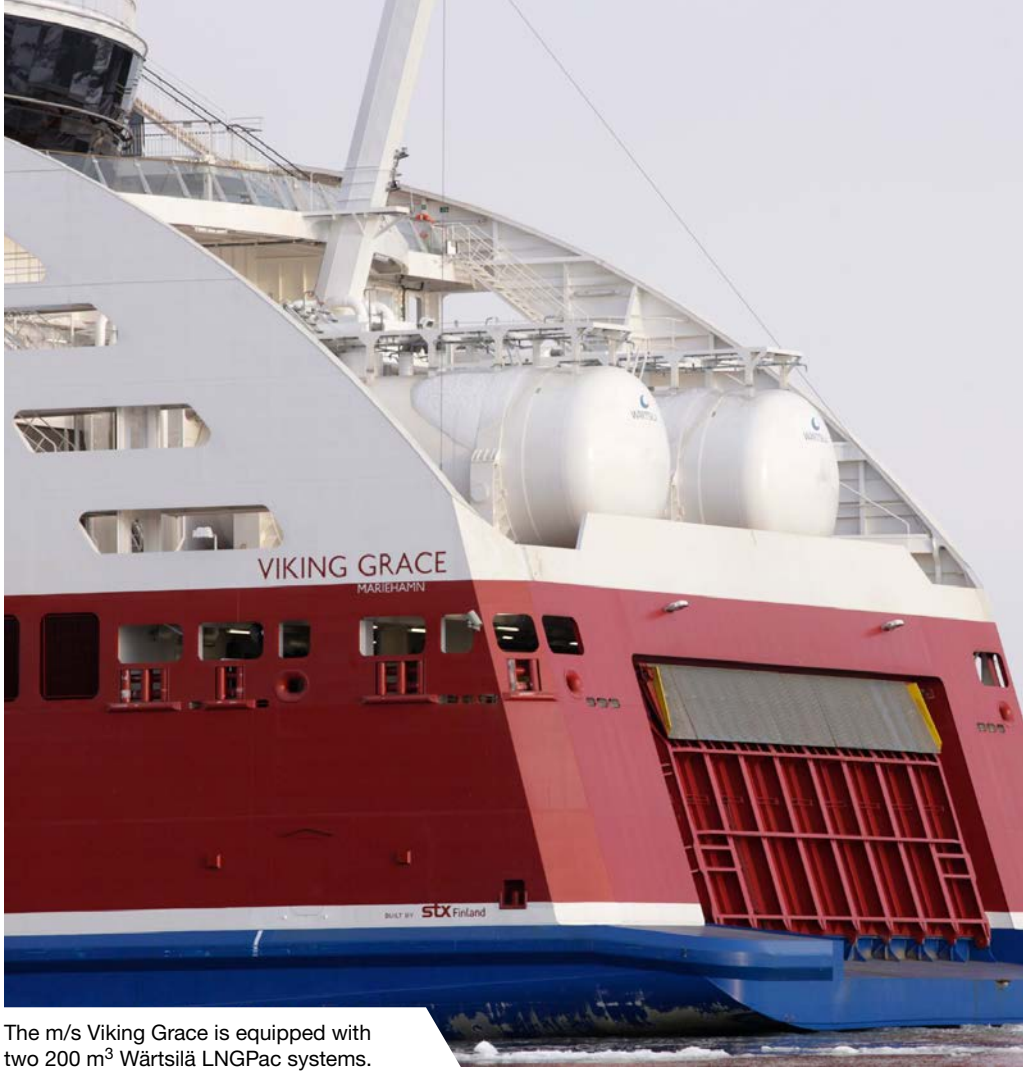
The LNGPac system has been specified with various types of ships. These include product tankers, cruise vessels, offshore vessels, roll on/roll off ferries, feeder container vessels, LPG and carriers and



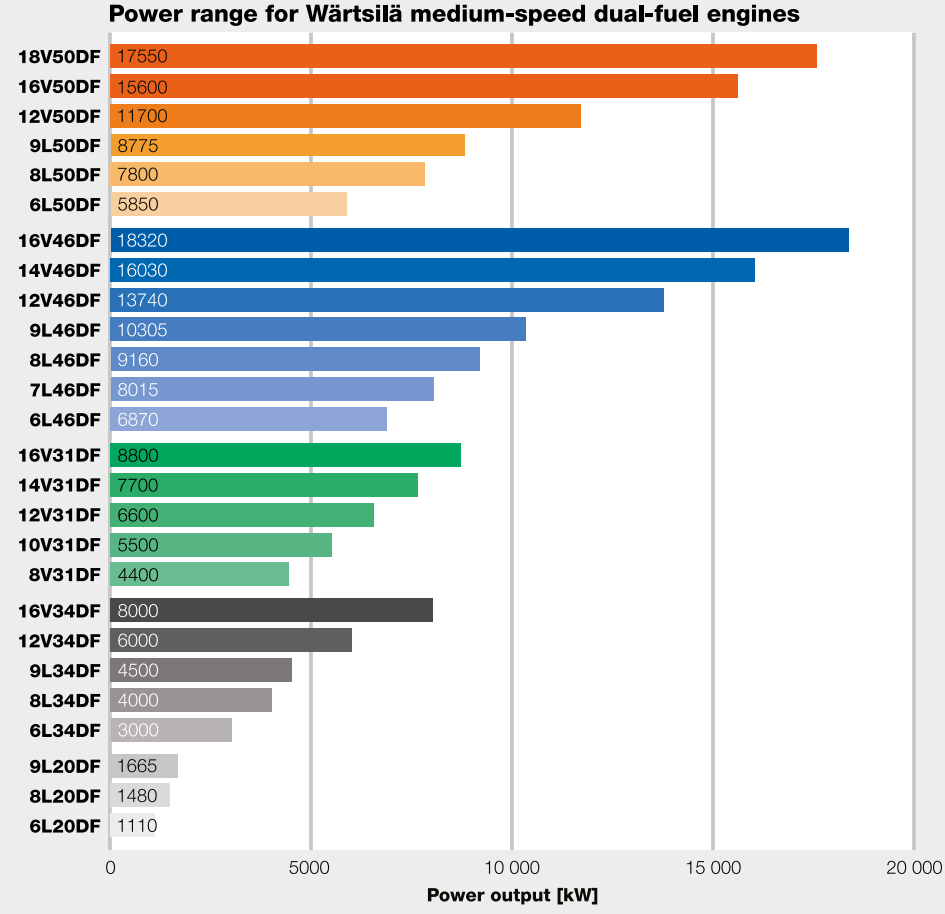
passenger ferries. One notable example is the ‘Viking Grace’ ferry operating between Turku, Finland and Stockholm, Sweden. This is the largest passenger vessel in the world operating on LNG fuel. It is equipped with two 200 m^3 Wärtsilä LNGPac systems, including a Wärtsilä patented solution that utilises the latent heat from the LNG evaporation process for the vessel’s HVAC system (air conditioning). This system provides significant energy savings for the whole ship by increasing its total efficiency.

Systems integration

With more than 20 years of experience, and with more than 1000 gas engines sold and in constant operation, Wärtsilä is today the marine sector’s market leader in natural-gas-based power production. Wärtsilä’s extended product portfolio, which is particularly strong on gas applications, is supported by deep know-how, competence, and design capability. Together, these attributes make Wärtsilä the ideal systems integrator whenever propulsion related equipment needs to be optimised.



The m/s Viking Grace is equipped with two 200 m^3 Wärtsilä LNGPac systems.



Wärtsilä’s medium-speed dual-fuel engine portfolio for both main and auxiliary power production. The portfolio is available both for electrical and mechanical propulsion applications.

Wärtsilä is a global leader in complete lifecycle power solutions for the marine and energy markets. By emphasising technological innovation and total efficiency, Wärtsilä maximises the environmental and economic performance of the vessels and power plants of its customers.

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