
# MAN B&W Dual Fuel Engines – Starting a New Era in Shipping

## With Project Examples

Engineering the Future – since 1758.

**MAN Diesel & Turbo**

# Contents

# MAN B&W Dual Fuel Engines – Starting a New Era in Shipping

## Introduction

The need for seaborne transportation will increase significantly in the years to come. At the same time, the heavy fuel oil (HFO) price is increasing, stricter emission requirements are coming into force and the public is becoming more concerned about the environmental footprint of shipping. As a result, the industry is investigating in alternative fuels for shipping. Liquefied natural gas (LNG) is an attractive option since it reduces emissions, and is expected to be cheaper than fuel oil in the future because of the large world reserves of natural gas.

This paper introduces dual fuel and LNG and presents state-of-the-art MAN Diesel & Turbo projects involving LNG new-buildings and retrofitting. At this point in time, MAN Diesel & Turbo has a total of 116 ordered LNG engine projects (including options), totalling orders of 2.2 GW. On top of this, more and more new-buildings are constructed as LNG-ready, which means that they can relatively easy be retrofitted with dual fuel engines at a later point.

As an important part of the puzzle towards LNG as a more commonly used fuel type, LNG bunkering and the LNG world infrastructure are also discussed.

## LNG Facts and History

### Background

The use of LNG as a ship fuel is not a new idea. LNG has been used for many years on gas carriers with boilers (in the case of steam turbine propulsion), on four-stroke diesel mechanical propulsion or where diesel electric propulsion is installed. All these solutions are based on the consumption of the readily available LNG as the fuel, and/or boil-off gas from LNG tanks.

In recent years, the LNG infrastructure has developed to the extent that other ship types, like Ro-Ro and smaller ferryboats, use LNG as fuel, and it is now established as a clean and reliable fuel for propulsion and auxiliary power generation. With the recent technology development, MAN Diesel & Turbo can offer both dual fuel medium speed engines and low speed LNG-burning ME-GI/ME-LGI type engines, offering propulsion power with reduced emissions.

The development of the ME-GI/ME-LGI dual fuel engine has made it possible to install a simple, yet unique, propulsion power solution with a total system efficiency similar to conventional vessels, but with reduced emissions.

### Emission regulations

The ME-GI/ME-LGI engine will fulfil IMO Tier III $NO_X$ levels when combined with the Exhaust Gas Recirculation (EGR) technology. A technology developed by MAN Diesel & Turbo for the complete low speed B&W engine programme for compliance with IMO Tier III $NO_X$ emission regulations. Methane slip, a problem commonly associated with dual fuel engines, is not an issue with the ME-GI/ME-LGI engine, due to operation according to the Diesel cycle principle.

In this respect, the ME-GI/ME-LGI is not vulnerable to the valve overlap, or localised gas fuel pocket formation on the cylinder wall, resulting in methane slip, which may occur as a consequence of operation according to the Otto cycle principle.

### The engine

The ME-GI dual fuel engine is not a new engine in technological terms, rather a natural development of the MAN B&W low speed electronically controlled ME family of engines. In 1987, the first testing of the GI principles was carried out in Japan and Denmark and MAN Diesel & Turbo introduced their first two-stroke ME-GI dual fuel engine series in 2011. In 2012, MAN Diesel & Turbo decided to expand the engine portfolio and the two-stroke dual fuel ME-LGI engine series was introduced in 2013.

The ME-LGI engine enables the use of more sustainable fuels such as methanol, ethanol and liquefied petroleum gas (LPG). It is the dual fuel solution for low flashpoint liquid fuels contrary to the ME-GI engine where the fuel is injected in a gaseous state.

In spite of this difference, the operation principle and safety concept of the ME-LGI engine is similar to the ME-GI concepts. However, due to the difference in fuel properties, the ME-LGI component and auxiliary systems are different from the ME-GI.

With an ME-GI or ME-LGI engine and a viable, convenient and economic fuel already on board, exploiting a fraction of the cargo to power a vessel makes sense. Especially, with another important factor being the benefit to the environment

## Gas Types and ME-GI/ME-LGI

Both ME-GI and ME-LGI engines can run on different gas types, see Table 1

**ME-GI fuel and ME-LGI fuel types**

| Common fuels | Known as | Delivery condition | Supply pressure | Supply temperature |
|---|---|---|---|---|
| **ME-GI fuel** | | | | |
| CH4 | Methane (LNG/NG) | Gas | 300 bar | 45°C tol. 10°C |
| C2H6 | LEG ethane | Gas | 600 bar | 45°C tol. 10°C |
| **ME-LGI fuel** | | | | |
| CH3OH | Methanol MeOH | Liquid | 8 bar | 10 - 55°C |
| C2H5OH | Ethanol | Liquid | 8 bar | 10 - 55°C |
| C3H8 | Propane (LPG) | Liquid | 35 bar | 10 - 55°C |
| CH410 | Butane (LPG) | Liquid | 35 bar | 10 - 55°C |
| C8H18 | Petrol/gasoline | Liquid | 8 bar | 10 - 55°C |
| | DME | Liquid | 30 bar | 10 - 55°C |

*Table 1: ME-GI and ME-LGI fuel types*

**Worldwide methane quality**

| MN range (AVL) | Global LNG production (mtpa) | % of total LNG produced |
|---|---|---|
| 0-70 | 26 | 10% |
| 70-75 | 118.3 | 43% |
| 75-80 | 26.1 | 10% |
| 80-100 | 102.8 | 38% |
| 0-100 | 273.15 | 100% |

*Table 2: Methane quality*

for details. Obviously, each engine offers good flexibility in selecting the best fuel for a given scenario, and based on an environmental and economic perspective, the owner can choose a vessel designed to accommodate fuel stores for both HFO and LNG.

### About gas types

A liquefied gas has a gaseous form at normal ambient temperature and pressure, but is liquefied by pressurisation or refrigeration, or by a combination of both. The main groups of gas relevant are LNG, LPG and a variety of petrochemical gases. LNG contains mostly methane naturally occurring in association with oil fields, whereas LPG contains the heavier gas types butane and/or propane. LPG is, for example, used as a bottled cooking gas. LPG may be carried in either pressurised or refrigerated form (butane –5°C and propane –42°C), but in a few cases also in semi-pressurised form.

### Methane

As can be seen in Table 1, ME-GI engines can run on methane and ethane and ME-LGI engines can run on a variety of liquid gases. Especially methane is interesting. This is due to the fact that the greatest production of methane is seen at lower methane numbers. An engine with a minimum methane number specification of 80 can use only 38% of the global supply of methane.

On the other hand, an engine with a minimum methane number specification of 70 can use 90% of global supply. Finally, an engine with no methane number requirement, like the ME-GI can – unlike other engine types on the market – use all methane qualities. See Table 2 for more details.

### Engine Operating Modes

As mentioned, one of the main advantages of the ME-GI/ME-LGI engines is the fuel flexibility. The engine efficiency in gas mode is equal to the engine efficiency in fuel oil mode – or sometimes even better. This ensures that,

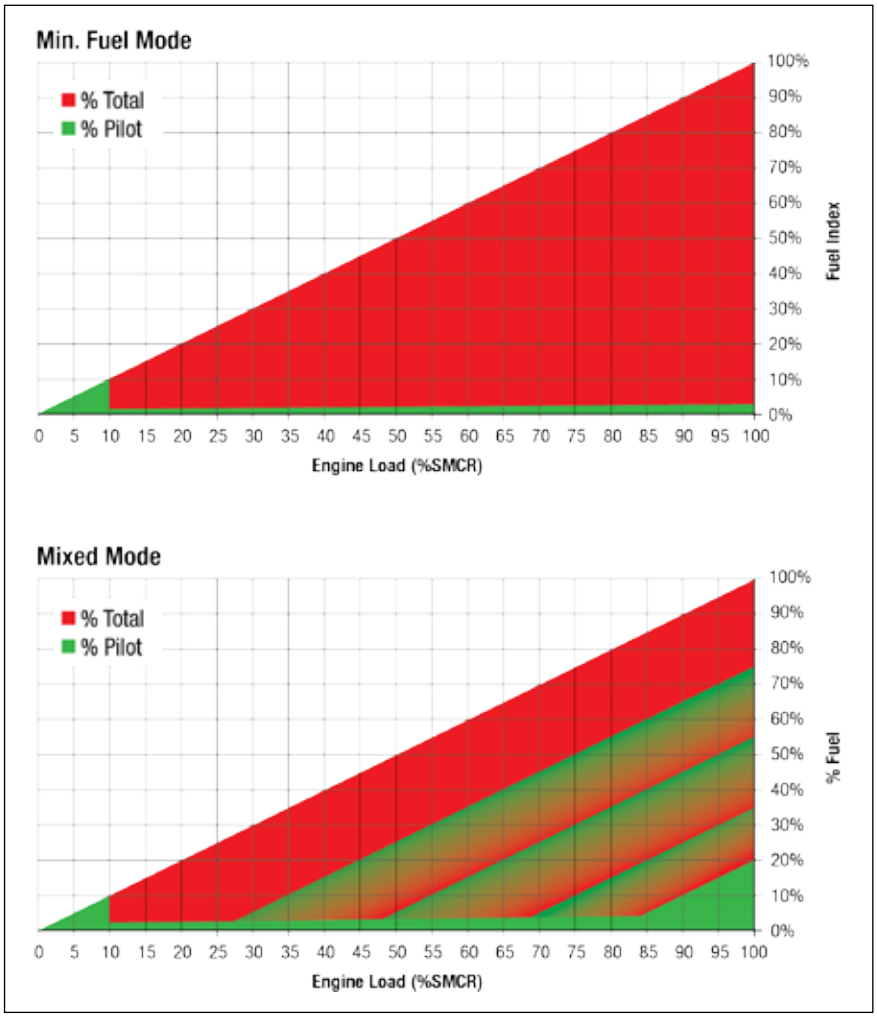



*Fig. 1: Fuel type mode for ME-GI engines for LNG carriers*

independent of the development in fuel prices, the ship is always competitive, see Fig. 1.

For ME-GI/ME-LGI engines, three different fuel modes exist:

- Fuel-oil-only mode
- Minimum-fuel mode
- Mixed gas mode.

In fuel-oil-only mode the engine runs on traditional fuel oil.

The minimum-fuel mode is developed for gas operation and the control system will allow any ratio between fuel oil and gas fuel, with a minimum preset amount of fuel oil to be used. Both heavy fuel oil, marine diesel oil and marine gas oil can be used as pilot oil.

The mixed gas mode is offered to give the operator full fuel flexibility and the option to inject a fixed amount of gas fuel. The ME control system will add up with fuel oil until the required load for operation is reached.

If a failure in the gas system occurs, the system will return to the fuel-oil-only mode which is considered »gas-safe«.

## Bunkering

Availability and bunkering of LNG as fuel, are often put forward as the main challenge when it comes to running large ocean-going ships on LNG. A number of LNG terminals exist around the world, and more are under construction, see Fig. 2. The most realistic bunkering option in the short term is taking LNG directly from the international trading network for LNG. Here, there are three different sources of bunkers:

- Import terminals
- Export terminals
- LNG carriers.

Bunkering directly from an LNG import or export facility would represent no major technical barriers.

Another option is to take LNG from import/export terminals via dedicated LNG carriers or bunkering barges to a suitable bunkering location. The container ship would dock alongside the carrier/barge, or the LNG carrier/barge could dock alongside the vessel while it is loading/unloading. This solution is

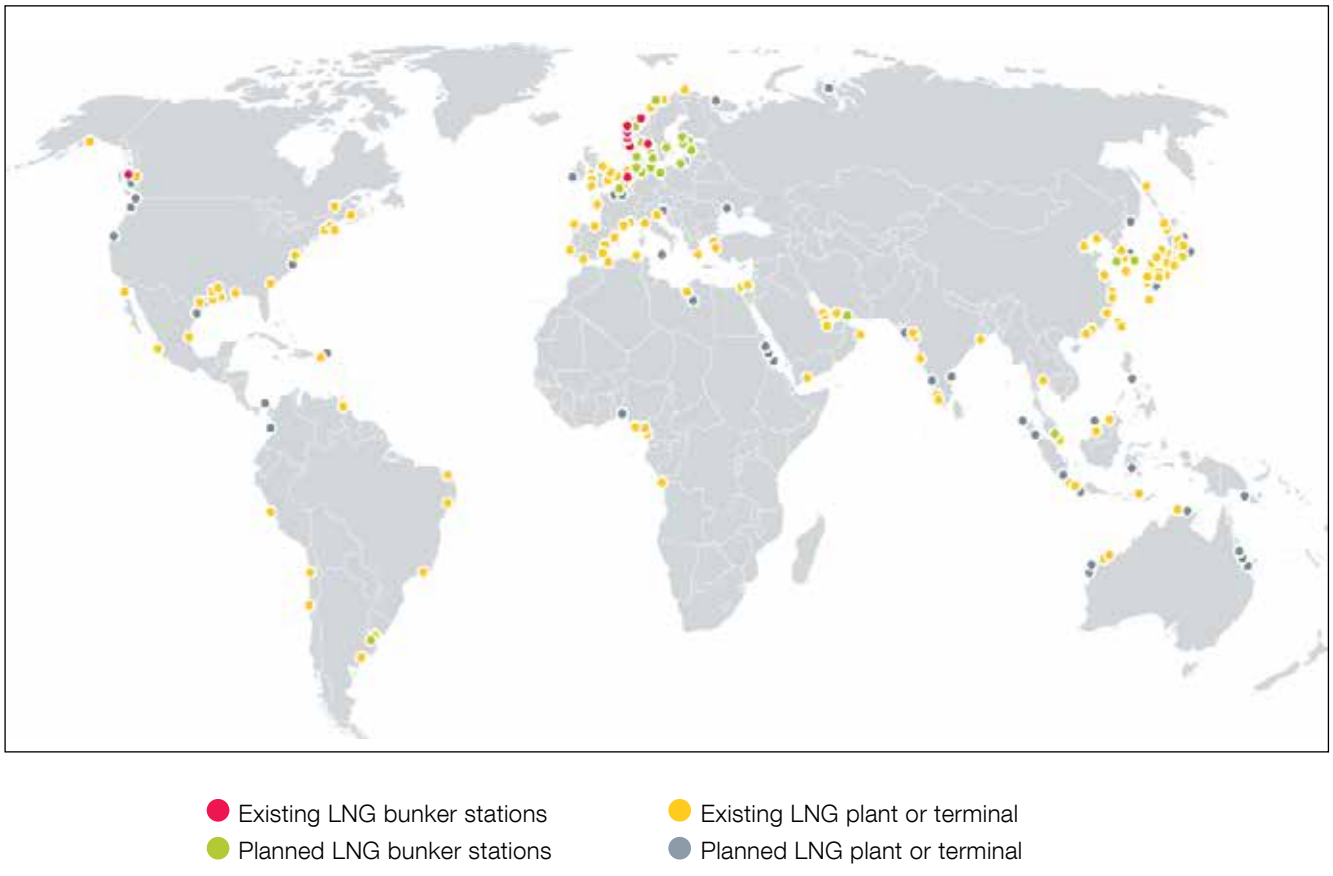



*Fig. 2: Bunkering/LNG world map*

flexible with the possibility of low investment cost in the case of the existing LNG carrier option.

No matter what, key players of the industry – confident that the LNG infrastructure is quickly becoming more and more tightly knit – have already placed 2.2 GW worth of orders for ships with MAN Diesel & Turbo ME-GI/ME-LGI enignes. A selection of these projects are presented in the following.

**LNG ME-GI Projects**
TOTE Maritime


**Order for two 3,100 teu LNG-powered container ships**

| Order details | |
|---|---|
| No. of ships: | 2 + 3 options |
| No. of engines: | 2 + 3 |
| Ship type: | Container |
| Capacity: | 3100 teu |
| Engine type: | 8L70ME-C8.2-GI |
| GenSets per ship: | 15 x L28/32DF |
| Builder: | Doosan |
| Yard: | NASSCO |
| Engine delivery year: | 2014/2016 |
| Fuel types: | HFO, MGO, NG |

## Teekay

### Order for five 173,400 cbm LNG tankers

| Order details | |
|---|---|
| No. of ships: | 8 + 2 options |
| No. of engines: | 16 + 4 |
| Ship type: | LNG tankers |
| Capacity: | 173,400 cbm |
| Engine type: | 5G70ME-C9.2-GI |
| Builder: | Hyundai |
| Yard: | DSME |
| Engine delivery year: | 2014 |
| Fuel types: | HFO, MGO, NG |

## Crowley


### Order for two LNG-powered ConRos

| Order details | |
|---|---|
| No. of ships: | 2 |
| No. of engines: | 2 |
| Ship type: | ConRo |
| Capacity: | 2,400 teu |
| Engine type: | 8S70ME-C8.2-GI |
| GenSets per ship: | 3 x 9L28/32DF |
| Builder: | HHI-EMD |
| Yard: | VT Halter |
| Engine delivery year: | 2015 |
| Fuel types: | HFO, MGO, NG |

## Matson Navigation


### Order for two 3,600 teu dual fuel powered container ships

| Order details | |
|---|---|
| No. of ships: | 2 + 3 options |
| No. of engines: | 2 + 3 |
| Ship type: | Container |
| Capacity: | 3600 teu |
| Engine type: | 7S90ME-C9.2-GI |
| Builder: | Hyundai |
| Yard: | Aker Philadelphia |
| Engine delivery year: | 2017 |
| Fuel types: | HFO, MGO, NG |

## Brodosplit


### Order for two 1,431 teu container ships

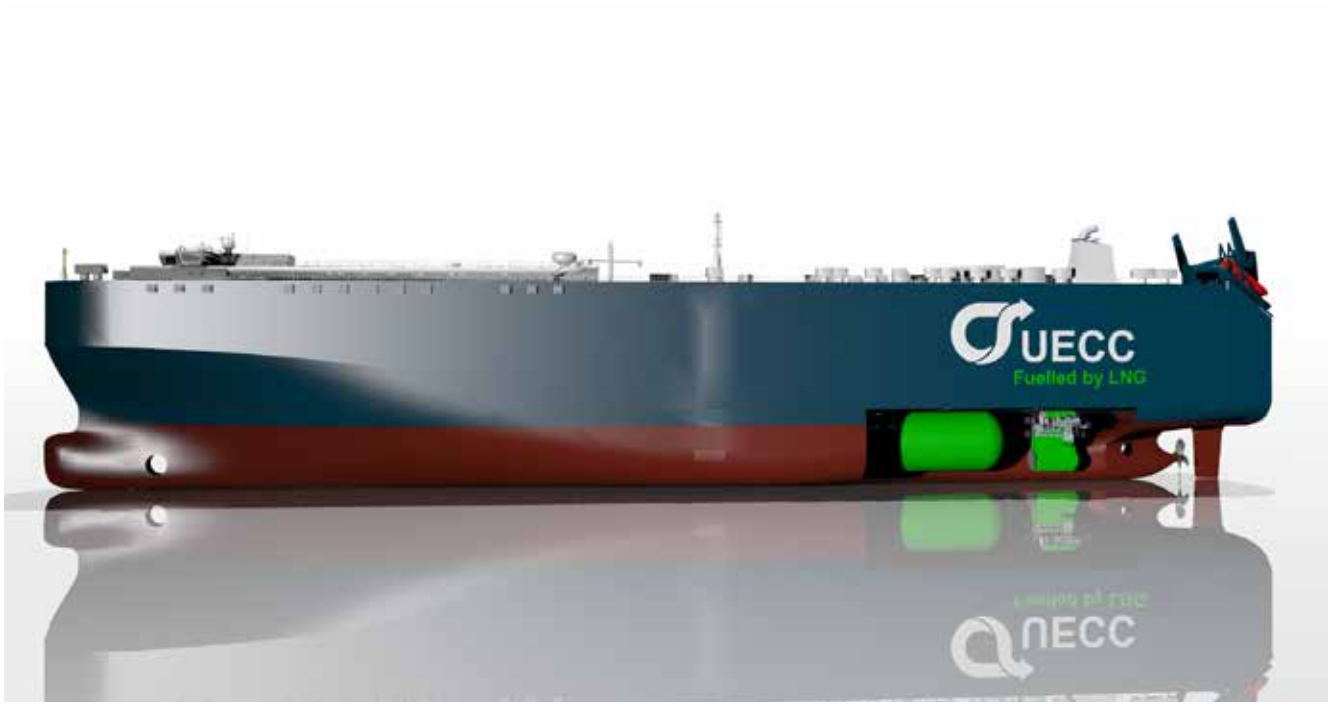
| Order details | |
|---|---|
| No. of ships: | 2 + 2 options |
| No. of engines: | 2 + 2 |
| Ship type: | Container |
| Capacity: | 1,431 teu |
| Engine type: | 8S50ME-C9.3-GI |
| GenSets per ship: | 8 x 7L28/32DF<br>4 x 5L28/32DF |
| Builder: | Brodosplit |
| Yard: | Brodosplit |
| Engine delivery year: | 2015 |
| Fuel types: | HFO, MGO, NG |

## Nakilat (retrofit)

### Order for one 260,000 cbm LNG tanker

| Order details | |
|---|---|
| No. of ships: | 1 |
| No. of engines: | 2 |
| Ship type: | LNG tanker |
| Capacity: | 260,000 cbm |
| Engine type: | 7S70ME-C7-GI |
| Builder: | MDT |
| Yard: | NKOM |
| Engine delivery year: | 2015 |
| Fuel types: | HFO, MGO, NG |

## Wallenius & NYK ((United European Car Carriers (UECC))




### Order for two 3.800 SSC LNG PCTCs

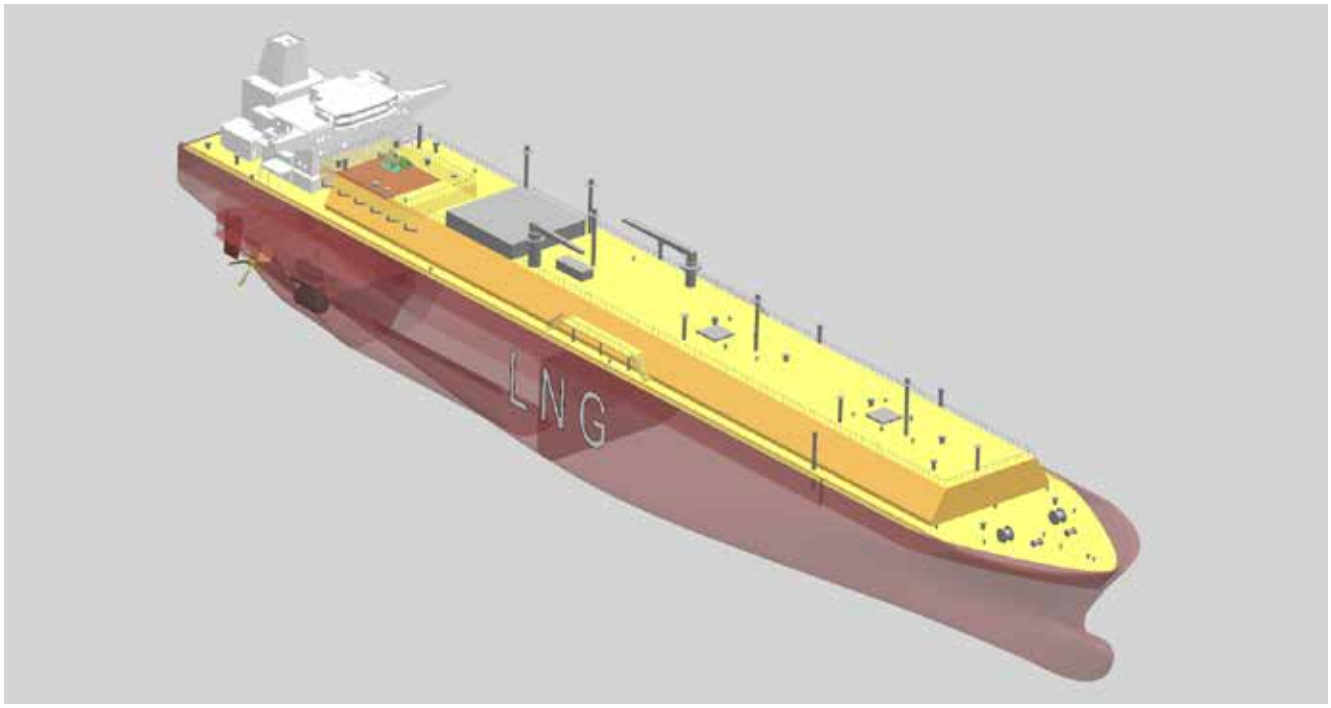
| Order details | |
|---|---|
| No. of ships: | 2 |
| No. of engines: | 2 |
| Ship type: | LNG PCTCs |
| Capacity: | 3.800 SSC |
| Engine type: | 8S50ME-C8.2-GI |
| Builder: | KHI |
| Yard: | NACKS |
| Engine delivery year: | 2015 |
| Fuel types: | HFO, MGO, NG |

**BW Gas**

## Order for two 173,400 cbm LNG tankers

| Order details | |
|---|---|
| No. of ships: | 2 |
| No. of engines: | 4 |
| Ship type: | Tanker |
| Capacity: | 173,400 cbm |
| Engine type: | 5G70ME-C9.2-GI |
| Builder: | - |
| Yard: | DSME |
| Engine delivery year: | 2017 |
| Fuel types: | HFO, LNG, MGO |

## Knutsen OAS Shipping




### Order for one 35,000 cmb LPG tanker

| Order details | |
|---|---|
| No. of ships: | 2 |
| No. of engines: | 4 |
| Ship type: | LNG tankers |
| Capacity: | 176,300 cbm |
| Engine type: | 7G70ME-C9.2-GI |
| Builder: | HHI-BMD |
| Yard: | HHI-SBD |
| Engine delivery year: | 2015 |
| Fuel types: | HFO, MGO, NG |

## Navigator Gas

**Order for one 35,000 cmb LPG tanker**

**Order details**

| | |
|---|---|
| No. of ships: | 4 |
| No. of engines: | 4 |
| Ship type: | LPG tanker |
| Capacity: | 35,000 cbm |
| Engine type: | 6S50ME-C8.2-GI |
| Builder: | - |
| Yard: | Jiangnan |
| Engine delivery year: | 2015 |
| Fuel types: | MGO, NG |

## Elcano

**Order for two 175,000 cbm LNG tankers**

**Order details**

| | |
|---|---|
| No. of ships: | 2 |
| No. of engines: | 4 |
| Ship type: | LNG tanker |
| Capacity: | 175,000 cbm |
| Engine type: | 7G70ME-C9.2-GI |
| Builder: | Mitsui |
| Yard: | Imabari |
| Engine delivery year: | 2016 |
| Fuel types: | HFO, MGO, NG |

## Undosclosed

**Order for two 174,000 cmb LNG tankers**

**Order details**

| | |
|---|---|
| No. of ships: | 2 |
| No. of engines: | 4 |
| Ship type: | LNG tanker |
| Capacity: | 174,000 cbm |
| Engine type: | 5G70ME-C9.5-GI |
| Builder: | - |
| Yard: | DSME |
| Engine delivery year: | 2017 |
| Fuel types: | HFO, LNG, MGO |


**Undosclosed**

**Order for two 174,000 cmb LNG tankers**

| Order details | |
|---|---|
| No. of ships: | 2 |
| No. of engines: | 4 |
| Ship type: | LNG tanker |
| Capacity: | 174,000 cbm |
| Engine type: | 5G70ME-C9.5-GI |
| Builder: | - |
| Yard: | Samsung |
| Engine delivery year: | 2017 |
| Fuel types: | HFO, LNG, MGO |


**Undosclosed**

**Order for two 174,000 cmb LNG tankers**

| Order details | |
|---|---|
| No. of ships: | 2 |
| No. of engines: | 4 |
| Ship type: | LNG tanker |
| Capacity: | 174,000 cbm |
| Engine type: | 5G70ME-C9.5-GI |
| Builder: | - |
| Yard: | DSME |
| Engine delivery year: | 2017 |
| Fuel types: | HFO, LNG, MGO |


**Undosclosed**

**Order for two 174,000 cmb LNG tankers**

| Order details | |
|---|---|
| No. of ships: | 2 |
| No. of engines: | 4 |
| Ship type: | LNG tanker |
| Capacity: | 174,000 cbm |
| Engine type: | 5G70ME-C9.5-GI |
| Builder: | - |
| Yard: | DSME |
| Engine delivery year: | 2017 |
| Fuel types: | HFO, LNG, MGO |


**Undosclosed**

**Order for eight 174,000 cmb LNG tankers**

**Order details**

| | |
|---|---|
| No. of ships: | 8 |
| No. of engines: | 16 |
| Ship type: | LNG tanker |
| Capacity: | 174,000 cbm |
| Engine type: | 5G70ME-C9.5-GI |
| Builder: | - |
| Yard: | DSME |
| Engine delivery year: | 2017 |
| Fuel types: | HFO, LNG, MGO |


**Undosclosed**

**Order for four 174,000 cmb LNG tankers**

**Order details**

| | |
|---|---|
| No. of ships: | 4 |
| No. of engines: | 8 |
| Ship type: | LNG tanker |
| Capacity: | 174,000 cbm |
| Engine type: | 5G70ME-C9.5-GI |
| Builder: | - |
| Yard: | DSME |
| Engine delivery year: | 2017 |
| Fuel types: | HFO, LNG, MGO |


**Undosclosed**

**Order for four 174,000 cmb LNG tankers**

**Order details**

| | |
|---|---|
| No. of ships: | 4 |
| No. of engines: | 8 |
| Ship type: | LNG tanker |
| Capacity: | 174,000 cbm |
| Engine type: | 5G70ME-C9.5-GI |
| Builder: | - |
| Yard: | DSME |
| Engine delivery year: | 2017 |
| Fuel types: | HFO, LNG, MGO |

## ME-LGI Projects

**Mitsui O.S.K Lines Ltd.**


**Order for two 50,000 dwt methanol-driven carriers**

| Order details | |
|---|---|
| No. of ships: | 3 |
| No. of engines: | 3 |
| Ship type: | Methanol carrier |
| Capacity: | 50,000 dwt |
| Engine type: | 7S50ME-B9.3-LGI |
| Builder: | Mitsui |
| Yard: | MNS |
| Engine delivery year: | 2015 |
| Fuel types: | HFO, MGO, Methanol |

## Marinvest

### Order for two 50,000 dwt methanol-driven carriers

| Order details | |
|---|---|
| No. of ships: | 2 + 1 option |
| No. of engines: | 2 + 1 |
| Ship type: | Methanol carrier |
| Capacity: | 50,000 dwt |
| Engine type: | 6G50ME-B9.3-LGI |
| Builder: | Hyundai |
| Yard: | HMD |
| Engine delivery year: | 2015 |
| Fuel types: | HFO, MGO, Methanol |

## Westfal-Larsen

### Order for two 50,000 dwt methanol-driven carriers

| Order details | |
|---|---|
| No. of ships: | 2 + 1 options |
| No. of engines: | 2 + 1 |
| Ship type: | Methanol carrier |
| Capacity: | 50,000 dwt |
| Engine type: | 6G50ME-B9.3-LGI |
| Builder: | Hyundai |
| Yard: | HMD |
| Engine delivery year: | 2015 |
| Fuel types: | HFO, MGO, Methanol |

## ME-GI/E Projects

Hartmann Schiffahrt/Ocean Yield


*Design/Drawing by HB Hunte Engineering GmbH*

### Order for three 36,000 cbm ethane gas carriers

| Order details | |
|---|---|
| No. of ships: | 3 |
| No. of engines: | 3 |
| Ship type: | Carrier |
| Capacity: | 63,000 cbm |
| Engine type: | 7G50ME-C9.5-GI/E |
| Builder: | - |
| Yard: | Sinopacific Offshore |
| Engine delivery year: | 2015 |
| Fuel types: | HFO, MGO, Ethane |

## Summary

ME-GI and ME-LGI came about because of interest from the shipping world in operating on alternatives to HFO. LNG, methanol and LPG carriers have already operated at sea for many years and many more LNG/LPG tankers are currently being built as the global LNG/LPG infrastructure grows. With a viable, convenient and comparatively cheap fuel already on board, it makes sense to use a fraction of the cargo to power the vessel. An important side benefit is the improved environmental profile. In line with this, MAN Diesel & Turbo states that it is already working towards a Tier III compatible ME-LGI version.

Senior Vice President of Promotion & Sales, Mr Ole Grøne says, "The LNG carrier market, like all sectors of the transportation industry, needs to control and, where possible, reduce operational expenses, while securing sound profit. We see many new opportunities in this area for cost-down solutions permitted by the increased flexibility and greater control with the ME-GI engine. Among the many proposals and ideas for LNG carrier propulsion, the ME-GI, also installed with reliquefaction technology, where preferred, provides the best solution for the future needs of the LNG transportation market."

*Senior Vice President of Promotion & Sales, Mr Ole Grøne*

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**MAN Diesel & Turbo**
Teglholmsgade 41
2450 Copenhagen SV, Denmark
Phone +45 33 85 11 00
Fax +45 33 85 10 30
info-cph@mandieselturbo.com
www.mandieselturbo.com

MAN Diesel & Turbo – a member of the MAN Group