

Germanischer Lloyd



Costs and benefits of LNG as ship fuel for container vessels

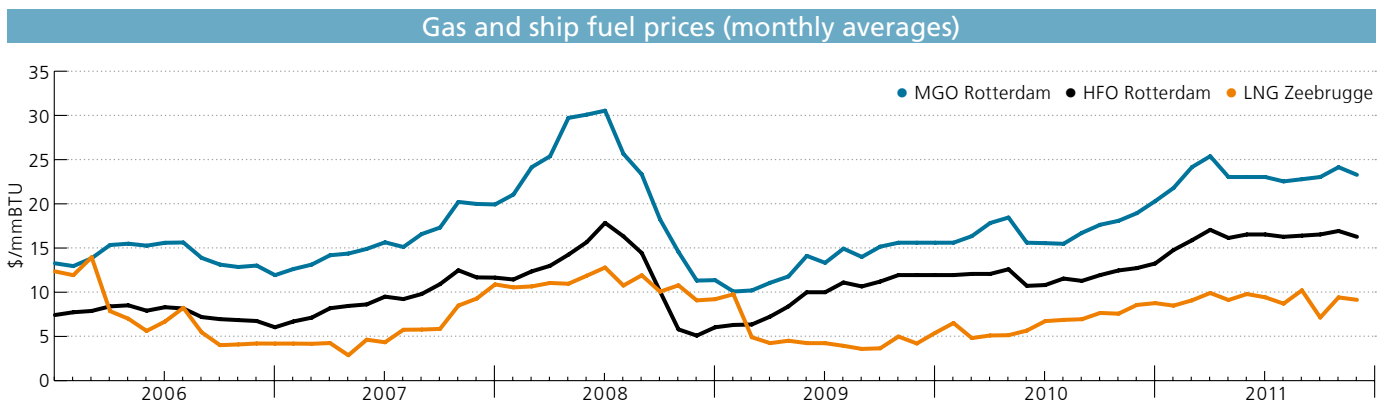
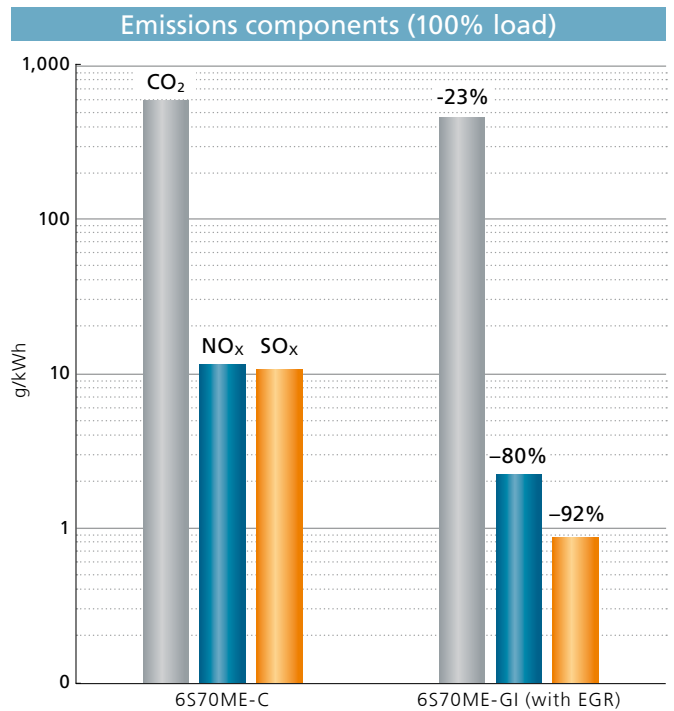
Key results from a GL and MAN joint study



Attractions of using LNG as ship fuel

Using liquefied natural gas (LNG) as ship fuel has recently gained more attention not only in Europe, but also in Asia and the USA. There are three noticeable drivers which, taken together, make LNG as ship fuel one of the most promising new technologies for shipping.

1. using LNG as ship fuel will reduce sulphur oxide (SO_x) emissions by 90% to 95%. This reduction level will also be mandated within the so-called Emission Control Areas (ECAs) by 2015. A similar reduction is expected to be enforced for worldwide shipping by 2020.
2. the lower carbon content of LNG compared to traditional ship fuels enables a 20% to 25% reduction of carbon dioxide (CO₂) emissions. Any slip of methane during bunkering or usage needs to be avoided to maintain this advantage.
3. LNG is expected to be less costly than marine gas oil (MGO) which will be required to be used within the ECAs if no other technical measures are implemented to reduce the SO_x emissions. Current low LNG prices in Europe and the USA suggest that a price – based on energy content – below heavy fuel oil (HFO) seems possible, even when taking into account the small-scale distribution of LNG.





Objectives of the study

Shipowners interested in LNG as ship fuel are currently facing a number of questions regarding the costs and the possible benefits of using such technology. And they wish to learn whether exhaust gas treatment systems could be the preferred technical solution. At the same time, increasing ship efficiency with advanced waste heat recovery systems becomes feasible. This suite of technologies is the focus of the GL and MAN joint study on container vessel power generation systems.

Status of regulatory framework

The IMO Interim Guidelines for gas as ship fuel (Resolution MSC.285(86)) contain the state of the art on safety concepts for using gas as a ship fuel. These are voluntary to the flag states. GL issued its own guidelines in April 2010, adding own interpretations. The IMO subcommittee BLG is working on the International Gas as Fuel Code (IGF) which will supersede the interim guidelines and which is planned to enter into force with the SOLAS 2014 edition. In parallel, work has started at ISO TC 67 on standards for LNG bunkering.



Approach

The study assumes costs for key technologies when applied to five differently sized container vessels and predicts their benefits in comparison to a reference vessel which uses marine fuel oil required by existing and upcoming regulations depending on time and location of its operation. I.e., the reference vessel uses MGO when inside an ECA by 2015 or within EU ports. Outside an ECA, HFO is used and a low-sulphur heavy fuel oil (LSHFO) with max.0.5% sulphur content by 2020.

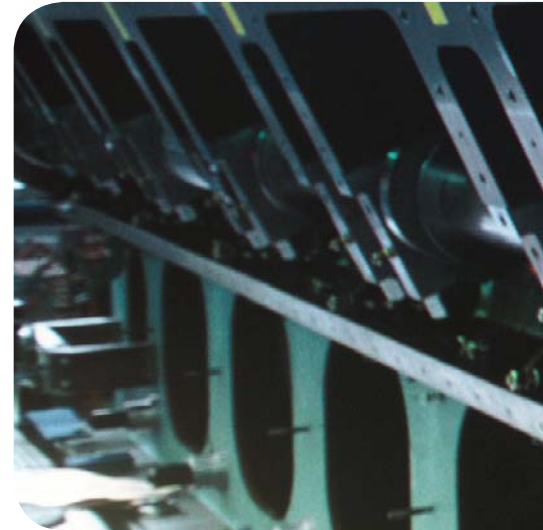
Costs for implementing the technologies are compared with expected benefits which are driven by fuel cost differences. The model assumes that the fuel with the lowest cost is always used, if a choice is possible. Space required by the technologies is taken into account by reducing the benefit.

Four technology variants were investigated in the study:

1. Exhaust gas cleaning by "scrubber"
2. Scrubber plus Waste Heat Recovery (WHR)
3. LNG system (bunker station, tank, gas preparation, gas line, dual-fuel engines)
4. LNG system plus WHR

For each technology variant, costs and space requirements are estimated and specific fuel oil consumption is based on current knowledge. Estimates were independently made for each selected container vessel size.

The same measures to reduce NOx emissions to IMO Tier III-levels are assumed for the reference vessel and each technology variant and, therefore, these have no effect on the cost differences between the reference vessel and the variants.

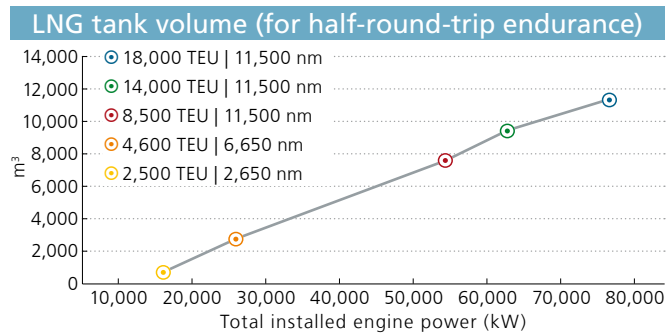


Ship size variants and route profiles

Five representative container vessel sizes were selected for the study. Assumed design speeds account for the current trend towards lower speeds.

Round trips were selected for three trades: intra-European, Europe-Latin America and Europe-Asia. The ECA exposure was used as primary input parameter.

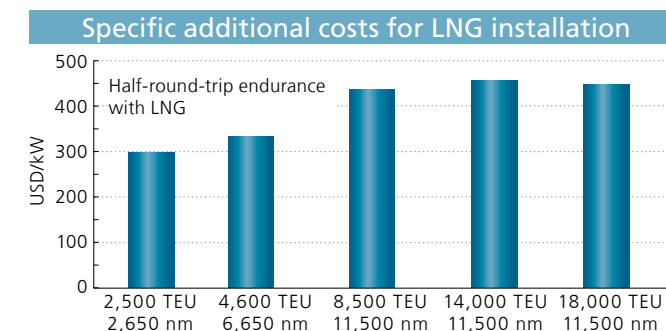
TEU	Speed (knots)	Main engine power (kW)	Round trip (nm)	default ECA share
2,500	20	14,500	5,300	65.1%
4,600	21	25,000	13,300	11.0%
8,500	23	47,500	23,000	6.3%
14,000	23	53,500	23,000	6.3%
18,000	23	65,000	23,000	6.3%

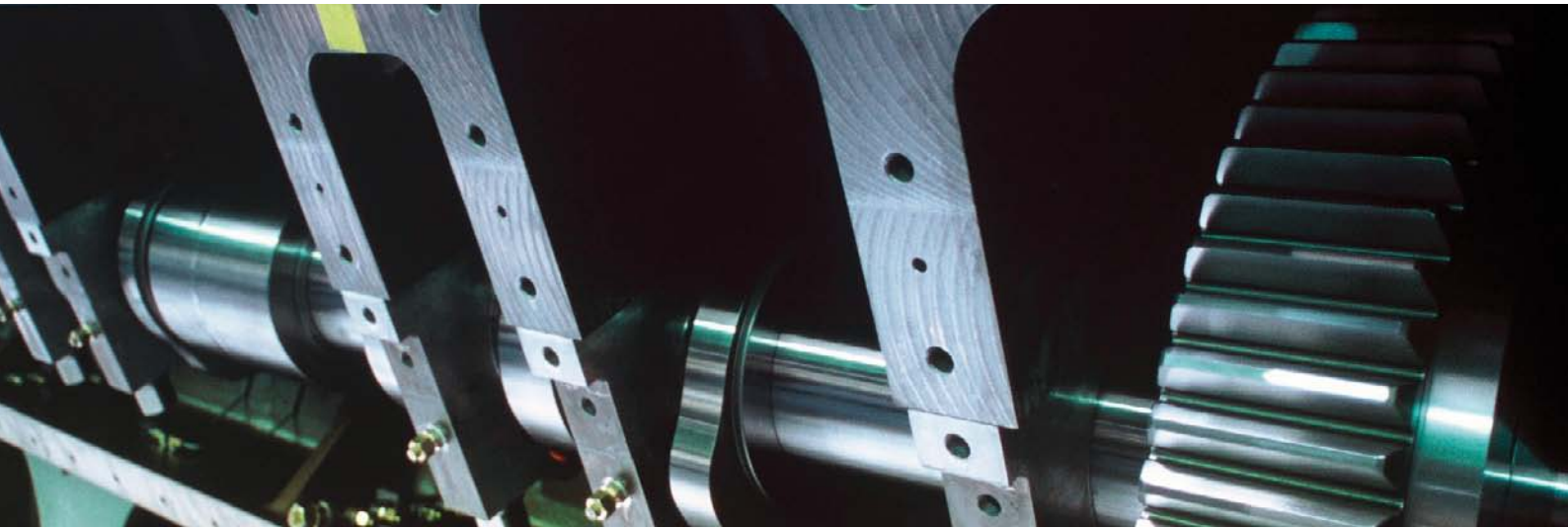


LNG technology and modelling assumptions

The main engine installed power is based on specific designs with given design speeds. Auxiliary engine power is taken as a fraction of the main engine power. Additional auxiliary engine power necessary for reefer containers is based on estimated reefer share. Engine loads are varied for port stays, approaches and open sea transit, which in turn depend on the route profile.

The LNG tank volume is selected to give the vessel half-round-trip endurance. This controls investment costs but increases exposure to volatile fuel prices. Costs for LNG system include costs for the tanks, bunker station, gas preparation, gas line and main engine. LNG tanks are assumed to consume TEU slots, resulting in lost earnings, assumed only for every second voyage. The medium-sized container vessels (4,600 TEU and 8,500 TEU) have the largest losses with a maximum of about 3% of the total available TEU slots. Other operation costs such as crew, spare parts and maintenance are assumed to be 10% higher than the reference vessels.

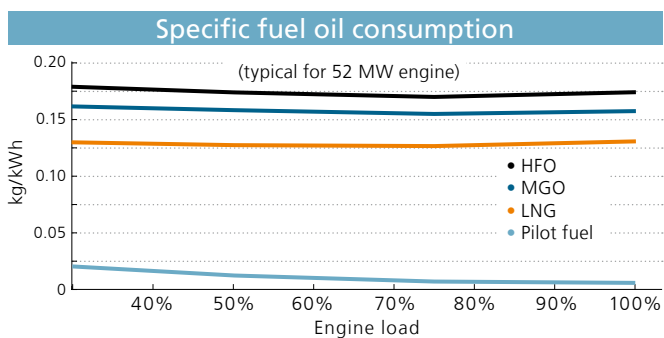




Main engine technology and modelling assumptions

The MAN ME-GI engine series, in terms of engine performance (output, speed, thermal efficiency, etc.), is identical with the well-established ME engine series. This means that the application potential for the ME-GI system applies to the entire ME engine range.

Specific fuel oil consumption is specified for different engine sizes, fuels and engine loads.



The control concept of the ME-GI engines comprises three different fuel modes:

- The fuel-oil-only mode is well known from the ME engine and, in this mode, the engine operates on fuel oil only, and the engine is considered to be "gas safe".
- The minimum-fuel mode has been developed for gas operation. In this mode, the system controls the amount of gas fuel, combined with the use of a minimum preset amount of fuel oil (pilot oil) which is set at 5% approximately. Both heavy fuel oil and marine diesel oil can be used as pilot oil. The minimum pilot oil percentage is determined from 100% engine load. When the engine passes the lower load limit, the engine returns to fuel-oil-only mode. If a failure occurs in the gas system, this will result in a gas shutdown and a return to the fuel-oil-only mode.
- Specific fuel mode, where any mix of gas and fuel oil is possible.

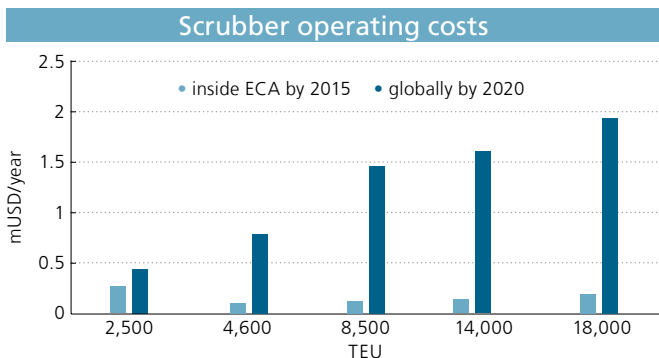




Scrubber technology and modelling assumptions

This study assumes usage of wet scrubber systems to reduce SOx emissions by scrubbing the exhaust gas from the engines with seawater in its primary operation mode. After the turbo-charger, the exhaust is led into a large scrubber placed in the exhaust stack of the ship, downstream from the exhaust gas boiler. The exhaust is led through an array of seawater droplets which washes the sulphur out of the exhaust gas. The washwater is collected, purified and discharged into the sea in conformance with current criteria set by IMO.

Scrubbers are assumed to be used only when needed to meet the emission values corresponding to the low sulphur fuel limits, i.e. inside ECA, in EU ports and globally by 2020. Their operating costs depend on operation time and engine loads. An average cost for open and closed loop scrubbing of 5 \$/MWh was used. Lost TEU slots depend on the space required for the scrubber installation. Up to 0.3% of the total available TEU slots are assumed to be lost. This is assumed to apply only every second voyage. Other operation costs such as crew spare parts and maintenance are assumed to be 20% higher than the reference vessels.



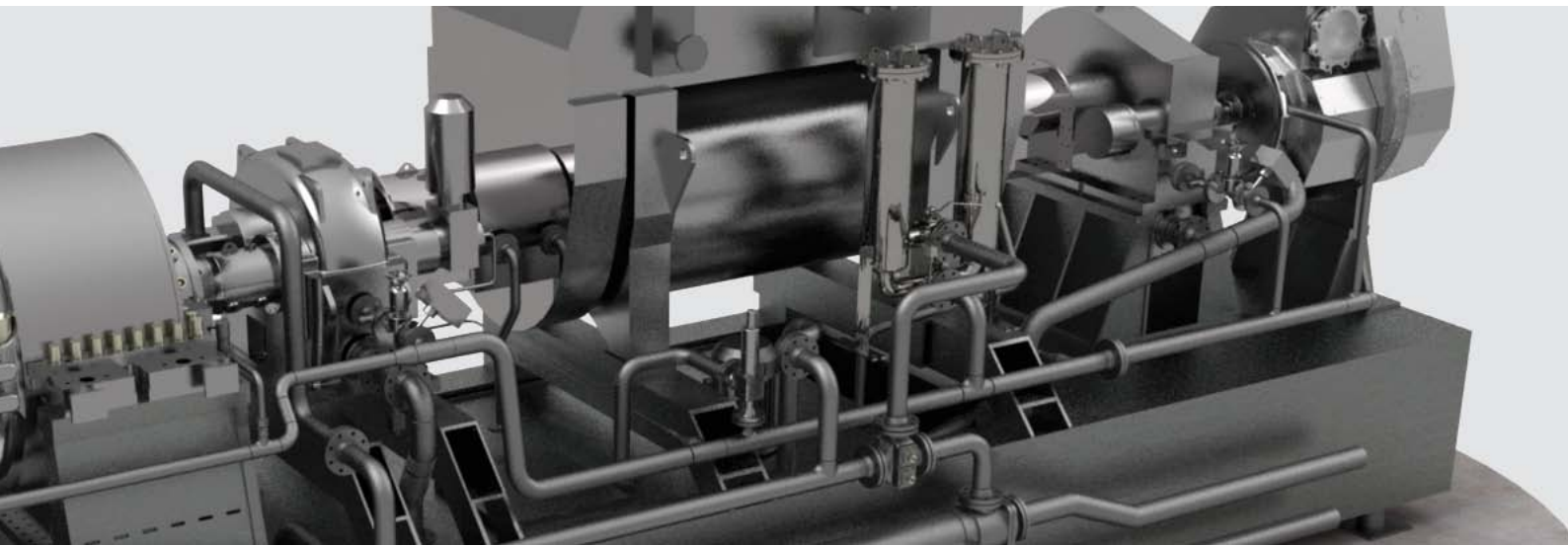
The cleaned exhaust gas is then passing through a reheater to prevent steam formation being visible when leaving the funnel. If the ship is sailing in an area where it is not allowed to discharge the washwater into the sea, there is a possibility of applying a closed-loop wet scrubber system using freshwater and caustic soda (NaOH) as reactive agent, neutralising the sulphuric acid formed during the exhaust gas washing process. For this operation a water cleaning unit will be applied.

Waste Heat Recovery technology and modelling assumptions

The waste heat recovery (WHR) system consists of an exhaust-gas-fired boiler supplying steam to a steam turbine to boost the electrical output. The system can be extended with a gas turbine utilising the energy in the exhaust gas not used by the turbocharger. To obtain the highest electrical production the optimal solution is to use a dual-steam-pressure system or even a triple-steam-pressure system if the engine is equipped with a system for exhaust gas recirculation.

Waste heat recovery systems are modelled to reduce specific fuel consumption. Savings depend on engine load and ship size. Maximum benefit of 13% was assumed for the largest vessels at 75% MCR.

Lost TEU slots depend on the space required for the WHR installation. For the smaller vessels (2,500 TEU and 4,600 TEU), up to 0.4% of the total available TEU slots are assumed to be lost. This is assumed to apply only every second voyage. Other operation costs such as crew spare parts and maintenance are assumed to be 15% higher than the reference vessels.

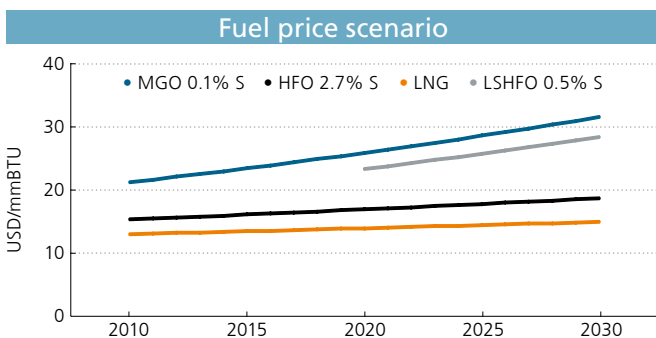


Use of distillate fuels

Running on distillate fuels for a long period of time is the straightforward solution to comply with the forthcoming emissions regulations on maximum allowable sulphur content in the fuel oil. The fuel system needs to be fitted with a cooler or a chiller arrangement to meet the fuel viscosity requirements for a safe operation of the engine's fuel system. A suitable cylinder oil will also be required. For running in non-ECA areas the fuel system must also be able to cope with the new fuel (LSHFO, with 0.5% sulphur) that might be introduced in 2020.

Fuel price scenario

The basic assumption for the fuel price scenario is a continuous price increase due to expected increase in oil and gas production costs. MGO and LSHFO are expected to increase faster than HFO and LNG with stronger increase in demand. Starting year for the fuel price scenario is 2010 and 650 \$/t (=15.3 \$/mmBTU) for HFO and 900 \$/t (=21.2 \$/mmBTU) for MGO are set. LNG is set at 13 \$/mmBTU which includes small-scale distribution costs of 4 \$/mmBTU. It is assumed that these distribution costs do not increase over time.

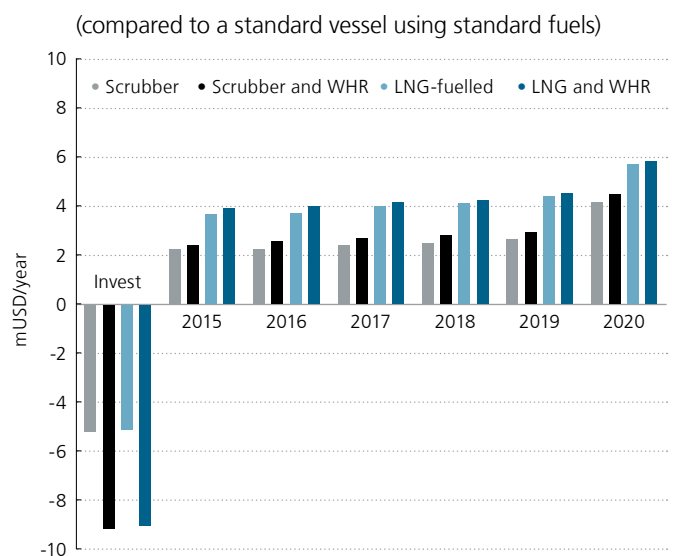


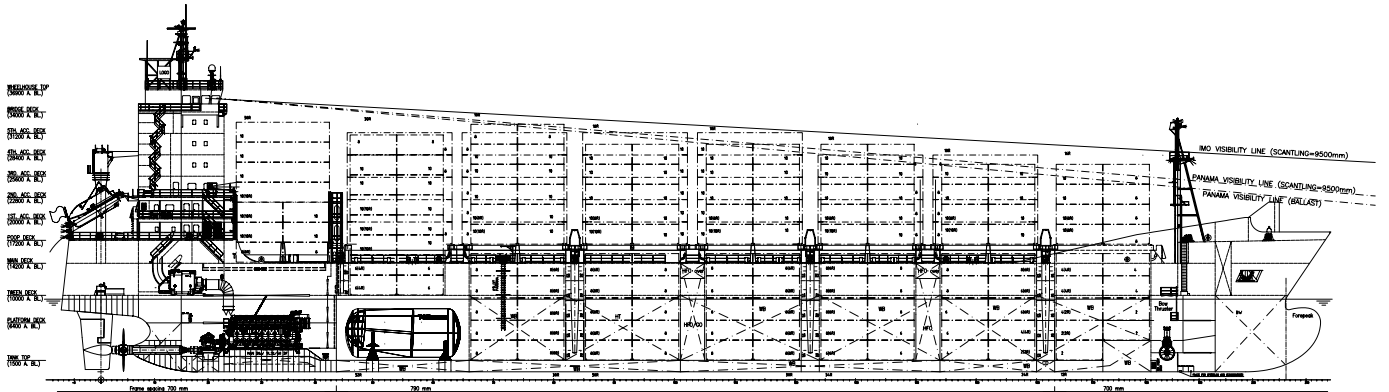
Results

Annual cost advantages, compared to the reference vessel using the required fuels depending on time and location, can be computed using the assumptions described above for each technology and vessel size. Cost advantages are the sum of fuel cost savings, additional operating costs and lost (negative) earnings.

For a 2,500 TEU regional vessel operating 65% inside European ECAs, significant cost advantages are predicted using LNG or scrubber by 2015 when strict fuel quality requirements enter into force. Payback time is shorter for solutions without WHR due to its relatively high investment costs.

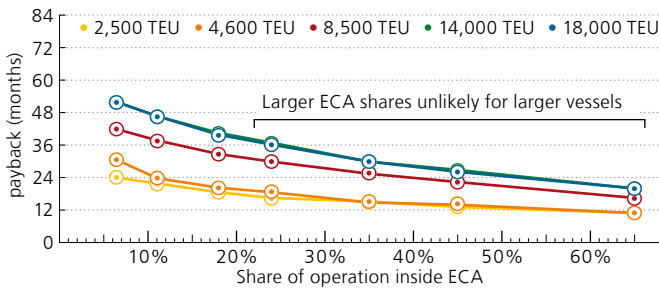
Annual cost advantage for 2,500 TEU container vessel





source: NSD - Neptun Ship Design

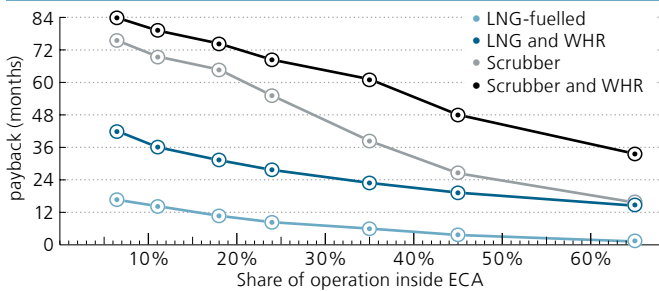
Payback for LNG system (starting in 2015)



Results – payback time

Benefits of technologies such as LNG or scrubber depend strongly on their usage. The higher the ECA exposure, the shorter the payback time for all variants, with operation starting in 2015. Payback time is shorter for the smaller container vessels (2,500 TEU and 4,600 TEU). This is caused by their relatively smaller investment for the LNG system compared to the large vessels. With 65% ECA exposure, LNG system payback time below two years can be achieved for smaller vessels.

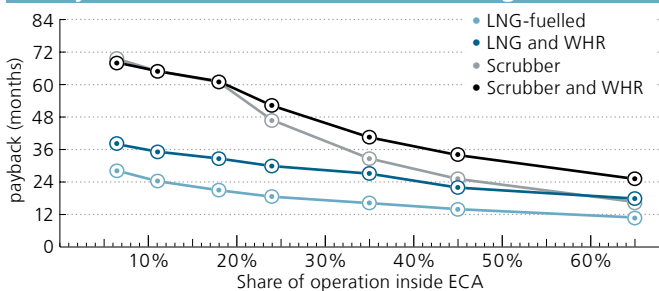
Payback for 2,500 TEU vessel (starting in 2015)



Comparing the different technologies with each other shows that the LNG system offers a shorter payback time than a scrubber for the 2,500 TEU vessel (using standard fuel price scenario). Payback time is longer for variants with WHR due to higher investment costs.

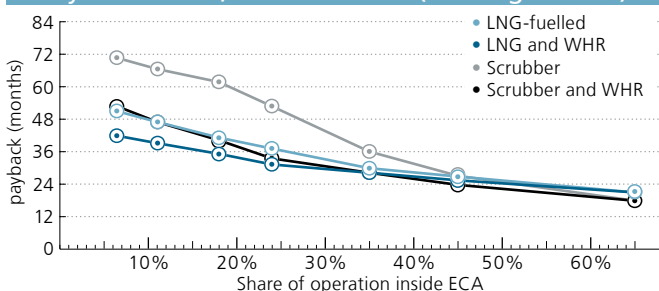
At ECA operation shares lower than 20%, the scrubber system payback time is longer than 60 months which indicates that payback is achieved only after the introduction of the LSHFO quality standard in 2020.

Payback for 4,600 TEU vessel (starting in 2015)



The 4,600 TEU vessel, operating 11% inside of an ECA, offers shorter payback time for LNG systems compared to the scrubber installation, too. Similar to the 2,500 TEU vessel, a WHR system does not shorten payback time. WHR systems offer larger benefits for large vessels with high-installed engine power and associated savings. Therefore, payback time for an LNG system or scrubber when applied to a 14,000 TEU vessel is shorter with a WHR system implemented.

Payback for 14,000 TEU vessel (starting in 2015)



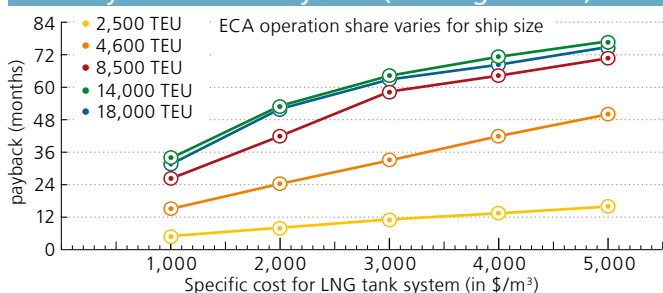
The LNG system offers shorter payback time than a scrubber system for the large vessel (using the standard fuel price scenario). Only at higher ECA operation shares (which are unlikely), the scrubber solution has a shorter payback time than the LNG system.

This documents that, when standard assumptions are used, LNG systems offer shorter payback times than scrubber systems.



source: iPP/Technolog

Payback for LNG system (starting in 2015)

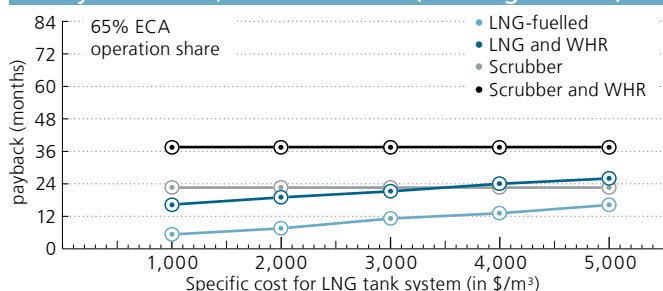


The drivers – LNG tank cost and LNG price

The largest share of the additional investment is related to the LNG tank. In this study, a type C tank is assumed to be fitted for the 2,500 TEU vessel and type B prismatic tanks are considered for the larger vessels. Smaller type C tanks are expected to have higher specific costs than larger type B tanks.

Payback for the larger vessels shows a stronger dependency on the specific LNG tank costs than for the smaller vessels (which also depends on the underlying ECA exposure levels).

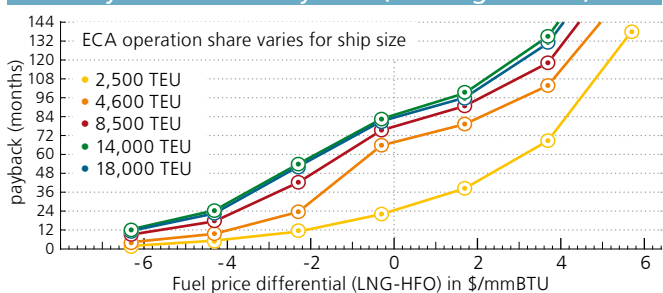
Payback for 2,500 TEU vessel (starting in 2015)



Comparing LNG and scrubber system's payback for the 2,500 TEU vessel shows that even at high specific LNG tank costs payback time is shorter for the LNG system (when the standard fuel price scenario is used) than for the scrubber.

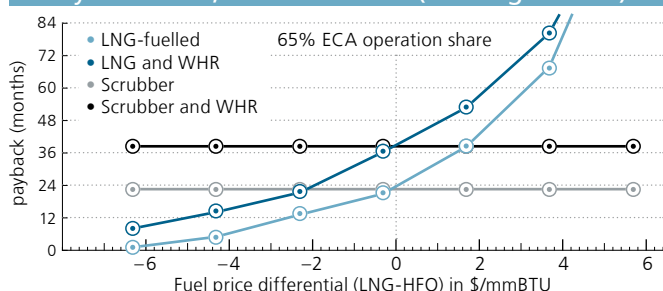
Although not shown here, specific tank costs above 3000 \$/m³ result in unfavourable payback times compared to the scrubber system for the larger vessels.

Payback for LNG system (starting in 2015)

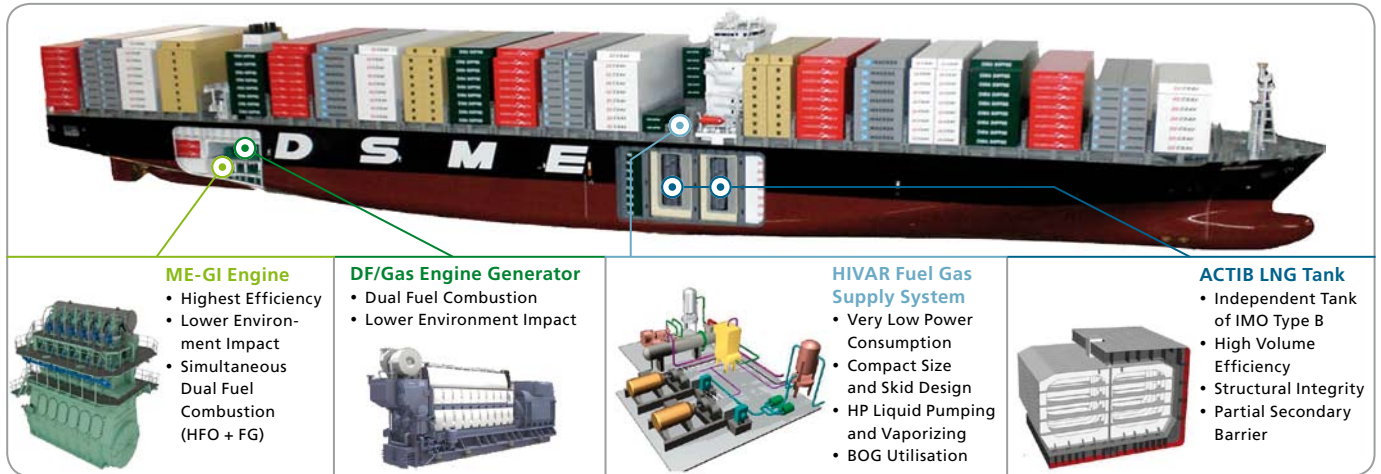


Considering the still not widely available LNG supply infrastructure for ships, changes in LNG distribution costs are considered to affect payback for LNG systems. In general, payback for the larger vessels with their relatively larger LNG system costs depend strongly on the LNG price (delivered to the ship). At price parity of HFO and LNG, based on energy content, payback time for the larger vessels is longer than 60 months (indicating a breakeven is possible only when the 2020 fuel standard is in force.)

Payback for 2,500 TEU vessel (starting in 2015)



For the 2,500 TEU vessel, a comparison of payback times for the scrubber and for the LNG system, and varying LNG prices, shows that the LNG system is attractive as long as LNG (delivered to the ship) is as expensive as or cheaper than HFO, when the fuels are compared on their energy contents. (In January 2012, LNG wholesale price in Zeebrugge was at 10.6 \$/mmBTU and HFO in Rotterdam was at 15.7 \$/mmBTU, indicating that LNG as ship fuel appears commercially attractive vs. HFO in Europe.)



source: DSME

Conclusions

Using LNG as ship fuel promises less emissions and, given the right circumstances, less fuel costs. The attractiveness of LNG as ship fuel compared to scrubber systems is dominated by three parameters:

- ➔ Share of operation inside ECA
- ➔ Price difference between LNG and HFO
- ➔ Investment costs for LNG tank system

With 65% ECA exposure, LNG system payback time below two years is predicted for the smaller vessel sizes (using the standard fuel price scenario).

For the 2,500 TEU vessel, a comparison of payback times for the scrubber and for the LNG system, and varying LNG prices, shows that the LNG system is attractive as long as LNG (delivered to the ship) is as expensive as or cheaper than HFO, when the fuels are compared on their energy content.

For larger vessels typically operating at smaller ECA shares, e.g. the 14,000 TEU vessel, the LNG system has the shortest payback time (when the standard fuel price scenario is used), and the use of a WHR system further reduces the payback time.

The price of LNG delivered to the ship is difficult to predict. Base LNG prices vary from the USA to Japan by a factor of four. European base LNG prices appear attractive at around 10 \$/mmBTU even with small-scale distribution costs added. An LNG price of up to 15 \$/mmBTU could give LNG systems a competitive advantage against scrubbers in terms of payback for the smaller vessels considered in this study.

Small-scale LNG distribution is just starting to become available in Europe (outside Norway) and it remains to be seen which LNG-fuel price levels will be established.

The model to predict cost and benefits for LNG systems, scrubbers and WHR systems onboard container vessels offers extensive possibilities to study additional variants. Options include different vessel size, route profiles incl. ECA operation shares and other LNG tank configurations. Targeted analysis is offered on request.



LNG as ship fuel has become a reality for international shipping. The product carrier Bit Viking started operation using LNG in October 2011. It is classed by GL.



Acknowledgements

This study was jointly conducted by GL and MAN in 2011. The work was performed by Mr Mads Lyder Andersen (MAN), Mr Niels B. Clausen (MAN) and Dr Pierre C. Sames (GL).

Further information can be obtained from

Dr Pierre C. Sames, Senior Vice President
GL Research and Rule Development
Phone: + 49 40 36149113
E-mail: Pierre.Sames@GL-Group.com

Sources:
Diagrams: GL-MAN container vessel advanced propulsion roadmap
Pictures on page 4–7: MAN

Germanischer Lloyd SE

Research and Rule Development

Brooktorkai 18, 20457 Hamburg, Germany

Phone: +49 40 36149-113

Fax: +49 40 36149-7320

research@gl-group.com

www.gl-group.com



Global Sales Offices

Germanischer Lloyd SE Global Sales

Brooktorkai 18
20457 Hamburg
Germany
Phone: +49 40 36149 6397
www.gl-group.com

North / East Europe

Germanischer Lloyd Denmark A/S
Amager Strandvej 390
2770 Kastrup
Denmark
Phone: +48 91 4315302
gs-ne@gl-group

Middle East / Africa

Germanischer Lloyd SE Branch Office Dubai
White Crown Bldg., Room No. 402
PO Box 8015, Sheikh Zayed Road
Dubai, United Arab Emirates
Phone: +97 14 3328842 200
gs-me@gl-group.com

Mainland China

Germanischer Lloyd (China) Co., Ltd.
Shanghai Central Plaza, Room 1201
381, Huaihai M. Road
200020 Shanghai, China
Phone: +86 21 23308 761
gs-cn@gl-group.com

Americas

Germanischer Lloyd (USA), Inc
1155 Dairy Ashford Rd., Suite 315
Houston, TX USA 77079
Phone: +1 83 23204 658
gs-am@gl-group.com

Central Europe

Germanischer Lloyd SE
Brooktorkai 18
20457 Hamburg, Germany
Phone: +49 40 36149 3738
gs-ce@gl-group.com

Southern Europe

Germanischer Lloyd Hellas M.E.PE
85 Akti Miaouli
185 38 Piraeus, Greece
Phone: +30 21 04290 373
gs-se@gl-group.com

Asia / Pacific

Germanischer Lloyd Singapore Pte Ltd
180 Clemenceau Avenue #03-01
Haw Par Centre, Singapore 239922
Phone: +65 6835 9610
gs-ap@gl-group.com