
# Costs and benefits

**MAN Energy Solutions**
Future in the making

**Costs and benefits**
**Alternative fuels for an LR1 Product Tanker**
**Key results from a DNV GL and MAN Energy Solutions joint study**

# Costs and benefits

## Alternative fuels for an LR1 product tanker



**The sulphur emission control areas (SECAs) in place in North-America and Northern Europe, in combination with the upcoming global 0.5% limit on sulphur in 2020 (or 2025) and similar EU limits in 2020, call for alternative fuels as a means for compliance. Several alternative fuels are available and, at the same time, new fuel oil products with very low sulphur content have been introduced.**

In June 2015, IMO's Maritime Safety Committee (MSC) adopted the International Code of Safety for Ships Using Gases or Other Low-flashpoint Fuels (IGF code). The IGF code aims to minimise the risk to the ship, its crew and the environment, taking into account the nature of the fuels involved, which can pose some safety risks if not properly managed. As such, the IGF code has created long-expected predictability for planning gas-fuelled ships.

### Objective of the study

The goal of this study was to analyse costs and benefits of various fuel options for a case with one particular ship and its operating pattern. The alternative fuels selected were LNG, LPG, methanol and a new ultra-low-sulphur fuel oil, a so-called hybrid fuel. Costs and benefits for a newbuild were determined by looking at its additional investment and operating costs compared to a standard fuel variant using HFO and MGO.

| | |
|---|---|
| Length, O.A. | 225 m |
| Breadth, Mld. | 32.26 m |
| Scantling draught | 14.2 m |
| Design draughtZ | 12.2 m |
| Main engine | 1 x MAN B&W 6G60ME-C9.5 |
| SMCR | 11 500 kW at 92 rpm |
| NCR (90% SMCR) | 10 390 kW at 88.8 rpm |
| Design speed at NCR | 15 knots, incl. 15% sea margin |
| PTO | Fixed ratio, 778 kW |
| GenSet | 3 x MAN 7L23/30H at 944 kW |

Table 1: Main particulars of the selected ship

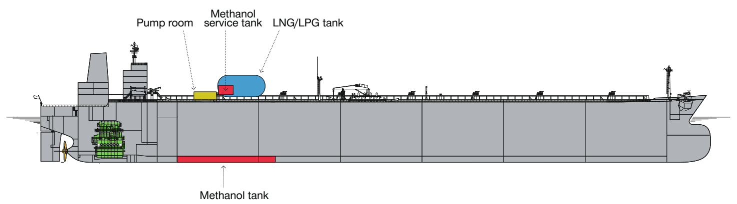


**Fig. 1: General arrangement of the selected 75 000 D.W.T. Panamax tanker. The tanks of LNG, LPG and Methanol are indicated together with a pump room used for the alternative fuel**

Contents

An LR1 product tanker on a fixed route was selected to perform a financial analysis. For the various fuels, the machinery setup was the same, except for the fuel system. Product tanker is a market segment where DNV-GL expects an annual growth to 2020 in tonnage demand of 3 to 3.5%. The general arrangement of the selected ship is shown in Fig. 1, and its main particulars are presented in Table 1.

### Operating pattern

The ship is assumed to operate on a route between Northern America and Northern Europe: Houston-Rotterdam-Ventspils-Houston. From the total distance of about 11,700 nautical miles, approximately 37% is inside a SECA.

The typical speed for similar sized product tankers on similar trades was determined from AIS data to be about 12.5 knots, and this speed was then used as fixed transit speed of the ship. With 360 operating days a year this corresponds to about 8 roundtrips per year with 87% of the time spend in transit, 3% in approach and 10% in port. The selected route is shown in Fig. 2. Typical cargoes from Europe could be light diesel and returning from North America heavier distillates, e.g. marine gas oil.

### Fuel variants

The main idea of the study was to investigate different fuel options for the selected product tanker on the selected route. The reference fuel case consists of HFO outside of SECA and MGO inside. In this study, the reduction in global sulphur cap has been assumed to be enforced from 2020, and hence LSFO with 0.5% S is the reference fuel outside of SECA from 2020.

Table 2 shows the fuel variants considered in this study. For the alternative fuels considered (LNG, LPG, and methanol), one variant includes use of the alternative fuel for the entire round trip (one-fuel variant, e.g. denoted "LNG"), while a second variant assumes use of the alternative fuel in the SECAs only and HFO/LSFO outside (mixed fuel variant, e.g. denoted "LNG/HFO"). Renewable diesel (also called hydrogenated vegetable oil) was also considered in the beginning of the study. It is a high-quality biofuel produced from vegetable oil and animal fat, but the current price of about 1000 €/tonne renders it uncompetitive in this study.

LNG and LPG can reduce the carbon footprint by up to 20%, depending on how the fuel is produced. Methanol offers future potential reductions by production from renewable sources, possibly at a lower cost premium than LNG and LPG.

The additional investment costs relative to the reference scenario for tanks, piping and engine modification were considered in the financial analyses, see Fig. 3. It has been assumed that tanks are placed on deck thereby not reducing the cargo capacity and, thus, earnings. Measures needed to reduce NOx emission to IMO Tier III levels were, for simplicity, assumed to be at a similar overall cost for all the fuel variants and, hence, neglected from the study. The investment year was set to be 2017 with operations between 2018 and 2030.

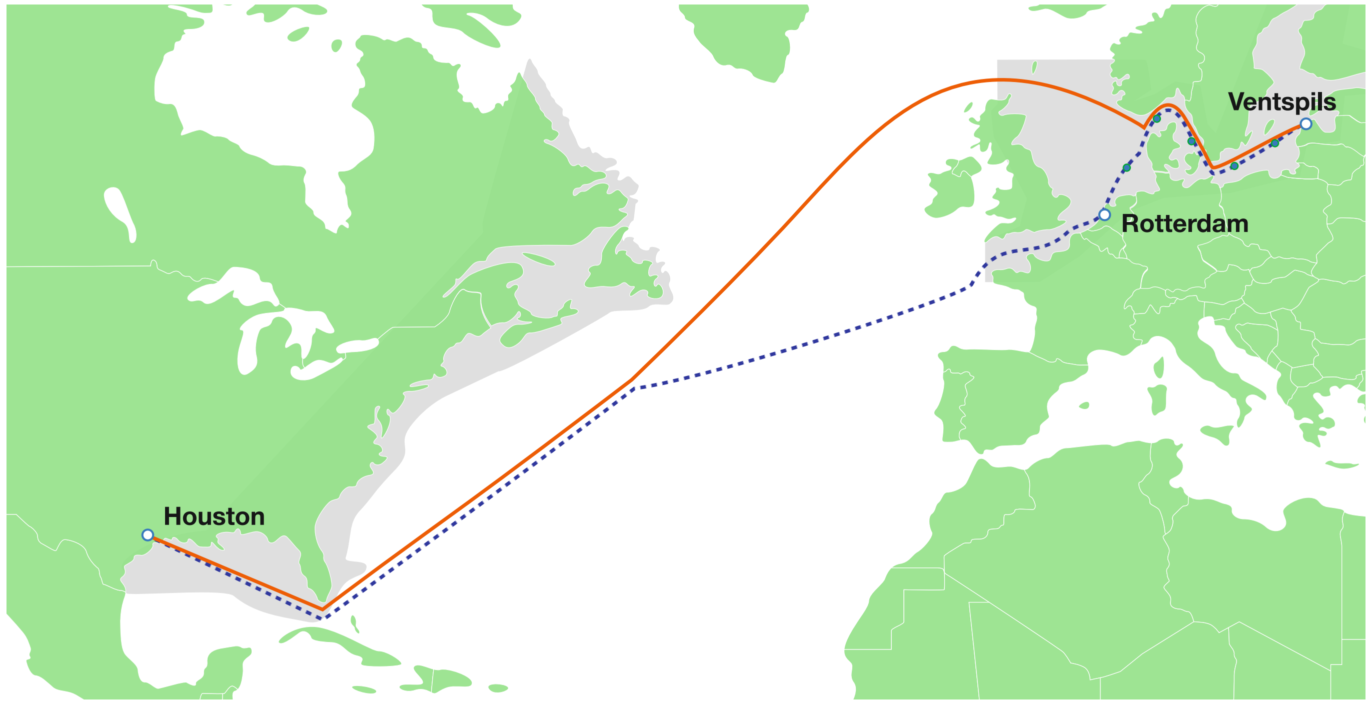


Fig. 2: Selected route between Northern America and Europe

| Variant | Inside ECA | Outside ECA, 2018-2019 | Outside ECA, 2020 |
|---|---|---|---|
| Reference | MGO | HFO | LSFO 0.5% |
| LNG | LNG | LNG | LNG |
| LPG | LPG | LPG | LPG |
| Methanol | Methanol | Methanol | Methanol |
| LNG/HFO | LNG | HFO | LSFO 0.5% |
| LPG/HFO | LPG | HFO | LSFO 0.5% |
| Methanol/HFO | Methanol | HFO | LSFO 0.5% |
| ULSFO 0.1% | ULSFO 0.1% | ULSFO 0.1% | ULSFO 0.1% |

Table 2: Fuel variants defined for this study

### Machinery

An MAN B&W 6G60ME-C9.5 was selected as the main engine. This provides the ship with a design speed of 15 knots at 90% engine load, including a 15% sea margin. The calculated power for propulsion to reach 12.5 knots is 5.3 MW. Specific fuel oil consumptions for this engine for each fuel at various engine loads were used in the calculations, and the efficiency is shown in Fig. 4. The 6G60ME-C9.5 engine is available as a standard oil-fuelled diesel engine, but also in dual fuel versions capable of burning LNG, methanol or LPG (the ME-GI and ME-LGI types, respectively):

The propulsion system is equipped with a fixed-ratio power take off (PTO). The capacity of the PTO is 778 kW offering a simple and cost-effective way to supply all the electric power from an alternative fuel when the ship is in transit. Apart from the reduced investment in equipping auxiliary engines for alternative fuel operation, the PTO also minimises the maintenance cost on the gensets. In approach and port, auxiliary engines running on MGO are used, as illustrated in Fig. 5. For more information about different PTO configurations, see our paper No. 5510-003-02, Shaft Generators for Low-speed Main Engines.

The main engine is for the three alternative fuel options equipped with a second fuel system enabling the engine to work as a dual fuel engine. This engine configuration offers full fuel flexibility with the same available power in both fuel oil and second fuel mode.

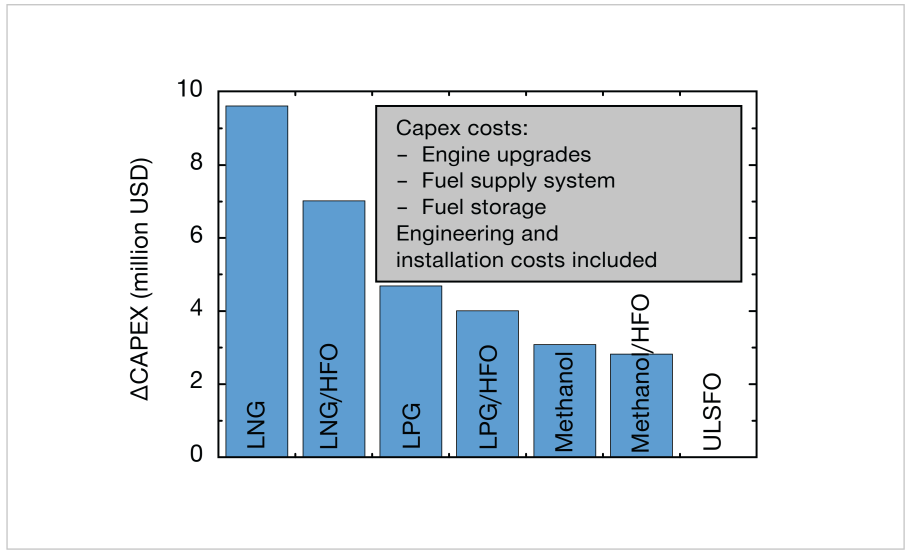


Fig. 3: Incremental investment costs for the alternative fuel variants

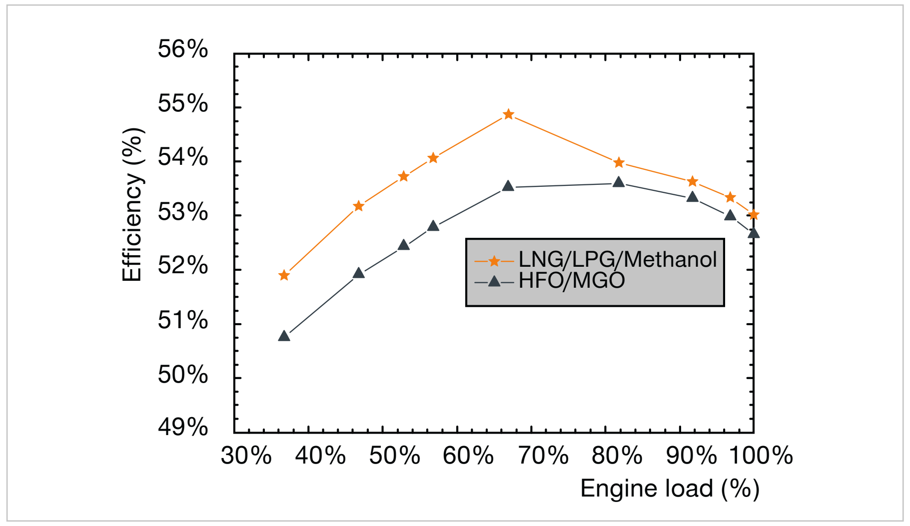


Fig. 4: Efficiencies of MAN B&W 6G60ME-C9.5 for the fuels at different engine loads

Fuel oil mode (or MGO mode in SECAs) acts as fallback mode in case of unintended interruption of the second fuel mode. Also for this reason, the original fuel oil tank capacity is kept unchanged in this study.

The tank size for the alternative fuels was selected to give the vessel half-round-trip endurance with a 20% margin. This limits the investment costs, but increases the exposure to volatile fuel prices. For LPG and LNG the tanks are placed on deck, and for methanol in the double-bottom of the ship. In all cases the cargo capacity of the case ship is left unchanged, and it has been assumed that there is no significant change in the draught of the vessel for any mass change of the ship related to use of the alternative fuels.

## Fuel price scenarios

The fuel price scenario is important for the financial viability of the various fuel options. Historic fuel prices are shown in Fig. 6 for the last 5 years.

Apart from the variations expected for each fuel type, the relative position of the fuel prices has changed over the period. MGO has become less expensive than methanol, and LNG has become equally expensive as LPG. In addition, the price difference between HFO and LNG has decreased recently. Two price scenarios were developed:

- High-price scenario based on mid-2014 fuel prices at a time when Brent oil was at 100-110 $/barrel.
- Low-price scenario based on mid-2015 fuel prices when Brent oil prices were about 50 $/barrel.

For each scenario, an annual increase in fuel prices of 1% has been assumed, due to expected increase in oil and gas production costs.

The LNG distribution costs are estimated to 100 $/t, or about 2 $/mmbtu, based on basis of the cost of operating an LNG bunkering barge. These costs are assumed to stay constant over time. Similarly, the distribution costs of LPG are considered to be half the distribution costs of LNG, i.e. 50 $/t.

The two price scenarios are illustrated in Fig. 7 based on the historic prices shown in Fig. 6. For the purpose of the analysis, we have differentiated between the prices in USA and Europe. For methanol and HFO, the prices are the same at the exchange rates. For LPG and LNG, the prices are cheaper in USA, whereas for MGO the prices have been considered lower in Europe. It should be noted that the price of the reference fuel outside SECAs is changing in 2020, from HFO to LSFO.

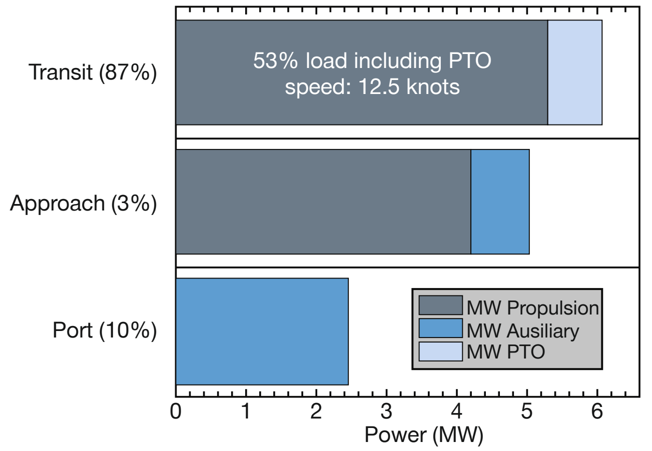


**Fig. 5: Power generated and distributed between PTO, main engine and auxiliary engines for the trading pattern selected**

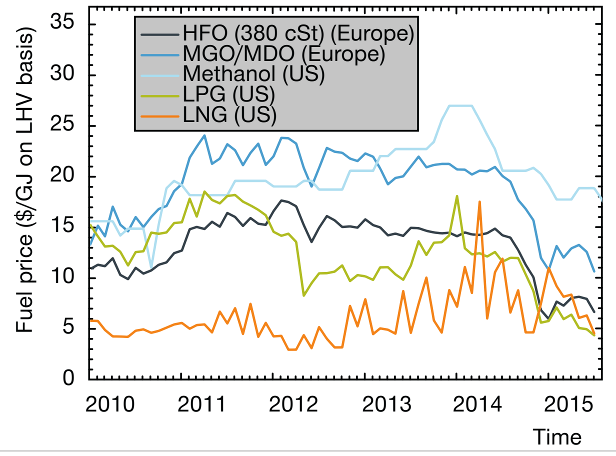


**Fig. 6: Historic fuel prices on energy basis**

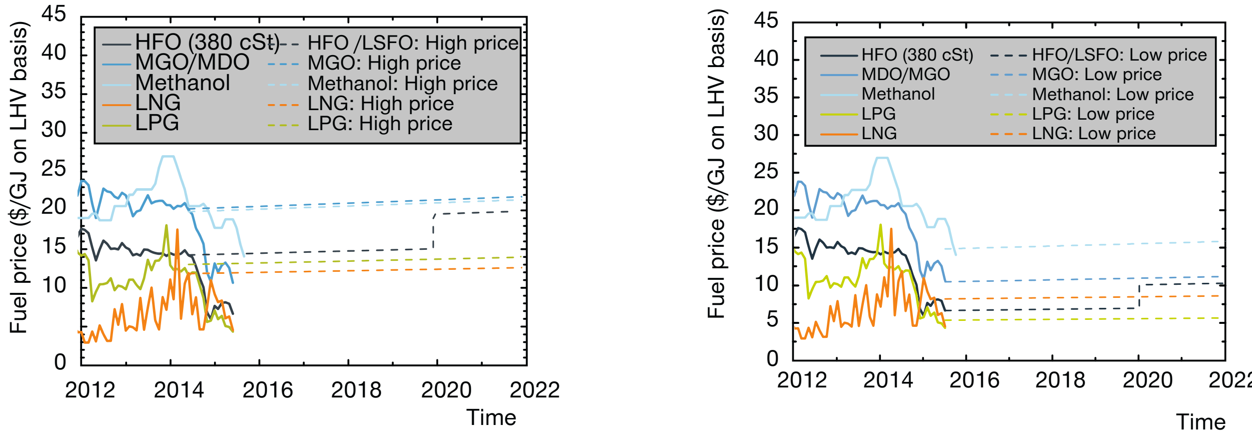


**Fig. 7: Fuel price scenarios: high-price scenario (left) and low-price scenario (right)**

## Results

For each fuel variant, the investment cost difference and the annual cost differences have been determined, see Fig. 8. The diagrams show cost difference (either advantage or disadvantage) for the various fuels against the reference variant for both fuel price scenarios.

In the high-price scenario, both in the one-fuel variants and mixed fuel variants, LNG and LPG deliver a cost advantage in operation when compared to the reference. However, these alternatives call for substantial investments. A large part of this, in particular for LNG, is related to investments for the tanks.

For the one-fuel variants, the cost advantage improves significantly after the global 0.5% sulphur cap enters into force. However, for the mixed-fuel variant, where the alternative fuel is only used in the SECA, the annual cost difference does not change by the global sulphur cap, because both the reference case and the project case change in the same way (from HFO to LSFO) outside SECA. However, since the fuel price is lower for LNG and LPG than for LSFO, the one-fuel variant becomes financially more attractive after the global sulphur cap.

LNG and LPG are both less attractive in the low-price scenarios. The cost difference for LPG stays positive for all operational years, whereas LNG is estimated to be negative before the global sulphur cap and positive after. Methanol does not give a positive cost difference compared to the reference case for any of the price scenarios, and hence the investment needed for engine upgrade, gas supply system and tanks is not paid back.

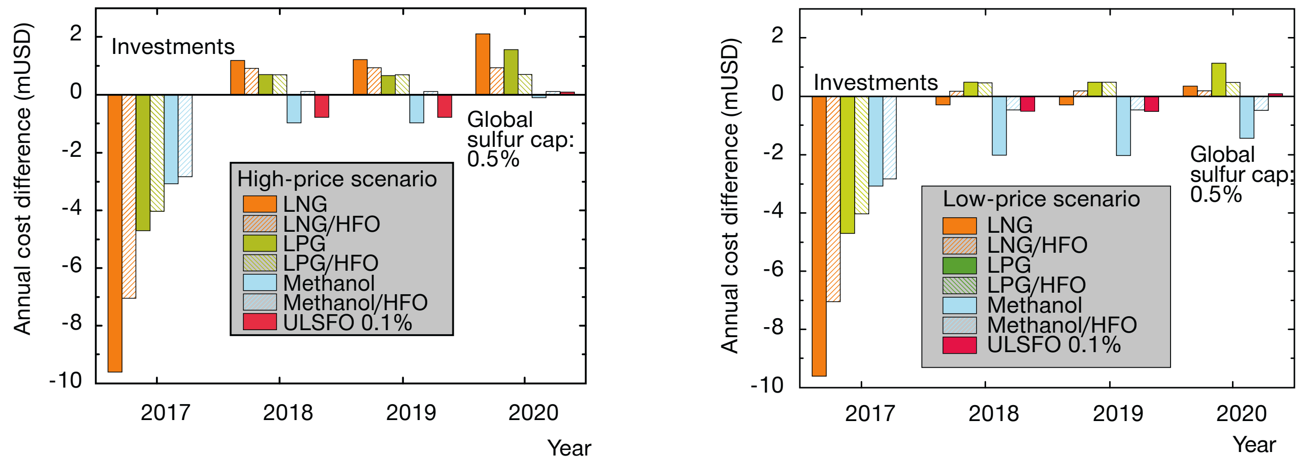


**Fig. 8: Annual cost difference for the various fuel variants under the two price scenarios: high-price scenario (left) and low-price scenario (right)**

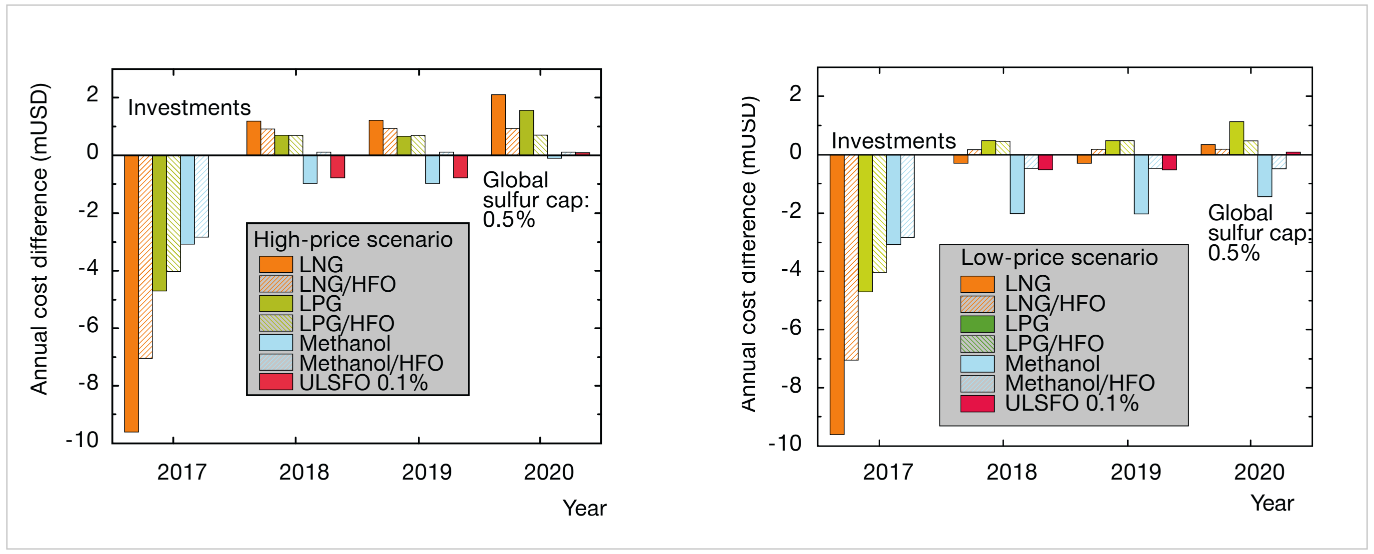


Fig. 8: Annual cost difference for the various fuel variants under the two price scenarios: high-price scenario (left) and low-price scenario (right)

Methanol becomes financially attractive if the methanol price drops, while the other fuel prices remain constant. If the methanol price drops to 18-20% below the MGO price, the high-price scenario will have a payback time similar to that of LNG and LPG. For the low-price scenario, the methanol price needs to drop even more. Such lower prices for methanol are more likely to become a reality if a lower grade fuel methanol is introduced on the fuel market.

Another option is to use ULSFO (hybrid fuel) for the entire round trip. The benefit of this is to avoid the compatibility issues related to fuel changes between hybride fuel and HFO when entering/leaving SECAs. Nevertheless, even after the global sulphur cap, the annual fuel costs for this scenario are at the same level and, therefore, not better from a financial point of view than the reference option. In the high-price scenario, both LNG and LPG have payback periods in the 5-10 years range. As expected, the payback time decreases at higher vessel speeds since the investment costs are the same and the cost difference for each year of operation becomes more favourable by a higher fuel consumption, the effect is shown in Fig. 9. At 15 knots, the payback times are less than 5 years for all four variants.

The payback times are shorter for the one-fuel variants than for the mixed-fuel variants. As a result, the increased initial investments are more than compensated for by the lower prices for LNG and LPG compared to LSFO in the high-price scenario.

One-fuel variants show that LNG and LPG look attractive. Thanks to the lower added investment for LPG-capable installations, LPG offers shorter payback periods, see Figs. 4 and 9. In the low-price scenario, the payback time for LNG is more than the 13 years considered in this study, whereas LPG has a payback time of approximately 6.5 years. Payback times for LPG in both price scenarios are shown in Fig. 10. Based on the fuel price scenarios presented in this work, LPG can be understood as at least as good as LNG based on a shorter payback time, less sensitivity to reasonable price variations and less initial investments.

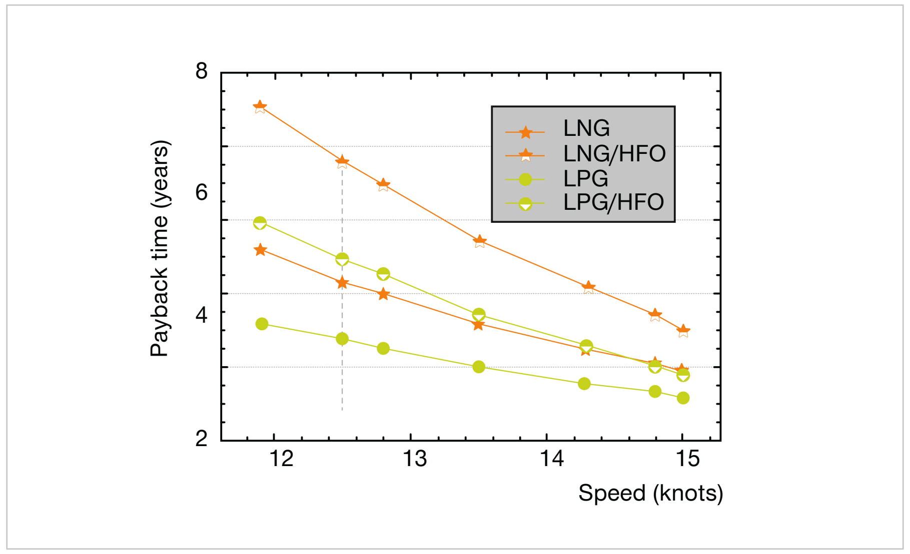


Fig. 9: Payback time as a function of ship transit speed for LNG and LPG pure and combined variants in the high price scenario (dashed line indicates reference speed)



## Sensitivity of fuel prices, LNG tank investment and bunkering choice

Fuel prices with their intrinsic uncertainty are critical for the outcome of the financial analysis. In addition, LSFO is not a common fuel today, and it is neither clear which refinery streams will be used to produce the LSFO, nor what the price level would be. A study carried out by Purvin & Gertz assumed that LSFO would be based on desulphurised atmospheric residue, and that the price would be 120-170 $/t higher than HFO. In order to take the uncertainty into account, a sensitivity analysis between LSFO and the alternative fuels was carried out. A large price spread indicates a larger driving force for a fuel switch to LNG or LPG.

As shown in Fig. 11, LPG requires a smaller discount than LNG to be financially attractive. This is due to a lower investment. Even though the expected discount is less for LPG than LNG, the payback time is shorter. Nevertheless, with reasonable prices for LNG and LPG in the high-price scenario, the additional investment required due to the alternative fuel is paid back within the project period of 13 years.

If 0.5% LSFO is based on a distillate, MGO prices will likely increase at the beginning of the global sulphur cap. This is not included in our study, but since such increases would make the alternative fuel look better, our estimated payback times are considered conservative in this case.

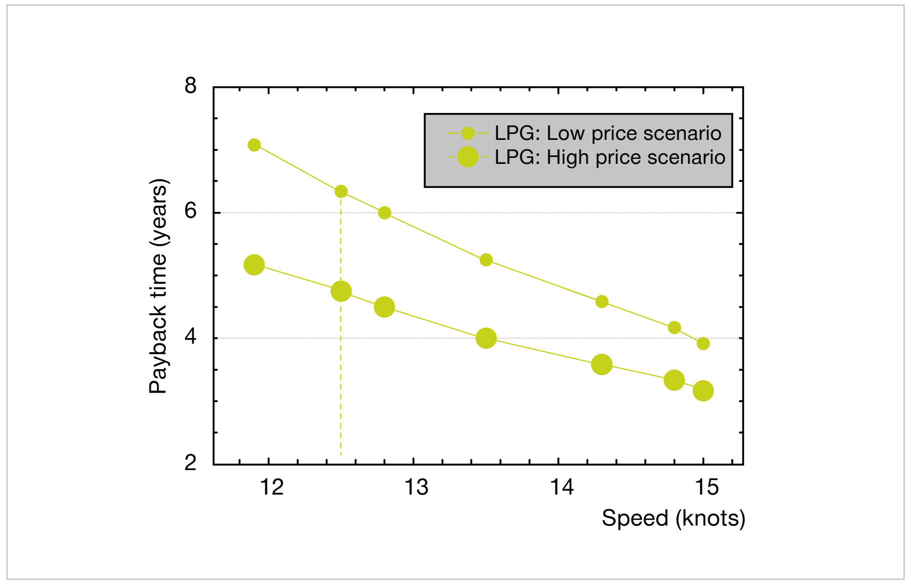


Fig. 10: Payback time as a function of ship transit speed shown for LPG in both price scenarios - LPG is used both inside and outside SECAs (dashed line indicates reference speed)

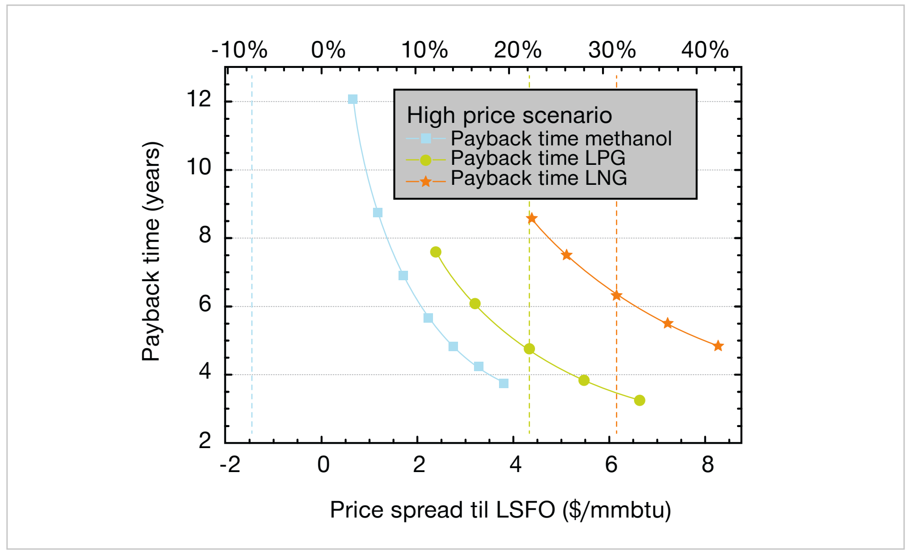


Fig. 11: Payback time as a function of price difference between LSFO (at 19.55 $/mmbtu) and the alternative fuel (dashed lines represent the values used in the high price scenario for each fuel)

The outcome of the financial assessment is also strongly dependent on the tank cost in the case of LNG. This tendency is shown in Fig. 12. For example, if the LNG tank investment was to be reduced to below 2000 $/m3, including the foundation, the LNG-based variant would have about a year shorter payback time and be closer to the payback time of LPG, compare with Fig. 9.

In this study, a tank capacity for half a roundtrip was assumed, which means that the vessel would need to bunker in Houston and in Rotterdam. However, there is a fuel price difference between the ports. Therefore, the scenario was also checked for bunkering LNG and LPG only in the cheapest location on the round trip, i.e. Houston. When LNG is used for the full round trip, the payback time increased from 76 to 97 months by reduction of bunkering to one location. Hence, the additional investment cost in a larger tank capacity is not returned by the lowered fuel price. However, for LPG the payback time is reduced from 57 to 51 months by installing the tank capacity necessary for a full round trip. The main reason for the difference is the high tank price for LNG compared to LPG.

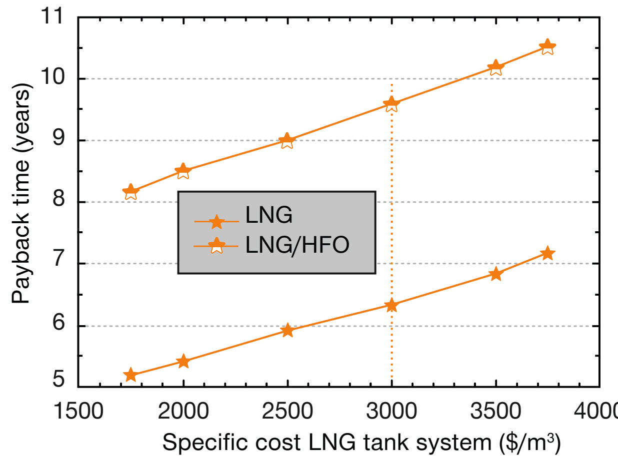


Fig. 12: Payback time as a function of specific tank cost for LNG, high price scenario (dashed line indicates reference value)

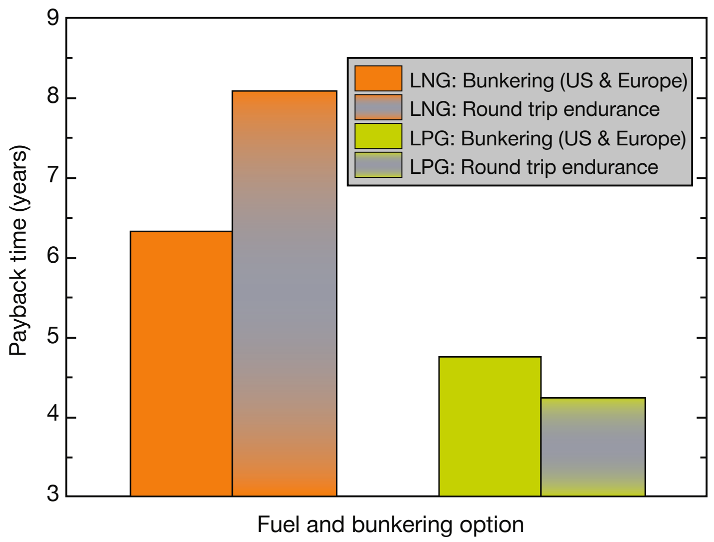


Fig. 13: Comparison of payback time for LNG/LPG bunkering for one location with full round trip endurance (Houston) or for bunkering in two locations for half round trip endurance (Houston and Rotterdam)

# Conclusions

The interest in using alternative fuels is growing, and the first ships with dual fuel two-stroke propulsion engines have now entered service.

The fuel alternatives LNG, LPG, methanol and ULSFO have been compared to a reference case using traditional fuels (MGO/LSFO) as a means of sulphur compliance for a typical LR1 tanker trading between Europe and Northern America. The comparisons were made with two different scenarios of fuel prices. Generally, the scenario with the highest absolute fuel prices resulted in the highest price difference between traditional and alternative fuels. As a consequence, the high-price scenario resulted in the highest annual cost difference for the alternatives as well as the shortest payback times.

With the two price scenarios used in this study, methanol and ULSFO did not show a financial feasibility. LNG and LPG are both financially interesting alternative fuels, and LPG was found to be at least as good as LNG. For these best fuels, the best alternative is to use it both inside and outside SECA regions. For LPG, it is recommended to consider full round trip endurance for the tank system.

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