# Cost factors

At MEPC 70, the IMO decided to reduce the maximum sulphur content in exhaust gas from 3.5% to 0.5% from 2020. **Dr Elizabeth Lindstad** of Sintef Ocean provides an analysis of alternative abatement options and compares their respective cost efficiencies

Historically, about 75% of maritime shipping's global fuel consumption has been heavy fuel oil (HFO). This fuel is mainly used by the largest ships, corresponding to 25% of the approximately 120,000 vessels in the global fleet. The remaining 25% of the fuel is consumed by a range of different vessels, generally smaller in size, representing 75% of vessels. Nearly all these smaller vessels currently use diesel, and the only change in 2020 will be that the sulphur content in the diesel must be lower than 0.5 % globally. For the approximately 30,000 vessels currently using HFO, the regulation implies that they can continue to use residual fuels such as HFO, if they employ scrubbers to desulphurise exhaust gases. Alternatively, they can use fuels with a minimum of 0.5% sulphur content, such as desulphurised HFO (HFO<0.5% S), distillates (diesel) or liquefied natural gas (LNG).

The advantage of HFO for the shipowners is its low price compared to distillates. For the refineries, selling residual fuel has been an alternative to making large investments in process equipment, to convert more of the residual fuel to distillates. The typical output from a conventional refinery is around two-thirds of refined products, including distillates, and one-third of residual fuel, including HFO.

An increased demand for distillates, in combination with global crude oil becoming heavier and with increased sulphur content, has created a need to convert residual fuel to distillates, independently of the International Maritime Organization (IMO) decision. Newer refineries are therefore 'conversion' or 'deep conversion' refineries, representing both a higher investment cost and higher energy consumption in the refinery process.

Desulphurising residual fuel oils implies cost and complexity similar to conversion from residual to distillate. This is in comparison to sulphur removals from distillates which are common technology for all refineries. The bi-products from the processes, such as petcoke from conversion of residual to distillate, and sulphur from both options will achieve a lower sales price per ton than HFO and this gap increases with higher crude oil prices.

Compared to crude oil and HFO, the coal price has been low and stable since 2006, around $100 per ton of oil equivalents (TOE), i.e. 15%-50% of the HFO price. This implies that it is not obvious that it will be more profitable for the refineries to convert the HFO into distillates instead of desulphurise to low sulphur residual oil (HFO< 0.5%). Or they may simply continue to process HFO for the scrubber market. Moreover, the desulphurised pathway enables the blending in of unprocessed HFO coming from refineries which use crudes with a natural low sulphur content, such as Brent crude from the North Sea. In total, this should enable refineries to supply the market with residual oil satisfying the 0.5% sulphur cap, (HFO<0.5% S) priced competitively. Distillates (diesel) will be mainly be an option for the smallest vessels with the lowest consumption currently using HFO.

The obvious benefit both with distillates (diesel) and low sulphur residual oil (HFO<0.5% S) is that they require no or only marginal modifications of vessels. In comparison, scrubbers or the use of marine LNG requires modification and installation of new equipment which comes at a significant cost. Generally, these costs are higher when retrofitted on an existing vessel, compared to when included in the process of building a new vessel.

| Fuel and abatement option | Fuel price 2017 | Basic Capex cost | Cost 1000 kW installed power | Equipment and installation 5MW vessel | Equipment and installation 10MW vessel | Equipment and installation 20MW vessel |
|---|---|---|---|---|---|---|
| | $/ton | $ million | $ million | $ million | $ million | $ million |
| HFO | 300 | - | - | | | |
| HFO < 0.5% S | 375 | - | - | | | |
| Diesel | 500 | - | - | | | |
| HFO - Hybrid Scrubber | 300 | 2.25 | 0.07 | 2.6 | 3.0 | 3.7 |
| Gas on LNG/LPG vessels | 300 | 2.00 | 0.10 | 2.5 | 3.0 | 4.0 |
| LNG - newbuilt vessels | 300 | 2.00 | 0.40 | 4.0 | 6.0 | 10.0 |

Table 1: Cost for abatement options

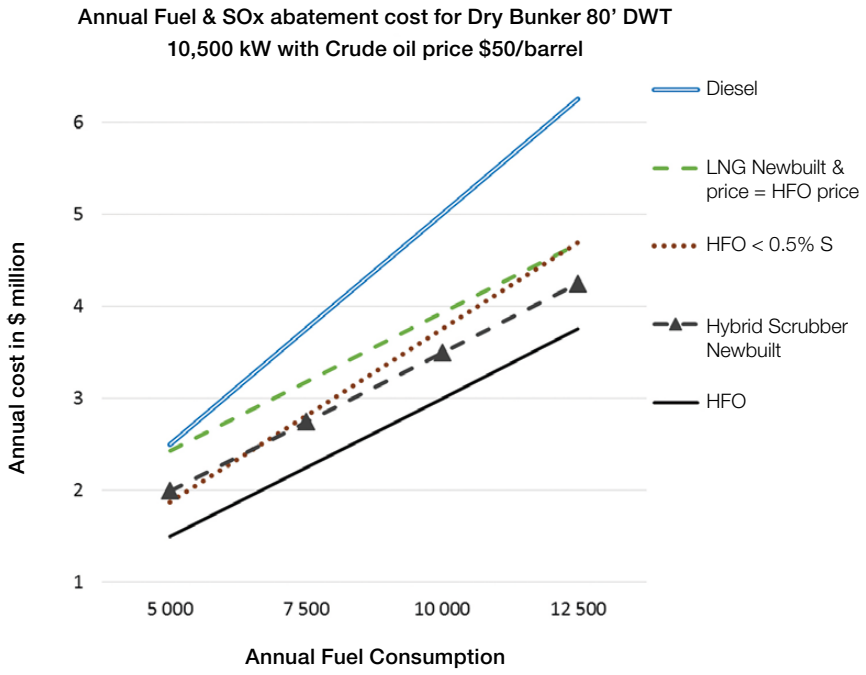


Figure 1: Annual fuel and SOx abatement cost as a function of annual fuel consumption and abatement option

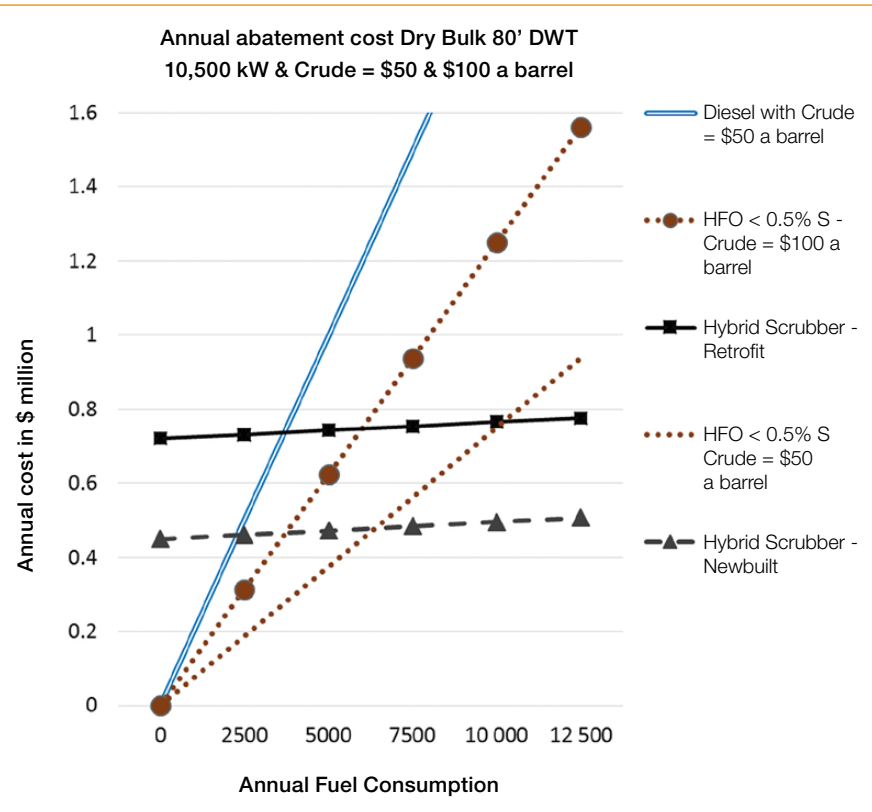


Figure 2: Comparing annual abatement cost for scrubbers versus desulphurised residual oil -HFO<0.5% S

Of these options, scrubbers are easy to retrofit on most vessel types and no challenge at all for new-buildings, apart from the acquisition cost. This is in contrast to LNG and methanol which for retrofit implies major engine modifications or even a new engine, in addition to the need for new fuel storage and handling systems, i.e. duplication of the existing fuel systems.

For these reasons, both LNG and methanol are only options for newbuildings unless favourable incentives are available (Norwegian NOx fund, research funding, or national incentives through measures such as fairway and port rebates).

With regard to scrubbers, there are three types: open loop, closed loop and hybrid. An open loop scrubber discharges the sulphur-rich wash-water directly into the sea. With a closed loop scrubber, the wash-water is treated with chemicals and particles are filtered out before it is reused many times. A hybrid scrubber combines the two modes and can run in open mode at sea and in closed mode in ports and sensitive areas. The starting cost for a hybrid scrubber is 50% higher than for an open loop scrubber, while the additional cost per kW installed is of the same magnitude as for an open loop. With an increased use of scrubbers, there will be ports where open loop types will be banned, while hybrid scrubbers running in closed loop mode will be allowed.

For LNG, there are two options: first, a pure gas engine which only runs on gas; second, a dual fuel engine, which means that the engine can run on purely traditional fuels like HFO (HFO<0.5% S from 2020), diesel, or on gas, where the gas is injected either at high or low pressure and ignited by a small amount of diesel.

In economic terms for the cost comparison of abatement options, the data for the main options can be summarised as presented in Table 1. All prices, apart from the desulphurised HFO (HFO<0.5% S), reflect 2017 cost levels. While the HFO<0.5% S price is based on sources and the discussions as presented in previous sections, it should also be noted that it is not the price level compared to HFO or diesel which may be expected in January 2020, but rather the level to expect a few years later. The reason for highlighting this, is that both studies performed before the MEPC decision (Faber et al., 2016; EnSys Energy and Navigistics Consulting, 2016) agreed on the need for increasing the desulphurisation and conversion capacity at the refineries if sufficient quantities are to be available for the shipping sector by 2020.

The main observations here are that for small vessels the cost difference between gas and scrubbers is small. For larger vessels, gas is only attractive on vessels transporting gas.

To illustrate the cost efficiency of the alter-

native abatement options, a typical 80,000 DWT dry bulker (what used to be termed a Panamax) has been used as an example. If operated as in 2012 (source: IMO Third GHG Study), it will have an annual fuel consumption of around 6,000 tons, while if operated as in 2007, in a booming shipping market, it would consume nearly double the volume, i.e. 10,000 tons of fuel. The reason for choosing the Panamax vessel type as the illustrative example is that its consumption is slightly less than the average for all vessel types currently using HFO. Figure 1 shows annual fuel and SOx abatement cost for a newly built Panamax as a function of annual fuel consumption and abatement options.

The main observations are that diesel is not competitive, even with the lowest consumption, i.e. 5,000 tons per year. Desulphurised residual oil, i.e. HFO<0.5 % S is an attractive option if priced competitively. If LNG is to be an option the fuel price has to be reduced, i.e. even lower than the HFO price, unless other incentives or exemption from fees or other rebates are given.

As we all know, current newbuilding activity is low and an assessment of retrofit versus the fuel options is more relevant than for newbuilding assessments at present. For newbuildings, the required annual time charter cost to operate the vessel and earn back the scrubber investment over 15 to 20 years is typically about 12%-15% (8%-11% for the capital and 4% for the operational cost). In comparison, for retrofits on existing vessels the investments typically have to be earned back within 3-10 years, which gives 20% of the capital expenditures even without interest for 5 years' payback time, and 24% annually when including a 4% operational cost.

The implication of these differences gives a scenario as illustrated in Figure 2, which includes the scrubber option for newbuild vessels and when retrofitted. Moreover, two alternative crude oil prices are included – the 'present' crude oil price of $50 per barrel and $100 per barrel.

The first observation is that the annual cost for a scrubber is nearly independent of the crude oil and HFO price, while the fuel with less than 0.5% sulphur becomes more expensive when crude oil prices increases. The explanation is the high energy consumption in the desulphurisation, or conversion process which add to the cost of the fuels.

Second, diesel is not cost efficient at all, not even with the present crude oil price versus retrofitting of scrubbers, unless the remaining use time of the vessel is short. If HFO<0.5% S is priced competitively it is an attractive option, versus the retrofitting of scrubbers.

To summarise, in a recent study by Lindstad E., Rehn C.F., and Eskeland G. S., (2017), we found that the continued use of HFO with exhaust gas scrubbing gives the lowest cost for the vessel with the largest consumption. Second, in a scenario with low crude oil prices, i.e. $50 per barrel or less, diesel is an interesting abatement option for the smaller vessels that currently use HFO; Third, desulphurised HFO (HFO < 0.5 % S) comes at a production cost which makes it a competitive abatement option for all vessels apart from the largest fuel consumers.

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Dr Elizabeth Lindstad
Sintef Ocean AS (MARINTEK)

Tel: +47 4641 5000
Email: Lindstad@sintef.no
Web: www.sintef.no/en