2020 Sulphur Cap options - EXCECUTIVE SUMMARY (October 2018)

The purpose of this memo is to summarize the main economic findings regarding 2020 Sulphur abatement Cap options generated through the SFI – Smart Maritime. The regulation implies that ships can continue to use residual fuels with a high sulphur content, such as heavy fuel oil (HFO), if they employ scrubbers to desulphurise the exhaust gases. Alternatively, they can use fuels with less than 0.5% sulphur, such as desulphurised HFO (LSHFO<0.5%S), diesel, LNG, LPG and biofuels.

Large seagoing vessels currently use heavy fuel oil (HFO) with a sulphur content of up to 3.5%, while smaller vessels use distillates with sulphur content less than 1.0 %. Maritime transport consumes 7 - 8% of a Global oil production of around 4 billion ton. HFO represents 75% of the maritime consumption (IHS 2018), which means that shipping consumes around a third of the 600 – 800 tons of residual oil coming out from the refineries (Lindstad et al. 2017). The advantage of HFO for the ship-owners 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. While LNG and LPG are an option for new-buildings it become too costly for retrofitting existing vessels due to the need for new fuel tanks and engine modifications or replacements. (Acciaro 2014; Lindstad et al. 2015). For these reasons we focus on vessels currently using HFO and the three main abatement options: HFO & Scrubber; LSHFO>0.5%S; Diesel.

The crude oil price is volatile, with 2008 peak at 150 USD per barrel and 2016 low at 25 USD and current levels around 75 USD per barrel (September 2018). When the crude oil price increases the price differential between HFO, Crude oil and Distillate increases as illustrated by Figure 1. These differentials will vary dependent on market conditions, which implies that the short-term price difference between distillate and crude oil or HFO and crude can be less than half or more than twice what's indicated by the figure.

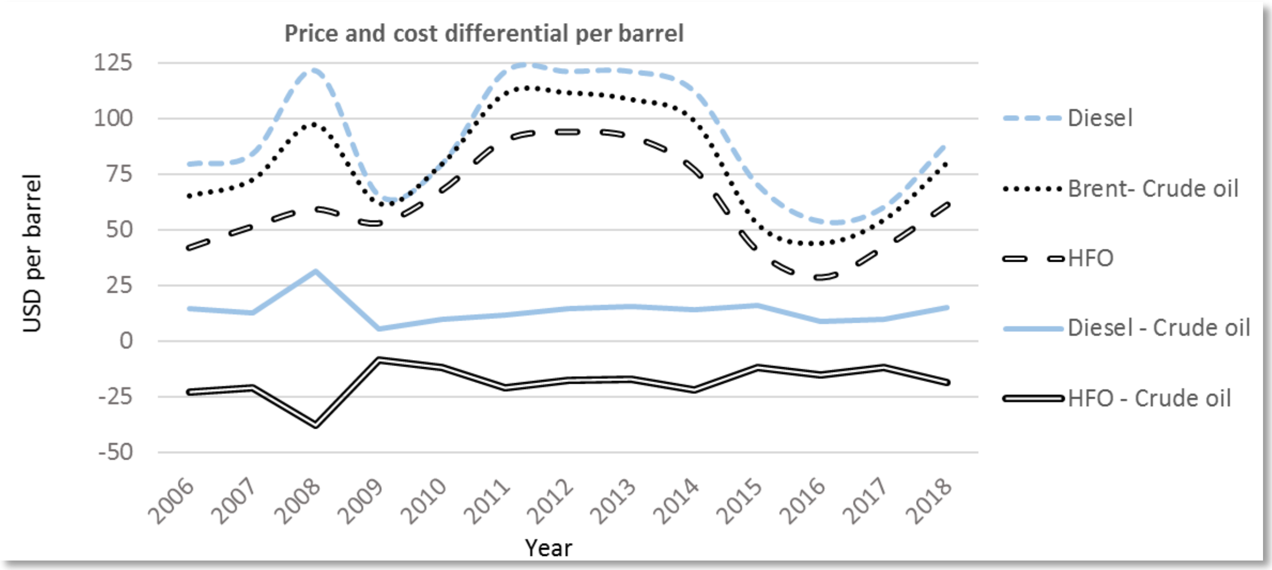

Figure 1: Oil and product prices 2006 – 2018, Source: Bunker World (2016); US Energy Information Administration; BP Statistical Review of World Energy 2017; IHS 2018.

There are three types of scrubbers: Open loop, closed loop and hybrid. A hybrid scrubber combines the two modes and can clean the wash-water in open mode at sea and run in closed mode in ports and sensitive areas. With increased use of scrubbers, there will be ports and coastal areas where open loop will be banned from being used, while hybrid scrubbers running in closed loop mode are assumed to be allowed. The cost estimate for retrofitting a hybrid scrubber, is 2.25 million USD, plus 70 000 USD per additional 1000 kW of installed power on the vessel (Lindstad and Eskeland 2016; Faber 2016; Wärtsilä 2017; Lindstad et al. 2017). Running the scrubber increases energy consumption by around 2 % compared to using compliant low sulphur fuels.

Desulphurising residual fuel oils implies cost and complexity similar to conversion from residual to distillate – this in comparison to sulphur removals from distillates which is common technology for all refineries. Shell, the major oil company, and Concave, the association of oil refineries (Concawe 2009, 2012, 2016; Shell 2016, 2017; Silva 2017) have published figures that conversion or desulphurisation consumes energy equivalent to 10 % - 15% of the energy content in the residual fuel input. Figure 2 a,b below presents the fuel price and differentials as a function of crude oil price. We estimate desulphurisation costs as 12.5 % of the crude oil cost plus 25 USD per ton (Lindstad et al 2017), reflecting a long-term perspective in which costs are passed on to users, and where costs are not coming much further down with volume and experience. When the Sulphur cap comes into force in 2020, the consensus estimate is that the price differentials will increase, i.e. drop in HFO prices and higher Distillate prices. However, while some forecasts assume that price differentials will come back to normal within 2020, others assume that it will take years before increased refinery capacity and more scrubbers on vessels again balances the fuel markets. Here LSHFO line is based on the assumptions made in the previous desulphurization section. From, this point onwards in the memo all comparisons are made based on equal energy content, i.e. ton of oil equivalent (TOE). For diesel, which contains around 7% more energy per ton than HFO, this implies that the HFO – Diesel differential is reduced from 135 to 120 USD/ton for a crude price of 25 USD per barrel and from 280 to 220 USD/ton for a crude price of 125 USD/barrel.

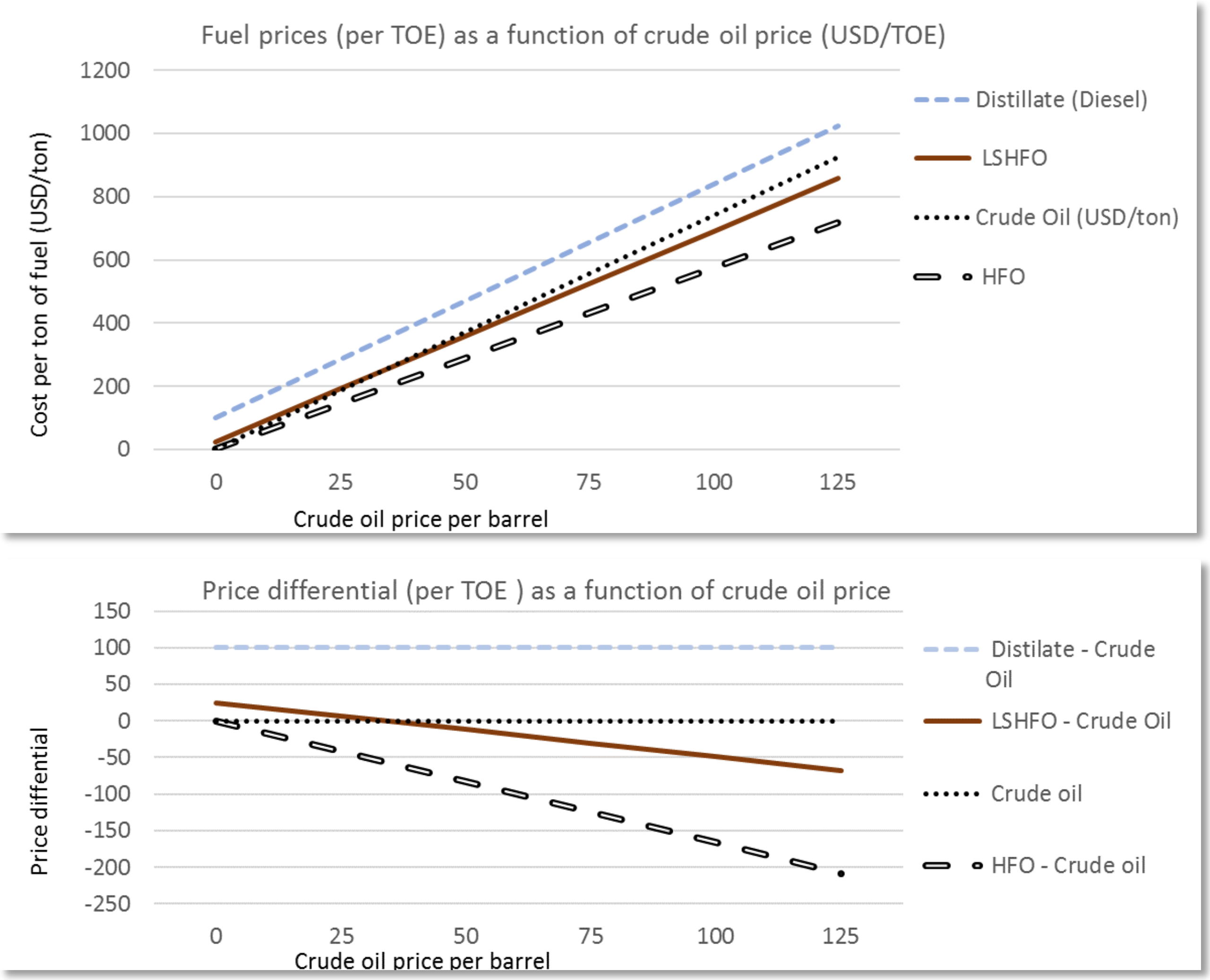

Figure 2 a,b: Fuel price and differentials as a function of crude oil price

We use four typical vessels using HFO as shown in Table 1 to assess the economic impact of the three main abatement options suited for existing vessels (HFO & Scrubber; LSHFO; Distillate). The operational values are based on Lindstad et al 2017 and rounded to increase readability. The 15' dwt chemical tanker represents the smaller vessels currently using HFO. The annual fuel consumption for a seagoing vessel is a function of operational pattern, sea conditions and parameters characterizing the vessel. If this vessel operates at design speed when steaming at sea half the year, it will consume around 5 000 ton of fuel, while if it operates at lower speeds as in 2012 (Smith et al 2014) it will consume from 3 500 ton upwards. With its 5 000 kW installed a hybrid scrubber comes at 2.25 MUSD + 0.07MUSD * 5 MW = 2.6 MUSD, i.e. an annual cost increase of 0.52 MUSD if we use 5 years as the payback time for retrofits without including return on capital (interest). Scrubbing cost with 2012 consumes becomes 149USD/ton and if operated at design speed 104 USD/ton.

Table 1: Engine size and fuel consumption for typical vessels using HFO today

Ship type and sizegroup - dwt indicates average vessel size	Installed Power (kW)	Average 2012 speed	Days at sea 2012	Cost of Hybrid Scrubber (MUSD)	Annual fuel with 2012 speed (ton)	Scrubber cost per ton of fuel	Annual fuel with Design speed (ton)	Scrubber cost per ton of fuel
Chemical Tanker 15' dwt	5 000	11.7	182	2.6	3 500	149	5 000	104
Dry Bulk 75' dwt	10 000	11.9	191	3.0	6 000	98	10 000	59
Tanker 120' dwt	15 000	11.6	186	3.3	9 000	73	15 000	44
Tanker 300' dwt	25 000	12.5	233	4.0	17 500	46	30 000	27
Average	12 854	12.2	190		7 300		12 500	

Figure 3 shows Sulphur cap options for vessel with main engines in the 5 000-kW range as a function of crude oil price. The light blue dashed line shows the abatement cost for the diesel option. The solid brown curves show the abatement cost with scrubbers as an abatement option, where the marked one shows abatement cost with a low annual fuel consumption and the plain one with a high fuel consumption.

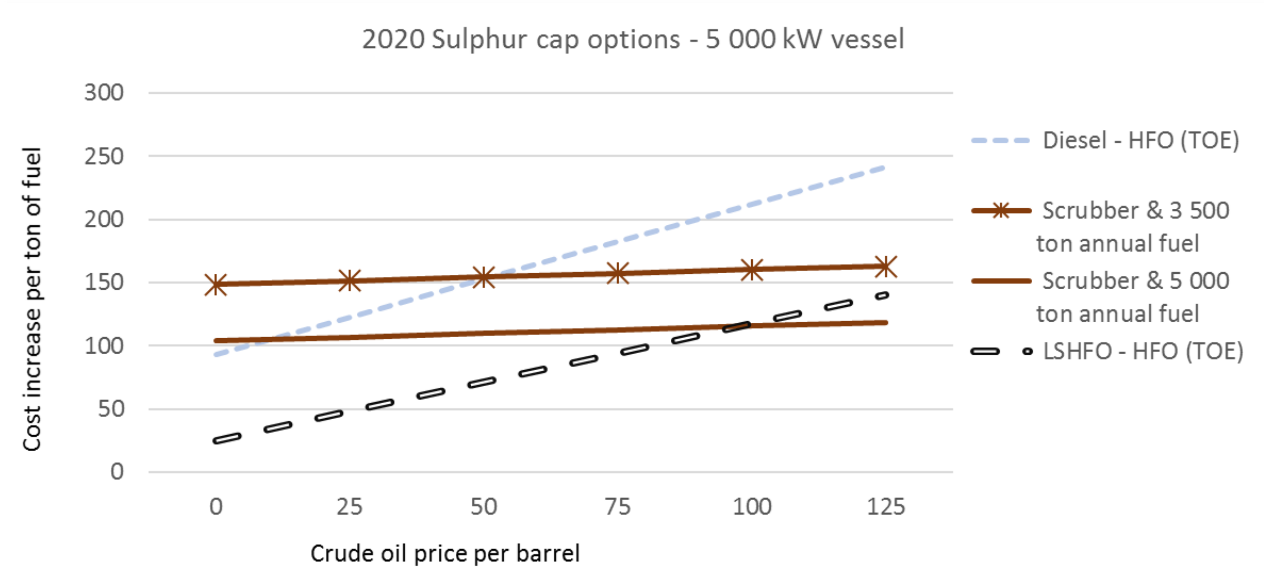

Figure 3: Assessment of Sulphur cap options for 5000-kW vessels

We observe that with a low annual fuel consumption, the scrubber abatement cost starts at 150 USD per ton at a low crude oil price increasing up to nearly 170 USD/ton at a high crude price due to the cost effect of the fuel consumption of the scrubber. Second, the double marked dashed black line shows the abatement cost per ton of fuel for the desulphurised HFO, i.e. the LSHFO<0.5% S, which here gives the lowest cost for all crude oil prices. Third that diesel is competitive for crude oil prices up to 50 – 75 USD per barrel. Fourth even for new-buildings, the Scrubber option might be less competitive than the LSHFO option for vessels types in this engine segment.

Figure 4 shows Sulphur cap options for vessel with main engines in the 10 000-kW range as a function of crude oil price. Main observations are that LSHFO gives the lowest cost for crude prices up to 50 – 80 USD per barrel, i.e. 60 with high annual fuel consumption and 100 USD per barrel with a low consumption. Second diesel is not a competitive option at any crude oil price. Third for new-buildings, the Scrubber option is more competitive than the LSHFO unless crude oil prices drop below 50 USD per barrel.

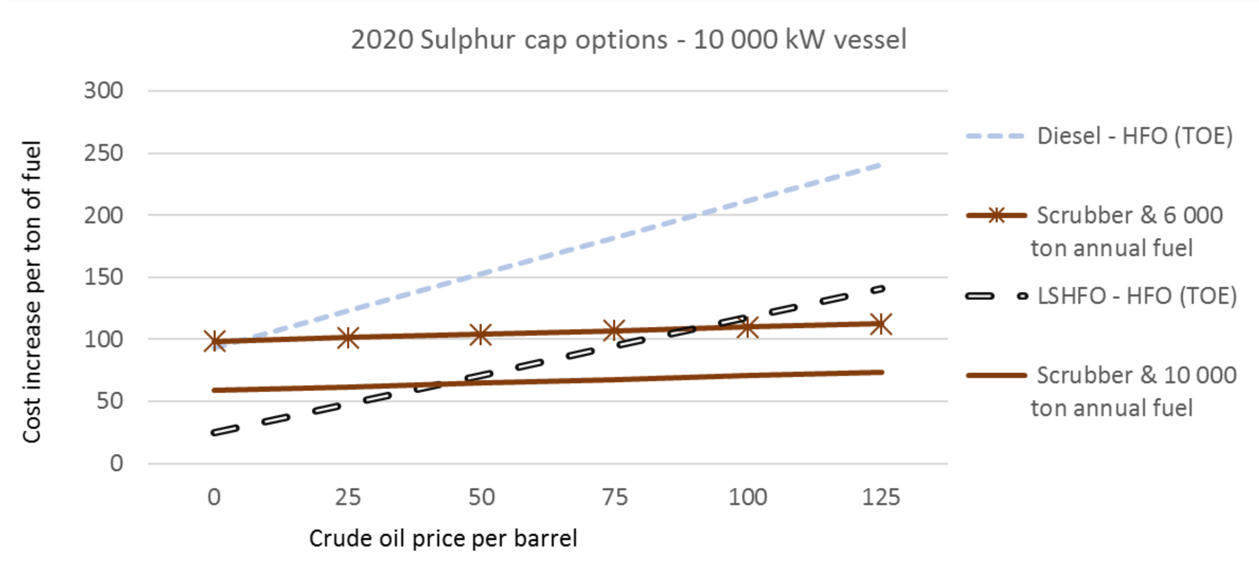

Figure 4: Assessment of Sulphur cap options for 10 000-kW vessels

Figure 5 shows Sulphur cap options for vessel with main engines in the 15 000-kW range as a function of crude oil price. Main observations from Figure 4 are that LSHFO gives the lowest cost for crude oil prices up to around 40 USD per barrel, i.e. 25 with high annual fuel consumption and 60 USD per barrel with a low consumption. Second diesel is not a competitive at any crude oil price. Third for new-buildings, the Scrubber option is more competitive than the LSHFO unless crude oil prices drop below 25 USD per barrel.

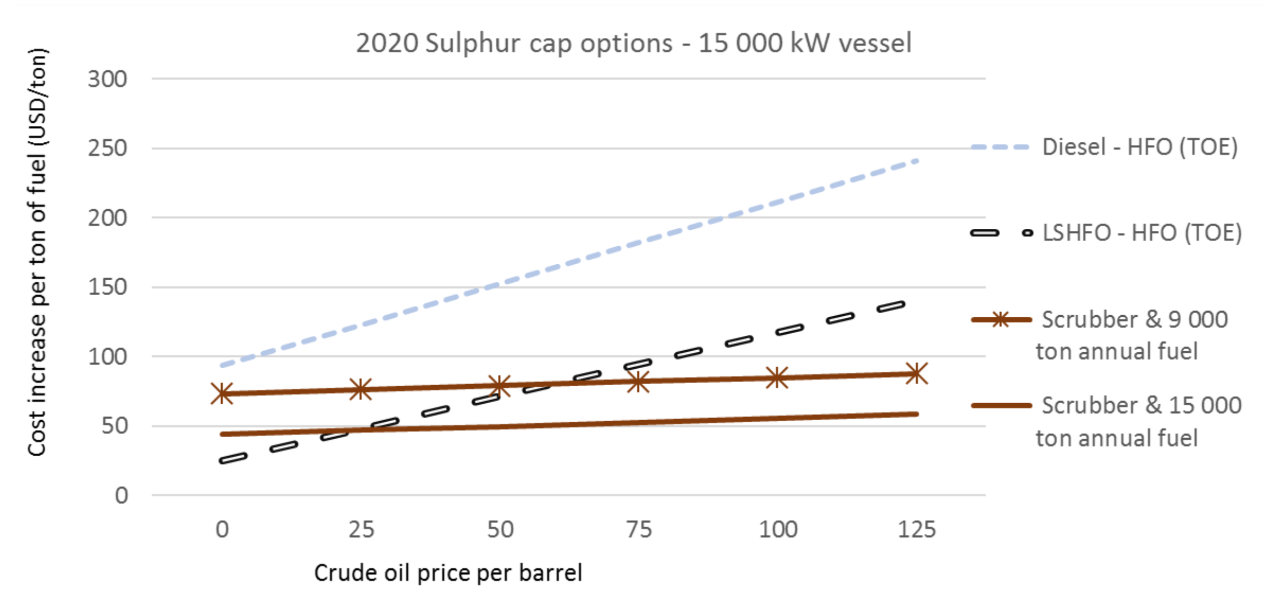

Figure 5: Assessment of Sulphur cap options for 15 000-kW vessels

Figure 6 shows Sulphur cap options for vessel with main engines in the 25 000-kW range as a function of crude oil price.

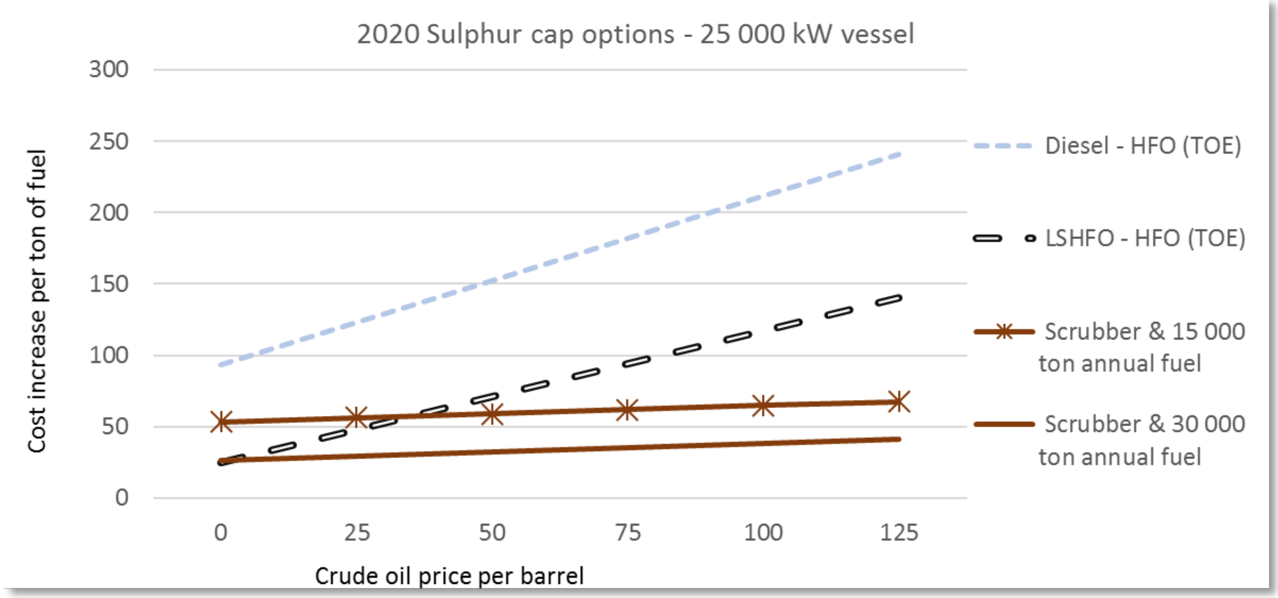

Figure 6: Assessment of Sulphur cap options for 25 000-kW vessels

Main observations are that scrubbers gives lowest cost for crude oil prices above 20 – 25 USD per barrel. Second diesel is not a competitive option at any crude oil price. Third for new-buildings, the Scrubber option gives lower cost than LSHFO unless crude oil prices drop below 10 USD per barrel.

To summarize, our findings are: First, for the vessels with highest fuel consumption, on-board exhaust gas scrubbing and continued use of HFO gives the lowest cost. Second, in a case with crude oil prices lower than 50 USD per barrel, diesel is an interesting abatement option for the smaller vessels that currently use HFO. Third, desulphurised HFO (LSHFO < 0.5 % S) comes at a production cost which makes it a competitive abatement option for all vessels apart from the largest fuel consumers. When the main studies supported by Smart Maritime was performed in 2015 – 2017 (Lindstad et al 2015; Lindstad and Eskeland 2016; Lindstad et al 2017) there was relatively few estimates found in the literature. Recently there has been a number of articles in the maritime business press (Bunkerspot, Fairplay and similar) indicating LSHFO<0.5 % S contracts for 2020 at price premiums of 90 – 120 USD per ton compared to HFO. Which is just slightly higher than the 80 – 90 USD price differential at the 75-80 USD per barrel suggested by Lindstad et al 2017. If these 90 – 120 USD per ton levels are available for 2020 contracts, the transition year it is not unrealistic to assume that they will come down further in 2021 and 2022.

To keep this document short and consistent we have not included any environmental impact of the Sulphur and its abatement options. However, on the legislative side, a number of articles (2018) in maritime business press gives the impression that the in the coming years will be more restrictions on using scrubbers in port and coastal areas than today. This will not change the profitability of investing in a scrubber for the big consumers, but it will make LSHFO a more attractive option for the medium consuming vessels compared to the scrubber option.

ACKNOWLEDGEMENT

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Wärtsilä (2017) Personal communication with Stian Aakre at Wärtsilä Exhaust Gas Cleaning Systems, which provided us with acquisition cost and operational cost and performance for scrubbers.