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"Sulphur Cap 2020 - How shipping companies are affected and how they should react".

by

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"I hereby declare that this particular thesis has been written by me, in order to obtain the Postgraduate Degree in International Shipping, Finance and Management, and has not been submitted to or approved by any other postgraduate or undergraduate program in Greece or abroad. This thesis presents my personal views on the subject. All the sources I have used for the preparation of this particular thesis are mentioned explicitly with references being made either to their authors, or to the URL's (if found on the internet)."

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Abstract

New International Maritime Organization (IMO) legislation to be enforced from 1 January 2020 aims to reduce the sulphur limits in exhaust gases emitted from vessels around the globe. The aim of the legislation is reduction of local pollutants and mitigation climate change by cutting greenhouse gas emissions.

The regulation dictates that ships can continue to consume residual fuels with a high sulphur content, such as heavy fuel oil (HFO), under the prerequisite that they deploy scrubbers to desulphurise the exhaust gases. Alternatively, vessels can comply with regulations by burning fuels which on their own contain less than 0.5% sulphur, such as desulphurised HFO, distillates (marine gas oil) or alternative fuels i.e. liquefied natural gas (LNG). Either option signals significant costs in the shipping industry, as well as the need for investments and higher energy consumption in the refinery sector.

The direct impact to the shipping industry is the mandate to change the fuel carried on board, into fuel type(s), which adheres to the new regulations or install a scrubber system, or resolve to alternative fuels. This need for alternative options will result into a reduction in local pollutants and will cut greenhouse gas emissions thus mitigating climate changes. For ship owners and operators, the selection of compliance method should meet specific criteria to be sustainable in the future. The strive of all stakeholders is either on conventional fuels or even rather alternative fuels, respecting the required production pathways. Of course, this could trigger a domino effect given the rise of the costs related to the investments, freight rates and demand needed to comply with the new legislation.

This thesis presents in detail the available options to the ship owners and vessel operators so as to efficiently adhere to the new regulations, with special focus on the advantages, disadvantages and challenges each one will present. A proper selection process should be based on solid technical and financial background. Thus, the methodology followed focuses on three major commercial vessel types and analyses the net present value of the accumulated costs related to each option over a period of ten years and the payback time of these options requiring a significant upfront investment.

The net present value / payback period analysis promotes the most technological and financially viable solutions, while the subsequent investment analysis supports further the

decision making on which option better fits owners' and operators' needs according to specific factors such as the vessel type, size, age, consumption and operating profile.

Finally, through the analyses, the thesis concludes that the scrubber solution is the optimum solution in the short term (within 5 years), while justifying that inevitably low sulphur compliant fuels will dominate the market in the long term.

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Chapter 1

Introduction

The International Maritime Organization (IMO) – has decided to set a global limit for Sulphur content in fuel oil used on board ships as of 1 January 2020. The regulation -named IMO Sulphur Cap 2020- calls for significant reduction of the amount of Sulphur in marine fuels from the current limit of 3.50% to 0.50% m/m (mass by mass). The goal is to achieve reduction of sulphur oxides (SOx) emanating from ships through exhaust gases, which should have major health and environmental benefits for the world, particularly for populations living close to ports and coasts.

The IMO 2020 framework is strongly challenged by ship owners and refineries mostly on the basis that the transition period will not be enough. As a result, it seems unclear how successful the new rules will be. In any case, this transition will definitely provide challenges and opportunities for both the refining and the shipping industry, with significant uncertainty looming over the initial years prior and post enforcement.

1.1 Identification of IMO 2020 regulation's impact

In this context, it is important to highlight that the refining industry is already in the process of undergoing the necessary preparations for 2020 through investments on secondary refining unit development – investments which will enable the conversion of the High Sulphur Fuel Oil reserves to compliant fuel types. Nevertheless, it is still unclear to market participants whether oil majors will be able to cover the demand for low Sulphur fuels and to provide sufficient quantity of the new fuels in all major ports. It is, therefore, forecasted that markets are likely to see a 1-2-year period of increased volatility and changing supply and demand volumes, until market drivers settle to their new levels.

For the shipping industry, the fuel market volatility will result in potentially higher fuel costs and the need for further capital investment. The situation is exacerbated by the fact that the Regulatory framework is still due to be refined at the 2019 MEPC 74 meeting of the IMO. Therefore, it will be shown later that, while the options for low-sulfur bunker fuel or alternative compliance methods are already available in the market, a significant question remains as to when the regulatory framework will be clear enough so as to decide on the compliance solution which will ensure acceptable profitability.

More precisely, for ship owners and operators, compliance options which are already in place include burning a desulphurised, compliant fuel oil. An increasing number of ships are now also using natural gas as a fuel, since natural gas (when ignited) leads to negligible Sulphur oxide emissions. The latter solution has been already supported by IMO, throughout the International Code for Ships using Gases and other Low Flashpoint Fuels (the IGF Code), which was adopted in 2015. A less-common, but nevertheless viable option is presented by another alternative fuel, methanol, which is already being used on some short sea services. Finally, an option with growing popularity is presented by new technologies providing approved equivalent methods of compliance, such as exhaust gas cleaning systems or "scrubbers", which "clean" the emissions before they are released into the atmosphere.

1.2 Scope

For shipping companies to remain competitive, it is necessary to understand the local and global factors and the changing circumstances that impact shipping markets and trade patterns in advance and adjust their operation strategy in time. In view of the IMO 2020 framework, they need to evaluate the level of capital and operating expenses that are willing to invest in order to comply. This means that, from now on, their competitiveness in providing customized transportation services is not only related to minimum operating costs but to their ability to operate efficiently in both economic and environmental terms. The scope of this thesis is to present the investment options among the most viable techno-economic compliance methods and relate them to the specific needs of major vessel types, by analyzing the accumulated costs over a 10 year period. This cost-benefit analysis, selected in this thesis, will examine different ship types and differentiate the analysis criteria based on the vessel age, ship specification, current market condition and other crucial factors that can alter the balance between the economic benefit versus cost. To further illustrate this, the payback period of the promoted solution will be calculated for each case.

1.3 Research objectives

In this contradicting environment, this thesis will present the current market conditions mainly, though not exclusively, from the perspective of ship-owners. The main thesis objective is to present to the ship-owners the most economical and competitive strategy for sulphur cap compliance. In order to answer the above, a series of more specific objectives are set. Firstly, a thorough evaluation of the available options will be presented. Thus, ship-owners will be able to better understand the compliance options and choose the one which will serve as a best fit for their fleet. The second objective is to provide an evaluation methodology sensitive to important aspects such as vessel age and trading pattern and assist them in developing an effective fuel strategy. Finally, the third objective is to provide a methodology which will assist ship-owners to calculate the CAPEX and OPEX of each solution and will be based on cost development diagrams and projected fuel costs.

Similar analyses will be vital for operators who seek to select the best option in economic, commercial and technical terms. These operators will remain competitive in the shipping industry, while increasing the value of their fleet. On the other hand, those who will fail to make the right decision, seem almost certain to face considerable difficulties in operating their fleet in the near future.

1.4 Thesis structure

After having defined the scope and the objectives of the thesis, Chapter 2 will provide a backdrop to the new IMO regulation on SOx emissions and try to briefly describe its exact requirements. Its main subject, though, is to present the compliance methods available and try to reply to the first objective.

In Chapter 3, we will present and analyze the relevant literature on Sulphur Cap 2020 and form a basis for better understanding of the context in the subsequent chapters. The large number of literature available, especially in such a short period of time, only emphasizes the criticality of the issue. The chapter ends with a set of questions vital to the methodology that will follow.

Further on, in Chapter 4, the conceptual model and research hypotheses are presented pointing to the research objectives identified early on in the introduction of this thesis. The conceptual model extends to a comparative analysis of the available options a ship owner or operator will face due to the implementation of the IMO 2020 regulations. A number of hypotheses are taken to simplify the framework of concepts and assumptions and assist the analysis to focus solely on the decision for the optimal compliance strategy.

In Chapter 5, a detailed description of the methodology is presented to provide ground for the subsequent analysis of the cost implementation of the alternatives in scope. It is made clear that this thesis focuses on providing a suggested path of analysis to be followed when decisions need to be supported with concrete numbers rather than reflectional and wide impact questions.

This will be based on the capital and operating costs analysis for each vessel type and for each compliance method.

Then, in Chapter 6, the compliance strategy analysis follows, based on the NPV and payback on investment determination. This analysis will provide answers to the last two research objectives as it will evaluate each compliance option versus vessel age and trading pattern and present the CAPEX and OPEX involved per vessel type and option.

In Chapter 7, the thesis discusses the research results in terms of feasibility given the current market constraints and try to raise awareness on possible implications and restrictions. Finally, in Chapter 8, the research results are presented. The analysis concludes that the most viable options are the scrubbers and the low sulphur complaint fuels but also points out that these should be checked against company's long term strategy and social responsibility.

Chapter 2

Background

2.0 Introduction

MARPOL Annex VI – one of IMO regulatory frameworks, and more specifically Regulation 14, "Sulphur Oxides (SOx) and Particulate Matter" dictates that the sulphur content of any fuel oil used on board ships shall not exceed definite limits, following a gradual implementation period (4.50% m/m prior to 1 January 2012; 3.50% m/m on and after 1 January 2012; and 0.50% m/m on and after 1 January 2020).

In chronological order, the past / present legislative changes are:

- 1st of January 2015 - SOx Emission Control Areas (SECA) introduced in North America and Europe Applicable for all ships trading in the SECA's
- 1st of January 2016 - NOx Emission Control Areas (NECA) introduced in North America and Caribbean waters Applicable for all ships trading in NECA in Americas, keel laid after 1stof January 2016
- 1st of January 2020 – IMO will enforce a global sulphur cap of 0.5% applicable worldwide for all ships

And future:

- 1st of January 2021 - NOx Emission Control Areas (NECA) will be introduced in Baltic Sea, North Sea and English Channel Applicable for all ships trading in NECA in Europe, keel laid after 1st of January 2021

It is obvious that the IMO frequently develops new regulations with regard to the acceptable level of emissions as part of an orchestrated effort to slash the negative effects caused by the shipping industry on the environment. The IMO has the authority to make those changes effective for the industry on global level. All these IMO SOx requirements are complemented by concrete legislative frameworks on regional / country levels as well, which put constraints not only on exhaust gas emissions, but also on the discharge of alternative compliance method effluents, such as scrubber water.

Examples of such regional legislation are the SOx Emission Control Areas (ECA), the European Union Sulphur Directive, the Water Framework Directive, the SECA wise legislation in China for the sea areas outside Hong Kong/Guangzhou and Shanghai, and in the Bohai Sea. These examples only serve to further prove that emissions regulations, whether local or global in scope, are here to stay. There is no further time or room for delays, but only space for specific action plans from stakeholders in order to remain in business long term.

2.1 Compliance options

The decision ship operators have to make when selecting the most appropriate way to comply with the new regulations is a rather pure techno economical one. Still, for any strategy followed, the decision process should also try to answer a range of questions like: will there be sufficient amount of compliant fuels available in future; how will fuel oil prices be affected; will this result in other cost implications and, how will the implementation of the Sulphur cap be rolled out. Anyone who tries to answer such questions should have previously made a thorough overview of the available options. To have a better understanding on the selections available to ship owners, this thesis will classify the option into the following order:

- Distillate fuels with 0.5% Sulphur content and below;
- New compliant fuels with 0.5% Sulphur content;
- Scrubber solution (New/Retrofit);
- LNG as fuel (New build/Retrofit).

The above classification is based on the unique characteristics of each vessel type and the fact that the ship operators at the end of the day need to avoid unwanted expenses, following their fleet operating profile and current market trends. In the case of LNG ready vessels, the placed production orders have a sharp increase since 2016 and the pricing of gasoil/ ultra-low sulfur FO demonstrate a steady uplifting trend as well in the same period. In this macro environment the Fuel oil to Gasoil (HFO to LSMGO) futures spread has widened significantly, with markets positively responding to this and enabling ship owners/operators to position and hedge in a 2 to 4 year pay back on a scrubber investment.

At this point it is necessary to have a snapshot of these options, so as to ensure that the reader has a concrete overview of the dilemmas and opportunities stakeholders are facing in the dawn of the IMO 2020 enforcement.

2.1.1 Distillate fuels with 0.5% Sulphur content and below

Marine distillate fuels such as the marine gas oil (MGO) and low Sulphur marine gas oil (LSMGO) perfectly comply to regulations requiring a max Sulphur content of 0.10%. They are currently available in the market and will continue to be widely available for use in the post January 2020 scene. Already the majority of marine distillate fuels bunkered in main ports have a sulphur content of 0.10% and below, and the demand for these fuels is expected to grow.

Fuel suppliers, in order to meet the increased demand for 0.10% S marine fuel and to be more competitive, have developed new formulations, which are expected to decrease the cost of production, allowing the final product to be more cost effective compared to present distillate fuels.

Such new fuel formulations will combine characteristics from both distillate and residual marine fuels. These new fuels can be categorized into (i) ultra-low sulphur residual fuel oils, (ii) blends of a distillate fuel with small amount of residual fuel oil and (iii) heavy distillates. Fuel properties may vary, while those that will mainly affect the engines ignition and combustion characteristics are the lower viscosity and the metal contents of low Sulphur distillate fuels.

2.1.2 New compliant fuels with 0.5% Sulphur content

New types of low sulphur compliant fuels are forecasted to become available, as refineries upgrade their installations. These will mainly be called VLSFO (Very Low Sulphur Fuel Oil) and LSHFO (Ultra Low Sulphur Fuel Oil). The de-sulphurisation process required for these new fuels is rather costly and there is a belief that refineries will select to refine higher grade fuels instead of investing in de-sulphurisation systems. Several stakeholders in the industry have expressed their doubts if the supply of these new complaint fuels will cover the excess demand coming in 2020.The same and have identified the underlying risk of having to rely on expensive distillate blends, should there be an unavailability in the spot market of the otherwise cheaper than distillate new types of fuels.

From a technical perspective, these new compliant fuels are likely to have the same issues and pose the same challenges to ship owners as the ECA blended / residual fuels of 0,10% S which became available in the market to cover the demand for complaint fuels post 2015 with the implementation of SECA areas. The most important issues experienced then and expected to be faced again are (i) the sensitivity in storage and compatibility (ii) the requirement for diligent use and handling to reassure proper and safe operation, and (iii) the need for vigilant quality control during bunkering.

Vessel operators will have to pay close attention to the properties of the new complaint fuels as each fuel supplier has their own formulation and a significant variation is expected in the market. Different formulation means also different requirements in storing, handling and use. To this extent, the use of the new compliant fuel should be carefully considered and planned with all parties including fuel suppliers, as well as engine and fuel treatment equipment makers to safeguard the proper and safe vessel operation.

In financial terms, making the choice to go forward with the new complaint fuel will signify a considerable increase in fuel costs (OPEX) while also requiring upgrades of specific onboard equipment due to the new fuel characteristics, mainly due to the low viscosity of them (CAPEX).

2.1.3. Scrubber solution (New/Retrofit)

Scrubbers are installations which allow vessels to continue burning high Sulphur residual fuel, while removing harmful SOx emissions and complying with regulations through post-processing of exhaust gases.

High sulphur residual fuels are currently the main fuel products used on board ships and have so far posed the largest number of technical challenges to the vessels and their operators, mainly due to low quality and high sulphur content. When the new IMO regulation for the ECA areas came out in the beginning of 2015, it signified the demise of 1.0% m/m Sulphur residual fuels and at the same time helped improve the HFO quality due to reduced blending. Quality wise, this will be the situation to be expected in the future.

After 2020, industry specialists expect a dramatic decrease of HFO demand, but at the same time it remains to be seen how this decrease will be affected by the degree to which scrubber technology will be adopted.

Scrubber utilisation has taken a prominent role in the discussions for the Sulphur Cap and remains until now a hot topic. One significant concern with regards to the environmental effect this option has was presented by initial scrubber designs which utilised sea water to neutralise the harmful combustion products emitted to the atmosphere but which are in turn discharged overboard. Countries with strict environmental policies and legislations have and may continue ban the use of such scrubbers in the territorial waters, leading to concerns about the long-term viability of this technology.

For this very reason, even though this initial scrubber configurations do fulfil IMO regulations, other more expensive and sophisticated scrubber configurations have become available having no overboard discharges.

From a financial standpoint, many in the shipping industry think of scrubbers to be a profitable investment with a quick turnaround period. This is evidenced by the fact that numerous ship owners have already ordered and installed scrubbers on board.

However, these operators will run the risk of the price differential between the HFO and VLSFO / LSHFO going against their projections and curbing the economic benefit of sticking with high sulphur residual fuels.

At the same time, the HFO availability worldwide may eventually become a concern given that currently refineries are upgrading their infrastructure to cover the demand of the VSHFO / LSHFO fuels and may move away from traditional high sulphur content fuels.

Thus, it is to the benefit of the ship owners to hedge their positions and to secure contracts with oil majors for the supply of HFO at a fixed differential below the VLSFO. In this way, they will be able to secure the amortisation period of the initial purchasing and installation cost of the scrubbers at the expected level, while also benefiting from any returns that may come up if the fuel supply contract durations exceed the amortisation period of the scrubber investment. Finally, they will be able to guarantee the supply of HFO irrespective of shortages in the spot market.

The drawback in this proposal, is the risk of the average differential of the HFO and VLSFO being greater than the one fixed in the contracted, negating any potential benefit of additional returns.

What is certain is that, in larger or smaller quantities, high Sulphur HFO will still be an option after 2020. This will likely be the way forward for the risk averse owners who are deeply concerned about the new compliant fuel pricing, availability and quality. However, to comply, operators should install scrubbers keeping always in mind of the complexity of the installation especially when this is performed on an existing vessel. They should also be aware of the significant initial investment cost and the added operational expenses related to increased power consumption, need for chemical consumables and sludge handling, and crew training.

2.1.4. LNG as fuel (New build/Retrofit)

It is expected that with the new IMO regulation on exhaust gas emissions, certain operators will welcome LNG as a marine fuel solution. Given the experience of LNG carriers, which are already using LNG as fuel for several decades, LNG as a fuel has been proven to be a viable technical solution with significant environmental benefits. In the meantime, the LNG bunkering infrastructure has shown rapid development and there are currently LNG bunker stations in most of the large ports worldwide.

The LNG option shows important commercial advantages and thus provides incentives mainly for the newly ordered vessels, but at the same time also for retrofits as done by many ship owners that operate mainly in ECAs. The coastal shipping sector of the North European Sea has many examples to show of successful application of this technology with numerous cruise ships and ROROs been retrofitted and ordered with LNG burning propulsion engines.

The decision to proceed with the LNG option should be taken based on the most up to date market information and after a thorough and in-depth analysis has taken place. Apart from the commercial aspects, the main advantage and reason that LNG as a marine fuel is gaining ground versus the oil-based marine fuels is the significant reduction of air pollutants in the vessel exhaust gases, consisting of sulphur and nitrous oxides and particulate matter.

Technical studies have proved the complete removal of SOx and PM emissions, a reduction of NOx emissions of up to 85% and finally reduced CO2 emissions, up to 25%. This fact may very well be the strongest argument in using LNG fuel, especially for vessel with increased sailing time in ECAs, given that in this way detrimental effects to human health and the environment in coastal areas are significantly reduced.

The description of the above options clearly leads to one conclusion; there is no case of "one size fits all" and each decision maker must weight all the pros and cons of each solution and find the one that better suits the specific needs of his fleet. To highlight the importance of this point, Table 1 below presents, the most important advantages and disadvantages of the above stated options.

Solutions available	New compliant fuels	Distillate fuels	HFO with Scrubber	LNG as fuel
Pros	Usable for most engine configurations	Usable for most engine configurations	• Can use HFO • Possible to retrofit • Reduce particulate matter as well as SOx • Financially viable, as compared to other options	• Has good environmental performance • Can reach Tier III performance • Positive impact on EEDI
Cons	• Unknown fuel cost • Not on the market (no track record) • Uncertain availability • May create operational issues due to off-spec fuel or incompatibility • Blending Stability & incompatibility problems	• Higher fuel cost • May create operational issues due to low viscosity fuel	• 3-5% fuel penalty • Requires space for scrubber tower and aux. systems • Requires chemical (closed loop) • Requires process monitoring system • High installation time • Yards capacity	• High investment cost • Costly to retrofit • Large variations in LNG price - availability • Methane slip in exhaust • Requires space for tank • Some engine types require additional systems to reach Tier III

Table 1: Compliance option comparison

2.2 Ship-owner reactions today

This simple comparative overview only further indicates that the change of high-sulfur fuel oil into a comparable volume of compliant 0.5% sulfur bunkers and alternative solutions of compliance, are more controversial than ever before.

Still all big shipping companies are adjusting their upcoming strategic plans, and weighting the balance of the above options. The strategy selected by major shipping companies is shown below.

- APM-Maersk: Switching to lighter fuel MGO, MDO
- MSC: Big retrofitting initiative (€250.000.000) for whole fleet
- CMA CGM: First to equip their 9-new build ULCVs (22,000 TEU) with LNG propulsion, Low Sulphur Surcharge since 1st January 2015, focus on Low Sulphur Fuel
- COSCO: Low Sulphur Fuel & Retrofit scrubbers on applicable part of their fleet
- Hapag-Lloyd: switching to 0.50% Sulphur marine fuel.
- VALE (Bulk sector): Invested heavily in scrubber for all existing fleet and provisioned considerations for LNG and scrubber for their newbuilding.

It is evident that major shipping companies act moving towards the 2020 horizon in different ways. This suggests that any decision taken is also related to a range of concerns on possible inconsistent and ineffective implementation. This can be affected by a range of differential factors like the ship size, age, route and fuel price. Maersk Shipping - Lindegaard (Ship & Bunker) stated *"In our opinion, scrubbers will not be the way forward for our fleet. Whilst the business case for investing in scrubbers may look appealing at first. It is not a long-term solution to place such complex machinery on our vessels"*. Later on, they added *"…longer-term approach to secure compliance is through the use of alternative fuels".* On the other hand VALE CEO, Fabio Schvartsman (Tradewinds) has stated that "*these new contracts also establish that shipments must be made by LNG ready vessels, equipped with scrubbers granting further optionality to comply with future regulations*" paving the road for those operators wishing to have the flexibility and quick payback of scrubbers while investing also in the longer term solution of LNG in order to comply with future more strict regulations.

2.3 How to translate market reactions and how to plan ahead

It is important to note that it should make more sense for the ship owners operating a large worldwide sailing fleet to invest in the scrubber and/or the LNG ready technologies given the reduced cost compared to a retrofit and the freight premium the vessel will enjoy. On the other hand, older vessels operating for more than 15-20 years (subject to vessel type) and vessels with low utilization (overcapacity) are not incentivized to retrofit and are better off to burn distillate/Low Sulphur FO and/or scrap early.

To conclude, it is imperative for ship owners, aside from analyzing their fleet requirements or vessel types, to swiftly initiate a dialogue with charterers and fuel suppliers on their ship's requirements and fuel type availability of the fuel post 2020. Only in this way, they will be able to include in their investment decision calculations important factors such as future trading patterns and worldwide fuel oil availability.

Chapter 3

Literature Review

“International shipping transports count more than 80% of global trade to people and communities all over the world. Shipping is the most efficient and cost-effective method of international transportation for most goods; it provides a dependable, low-cost means of transporting goods globally, facilitating commerce and helping to create prosperity among nations and peoples” (IMO, 2016).

The above statement highlights that shipping in general is a means of transportation which threatens the environment in the least amount, when measured in distribution per unit weight. In other words, more harmful emissions are emitted to transport one tonne of goods by train, truck or plane than to transport the same tonne by ship. This may be the root cause behind ship owners / operators traditional reluctance to take meaningful steps towards decreasing emissions.

Cullinane, (2013) outlines the current and planned regulatory regime for the atmospheric emissions from ships. He interestingly concludes that although the shipping industry has been slow to improve its environmental credentials, a combination of regulation and technological innovation provides it with significant potential to reduce its environmental footprint.

While there are quite a lot and different emission types, many of them harmful to humans, the available literature on air pollutants is mainly focused on sulphur oxides (SO_x). Research demonstrates that ships’ emissions account for approximately 10% of global SO_x emissions, which is likely why these emissions appear to be the primary concern for policy-makers leading them to frameworks like the IMO 2020 rules.

The relevant literature highlights that there can be different ways for ship-owners to adhere to the regulations for sulphur emission levels. To this end, Wang, Corbett & Winebrake, (2007) discuss the optimization of ship emissions reduction strategies and show that combining performance standards with market-based instruments improves policy cost-effectiveness and reduces fleet wide SOx pollution near shore.

In the same spirit, Lindstad, Gunnar & Eskeland, (2017) effectively provide a clear scope in effectively separating sulphur compliance options based on vessel size. Their proposition is that the distillate option is better suited to smaller size vessels, while the scrubbers’ option is preferable for larger ships. Their analysis goes one step further, proposing that, in addition to distillate fuels and scrubbers, the use of residual fuels of 0.5% sulphur content or less can be a viable option as well and should not be neglected. What they achieve to present is that emissions may be decreased beyond initial expectations because the increased price of distillate fuels may further push ship owners set to limits to the average speed of their fleet to reduce fuel consumption and cost, thus indirectly achieve the desired result of fewer emissions.

Such studies indicate that for emissions reduction regulations to be effective, they must refer to emissions from both the shipping and the refinery sectors. Still this topic is more controversial, since the price spread between marine gas oil and heavy fuel oil, a spread determined in part by refineries, is a determining factor in making any Sulphur compliance choice. For this reason, Jiang, Kronbak & Christensen, (2014) conclude that it is more beneficial to install a scrubber on new ships than retrofits.

In all literature it is clear that the element of risk seems to be manifest, due to the intense uncertainty of the market environment. To make matters worse, the recent experience from the ECA areas shows clearly that the possible benefits to the ecosystem from emissions restrictions could be minimal or even negative. For this reason, recent literature seems to step away from proposing any option related to scrubbers due to potential environmental side effects from effluents as well as the reduction of the energy efficiency of the vessel due to scrubber power needs.

There is also a legitimate risk that compliance decisions will be taken with the primary goal of finding quick solutions for regulatory compliance, instead of focusing on the intended and ultimately desired goals of using as cleaner and renewable fuels (Lindstad, Haakon & Eskeland, 2017).

Given the current market uncertainty and the fear of future, more strict regulations, many believe that now is the optimal time for investment in LNG retrofit (Acciaro, 2014). This study considers the value of an investment deferral strategy versus the advantages obtainable from the immediate exploitation of LNG vs. HFO fuel price differentials. Hendzik, (2013) also supports the viability of LNG fuels or even compressed natural gas (CNG). Getting firm aspirations from ECA regulations, he solidly presents that there is real life proof that industry positively reacted to the LNG as fuel solution while manufacturers already developed and produced exhaust gas treatment equipment –such as Exhaust Gas Recirculation and Selective Catalyst Reactors- needed to make LNG SOx solutions complaint to NOx regulations set. His expectation is that by 2025, a good share of vessels will have LNG burning engines; nevertheless, he notes that that the expansion of the LNG bunkering industry is dependent on the enhancement of proper LNG distribution and bunker networks globally.

Other literature focuses on another surprisingly interesting aspect of the global push for cleaner energy, specifically on the impact of the sulphur cap and CO2 pricing on the inter-competition between fuel oil and alternative low-sulphur fuels Alshammari & Benmerabet, (2017) note that any increase in crude oil prices (as a result of limitations on CO2) could improve the cost-effectiveness of utilizing middle distillates against that of using high sulphur fuels in combination with scrubbers. Furthermore, the study shows that setting a CO2 price between \$50–150/Ton CO2 can reduce the emissions from fuel oil combustion even by 87 per cent till 2040. Nevertheless, the study also maintains that in the case of the scrubber option- in contrast with previous literature- that fuel oil consumption will stand at an approximate 56 per cent till 2030, a price point well below the low oil price scenario.

In all the literature available relevant to IMO marine emissions regulations, two of the most crucial documents were commissioned by the IMO itself. In examining the outlook for 2020, the debate prior to IMO’s decision was quite heated. The dissent was intensified by these two commissioned studies, which surprisingly provided opposing conclusions on the availability of low sulphur fuels by 2020. The disparity between the two documents conclusions resulted in a serious debate regarding the assumptions that were made in each document and possible outcomes on shipping if either study was to be believed.

What is certain is that both surveys show that predicting the availability and the pricing of fuels is not only difficult, but requires numerous assumptions which are not always cohesive.

Even though the (CE Delft, 2016) and the (Ensys-Navigistics, 2016) studies arrived at different projections of the hydrogen and sulphur-handling plant capacity at the end of 2019, while both noting that any hydrogen and sulphur-handling plant capacity limitations could directly implied a possible shortfall of 0.5% sulphur Global Fuel.

The Ensys-Navigistics Study highlighted that- even assuming sufficient hydrogen and sulphur capacity - clean petroleum product markets globally would be strained due to the volatility of the prices of available fuels (i.e. price spikes for low sulphur marine distillate or clean non-marine fuels and a price slashes for high sulphur residual fuels). The CE Delft study did not take into consideration any similar economics/economic impacts, as these impacts were not in the scope of work provided by the IMO.

The CE Delft, (2016) study analyzed three basic scenarios, where the transport demand, new buildings, alternative fuels and scrubbers were assigned various values, enabling close examination of all possible scenarios and outcomes. In this way, cases of new complaint fuels for newbuilding orders were compared with different demand levels for LNG and scrubber options. The study compared the expected available amounts of maritime fuels with a sulphur content of 0.50% m/m, to the production amount which would be needed to address the projected demand of maritime fuels for all related markets. The ultimate conclusion of the study was that production can cover future demand. However, the study reported that for fuels with 0.10% to 0.50% m/m sulphur content, demand can be covered only with blends of residuals fuels, hydrotreated residuals, heavy fractions from hydrocrackers and lighter hydrotreated fractions; all of which critically depend on refineries ability to increase production capacity. Lastly for fuels with sulphur content of 0.10% m/m or less, no problems with supply are expected since the natural option will be MGO.

One important assumption of the CE Delft study was that the refinery industry will greatly invest in the required infrastructure to increase production capacity. Another one was that only blended fuels will dominate the market while technical issues of blended fuels such as fuel stability was not considered. Both assumptions are considered critical and form the basis of the residual fuels sustainability conclusion.

This is the point on which the Delft study was challenged by the Ensys –Navigistics study. The scope of the latter study was to offer a feasibility perspective to the available compliance options. The main projection made by the study was that it is highly likely that the option of scrubbers onboard will be neglected in the short term and most of vessels will rely on 0,5% m/m sulphur fuels. The analysis showed that capacity limitations of the refinery industry cannot be easily overcome, and even if they are, the increased demand for low Sulphur fuels could finally lead to high supply costs for all market sectors and significant economic impacts globally.

Therefore, the shipping industry is currently facing multiple dilemmas: (i) what is the cost and extent of the mandatory equipment changes required to be able to bunker the new and possibly cheaper complaint fuels with 0,5% sulphur content? (ii) how does this cost compare to that of currently more expensive distillate fuels? (iii) how will current fuel pricing be affected by the alternative compliance means, as many ship owners seems to find more incentives into these solutions? The answer to the above questions will define the final economic impact of IMO 2020 legislation on the market.

In this context, the position of IMO on the debate regarding the availability of low sulphur fuel after 2020 is positive. IMO deems the supply to be sufficient, although several stakeholders have questioned this. What is certain it that fuel price trends will remain a dominant issue for the industry post 2020.

Chapter 4

Conceptual Model and Research Hypotheses

4.0 Introduction

In the previous chapter, a brief overview of the existing literature was presented, focusing on the effect the new emissions regulations will have on the shipping and refinery industries and their stakeholders. We see many predictions being made based on future fuel price differentials and as a result of these, proposals arising on optimum compliance solutions. However, since fuel price forecasts and actual trends post 2020 can vary significantly, the purpose of this thesis is to present a methodology that ship owners can use during their decision process on compliance methods rather than making another generic proposal. Of course, it is inevitable that to draw a conclusion, certain assumptions have to be made. This conceptual framework and the research hypotheses of the thesis will be presented in this chapter.

The conceptual model extends to a comparative analysis of the available options a ship owner or operator will face due to the implementation of the IMO 2020 regulations. Through the proposed framework, we will examine the impact of fuel price differential on ship owner's optimum decision through the level of initial investment required and through the expected life cycle costs over a period of 10 years for three vessel types. In this way, the proposed framework provides the means to proceed on a sensitivity analysis and investigate how the expectations on fuel prices could influence decision making. The model used is based on the net present value of the accumulated costs and the payback method.

4.1 Hypotheses

This thesis aims to refine the framework of concepts, assumptions, expectations, beliefs, and theories and try to shed light on optimal decision strategy in fuel selection to comply with the new legislations. To achieve this, the following hypotheses are used:

H.1: Shipping company adherence to the new regulations will positively affect fuels costs

Therefore, in the analysis, price of HFO remains stable to current levels and price differentials are taken for the other fuels.

H.2: The type of vessel moderates the relationship between IMO compliance and the acceptable level of investment.

H.3: Vessels with larger life cycle periods and trade patterns moderate the relationship between investment level and fuel sulphur composition.

In the analysis, three case studies are examined, while conclusions on the most appropriate way to comply are drawn mainly based on the above parameters.

H.4: The refinery industry is able to process discounted medium and heavy crudes in time for kick off in 2020

In this way, there is no need to risk adjust the NPV values of the investment options, as the uncertainty of the refinery industry's ability to cover future demand is isolated.

H.5: The price differential between VLSFO & HFO is flat.

The factor of yearly fuel costs is included in the calculations, as these costs sum up to a substantial amount and can be as much as the 1/3 of the total construction cost of a new build. The hypothesis of flat price differential, isolates the potential fuel costs volatility. Bunker experts say that a reasonable assumption for the price differential between VLSFO and HFO is flat at $300 (low estimate) or $400 (high estimate).

H.6: Ship-owners have solid environmental stand point, interested in emission reduction

This means that any decision will be regulated and assessed from an environmental perspective as well.

Possible limitations to the hypothesis are faced due to the uncertainty in the environmental and technical performance of alternative fuels. It is beyond the scope of the current analysis to highlight the ideal way – and if such way could be plausible- for worldwide implementation. Therefore, the assessment presented focuses on the potential of an alternative option, to become a viable fuel solution, both in context of wide-scale roll out and of supporting the sector's requirement for wide emission reductions.

Hence, the investigation on alternative compliance options in the shipping sector should be viewed as two-fold story. In a short-term period, the sector is required to reduce fuel sulphur content to 0.1% in Emission Control Areas since 2015 and to 0.5% globally from 2020. Furthermore, the longer-term scope is the reduction of the greenhouse gas emissions. These attributes define the core criteria for an ideal choice of fuel and raise the question of alternatives to conventional fuels currently used.

4.2 Focusing on the long-term

Throughout the analysis, any questions, direct or indirect but still logically inferred and/or stated, present the possible trade-offs any decision should tackle, against the emissions reduction achieved over the course of the vessel economic life. The final compliance strategy should optimally fit in a longer-term prospect as well, delivering significant emissions savings for the sector as a whole. This is important and thus included in the analysis hypothetical framework, since fuels may incur emissions at different stages of their life-cycle, either during refining or transportation, or during the production (especially for the bio-derived ones). Thus, all those research questions are not the starting point or primary determinant of the design, rather are used as the sensitivity check for any addressed solution.

Chapter 5

Research Methodology

5.0 Introduction

Following the extensive literature and theory, it is obvious that the main concern in the industry is the next day for what the industry look like once IMO 2020 legislation is enforced. As already stated, the purpose of this thesis is to examine the alternative options on fuels usage and to get an overview on how these can be optimal in techno-economic terms, but also following an environmentally conscious approach. It is important to give an answer not only to which is the best decision to be adopted, but also to what are the real consequences and the attributes which will shape the industry's path in the aftermath of implementation. At the end, it could be possible that new questions and thoughts may arise, which could be researched further in the future.

5.1. Research layout

In line with the above scope, the methodology followed in this thesis focuses on providing a suggested path of analysis to be followed, when decisions need to be supported with concrete numbers rather than reflectional and wide impact questions.

It is often that data analysis brings new issues to the surface that available literature has not yet addressed or for which possibly ship-owners or operators may need to enter into another round of discussion where projections considered in this paper could be included. Bearing this in mind, an adoption of hypothesis-generating research using the ground theory method (Auerbach and Silverstein, 2003) can be followed to successfully incorporate such findings in the decision process, something which could be interesting to research further in the future.

In the planning phase, different ways for ship-owners to comply with the sulphur emission levels were considered along with the related pros and cons of each one. Some technologies have come further in their development and these measures would be the most realistic choice for the fleet existing prior to the legislations implementation. This means that any option concluded to be worthy of further analysis, is a plausible selection in the hands of decision makers. In order to further strengthen this point, the method of data collection used is based on gathering actual data from various sources of bunker traders and agents, shipbrokers and marine equipment manufacturers. In this way, "real time" actual data can provide a better overview of the situation, which will only strengthen the validity of any conclusions made.

The goal of the thesis is give ground to the quest for the most profitable compliance option in the shortest period of time, taking of course into consideration every aspect of legislation compliance. To foster the credibility of the thesis, it will be important to analyse all options with different fuel usage for ships, so that any outcome can provide interesting conclusions for different market segments.

5.2. Classification approach of available options

Hence, in order to have a consistent granular approach on the classification of the options, this thesis considers firstly Heavy Fuel Oil (HFO) and intermediate fuel oil (IFO), since these are the most common fuel option for ships currently (3.5% S m/m). Further on, the interest here lays in the two different types of distillate fuels used, Marine Gas Oil (MGO) and Low Sulphur Marine Gas Oil (LSMGO). This classification method is based on the hypothesis that the sulphur content in the various grade of fuels, is directly connected to the sulphur levels in the crude oil and the particular refinery streams, which are both part of production process, (Brynolf et al., 2014) so the change from IFO, which contain less than 3.5% SO_x, into Low sulphur marine gas oil (LSMGO) containing less than 0.1 % of SO_x, is a clear option adhering to the new legislation, (Panasiuk and Turkina, 2015). The limitation of this hypothesis is that this production process is available at a few refineries today and any further expansion/ changes in refining industry could signal the need for increased energy use and thus more emissions from the refinery side this time, (Brynolf et al., 2014)

Another option is Liquefied natural gas (LNG), which occupies a fraction of the relative volume required for on board storage versus other fuels, not mention produces very low emissions of sulphur oxide (SOx), nitrogen oxide (NOx) and particle matter (PM) by its combustion. Last option taken into consideration, -an option related to further investment on the existing vessels- is the installation of scrubbers.

5.3. Research design

To approach the topic with a more quantitative scope, it is important to address the dependence of these different options on a range of factors. Therefore, the analysis will be based on determining (i) the NPV of the capital and operating costs involved for each vessel type and for each compliance method, through cost development diagrams and (ii) the payback period of the promoted solution.

Capital expenses involve the scrubber and alternative fuel solutions (LNG), as these are the only ones that require important modifications in the vessels. The price for the scrubber installation ranges from 5.0 to 10.0 million dollars depending on the scrubber type, fuel used and finally the capacity. The price for the alternative fuels solutions (LNG) is approx. 7,0 to 30 million dollars as major upgrades must be done to the propulsion engines (if possible) apart from the additional installation required for the fuel gas supply. Fuel projection costs will be based on the absolute price spread of the alternative fuels against HFO as HFO prices fluctuate through time. Finally, all cost comparisons are made basis to the HFO price, which was set at $300, according to latest fuel price data in Singapore.

5.4 Link to the Hypotheses

Firstly, it is important to note that the analysis will be based on the costs of the available technological solutions including CAPEX costs (for scrubbers/ LNG installations) and their payback period as well as OPEX costs (including the increased maintenance and repairs required in such installations and the increased power consumption in the case of scrubbers) and how these compare to the pricing of the new compliant 0.5% S fuels. To this end, it is not taken into consideration the availability of the complaint fuels – since this is part of the hypothesis set (Hypothesis #4).

Of course, the vessel type and size is an important factor in all the sizing (i.e. scrubber capacity, LNG bunker tanks size and remaining economic life) and consumption calculations and therefore can greatly affect the final decision (Hypothesis #2). In more detail, this thesis will present the cost effect each solution has, on the three major commercial vessel types under the prevailing market conditions. The vessel types will be a Suezmax Tanker, a 12,000 TEU Containership and a Panamax Bulk Carrier. The specific vessel types were selected as according to writers' opinion, are the most representative types within their respective market segment. For each case, the hypothesis will partially be adjusted in order to reflect the specific requirements of each vessel type (i.e. consumption) and ensure that the comparison will be done on a common basis. It is must be very clear from the beginning whether owner or charterer covers fuel cost, what will be the time in ECA and if there are local regulations impacting system operation.

Furthermore, probably one of the most important factor of all is the trade the vessel is involved in, along with its remaining life cycle (Hypothesis #3). Indeed, the option selected from ship owners (as presented in Paragraph 2.2) operating a large sailing fleet with worldwide trade patterns would be to invest in the scrubber and/or the LNG ready technologies. The reason is the reduced cost compared to a retrofit and the freight premium the vessels will enjoy. On the other hand, it is important to always consider that older vessels operating for more than 15-20 years (subject to vessel type) and vessels with low utilization (overcapacity) are not incentivized to retrofit and are better off to burn distillate/Low Sulphur FO and/or scrap early.

Finally, the operating expenses will be analysed basis the HFO price differential (Hypothesis #5) with each solution and especially for the case of 0,5% fuels, the model includes both a high and a low expected pricing (but always above the HFO price) to avoid overstating or understating the economic impacts (Hypothesis #1).

Chapter 6

Data Analysis and Results

6.0 Introduction

The result of the NPV determination and payback period as well as the distinct analysis of the alternative options give some interesting points to elaborate further. The increased costs of choosing to install scrubber systems on the vessels, retrofitting or order new LNG-ships or choosing the more expensive MGO/MDO fuel, only further increase the need to answer the question: which is the best solution to address with these costs?

6.1. Cost Components Analysis

6.1.1. Net Present Value method

Looking further to the incentives of ship owners/operators, it is important to calculate possible scenarios they may confront. These scenarios mostly related to three different ship types, each with three different ages and trades. A direct cost comparison between all the available compliant fuels and the exhaust scrubber and LNG options is illustrated through graphs and tables per ship type. The scenarios selected represent the present condition of each market and for each one assumptions were made, thus conclusions may vary. All cost comparisons are made basis the HFO price, which was set at $300, according to latest fuel price data in Singapore.

The Scrubber and LNG options require substantial upfront capital investment for the installation of the systems and for commissioning of them onboard. These options are coupled as well with increased operating expenses, since their usage entails increased power requirements, and a significant price differential over the base HFO respectively. Of course, any price deviations is highly dependent on the specific vessel type and the trading pattern the vessel shall follow. The LNG price is considered different in each vessel type case, to factor in the difference in the quantity amount of LNG required, given the different propulsion power requirements. To incorporate this factor and ensure a granular approach in the analysis, the assumption taken is that the price differential above HFO will signal directly an increased consumption. Thus, this is set for the tanker at 10%, containers at 5% and bulkers at 15%, with the assumption that the larger the LNG amount ordered, the lower the price will be.

Furthermore, the fact that the determination of the 0.5% alternative fuel price is not possible in the first place, the compliant fuels are following a range logic. The lower side end of the expected range represents an increase in fuel cost of 30% -or $90 above the HFO price, while the upper end represents 80% -or $240 above the HFO price. It should also be noted that the absolute price spread of the alternative fuels will vary as HFO prices fluctuate through time. When sailing within ECAs, a 0.1% ECA compliant fuel is used with a high price estimate of 100% -or $300 above the HFO price.

The analysis will be based on two pillars, (i) the Present Value calculation of the accumulated costs (compared to base HFO), over a period of 10 years and the graphical representation of the results, including all compliance methods; (ii) the CAPEX and OPEX projections, to identify the actual level of investment size. To summarize the analysis for each vessel type, a table will list 3 different trading scenarios and provide 3 solutions fitting different operator profiles.

In this context, the focus will be on a rather new vessel being under a time charter contract sailing at high speed coupled with a medium ECA exposure. The other two cases will represent the older and new built vessels of the segment having different utilization profiles. The first assumption aims at the cheapest solution available, considering the limited life, and the latter at the most technologically advanced and expensive options, ensuring favorable terms in future freight contracts.

6.1.1.1. Tanker Vessel Case

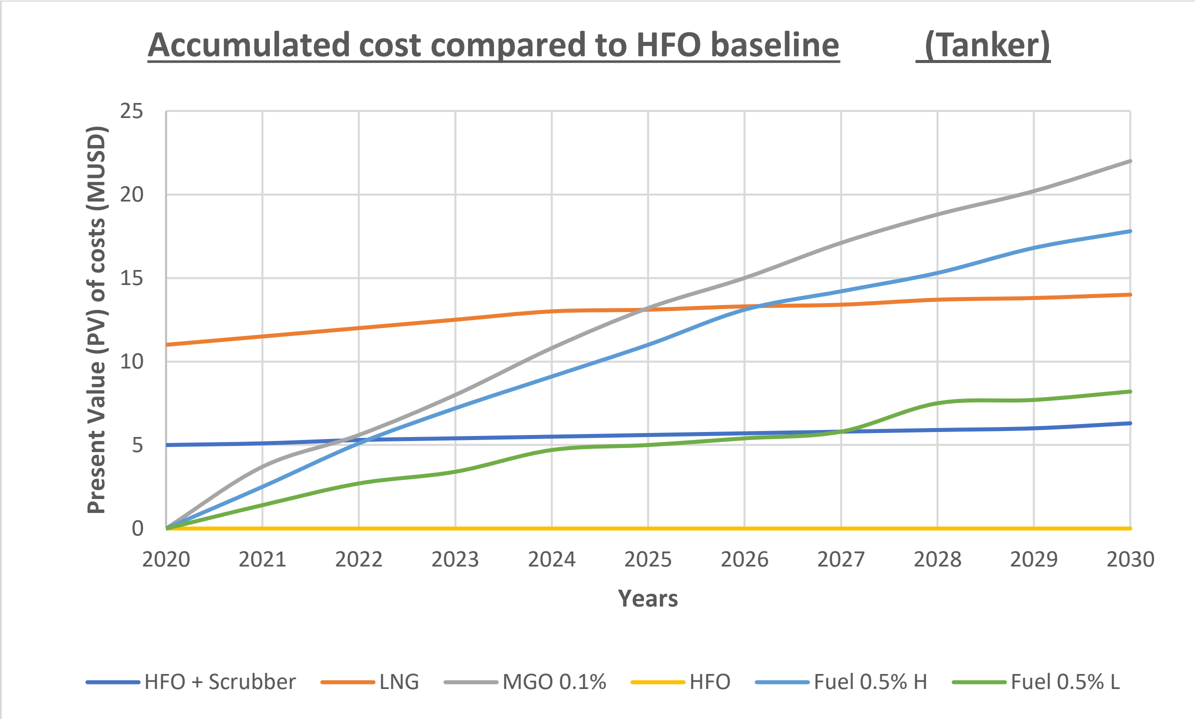

Chart 1: Tanker costs

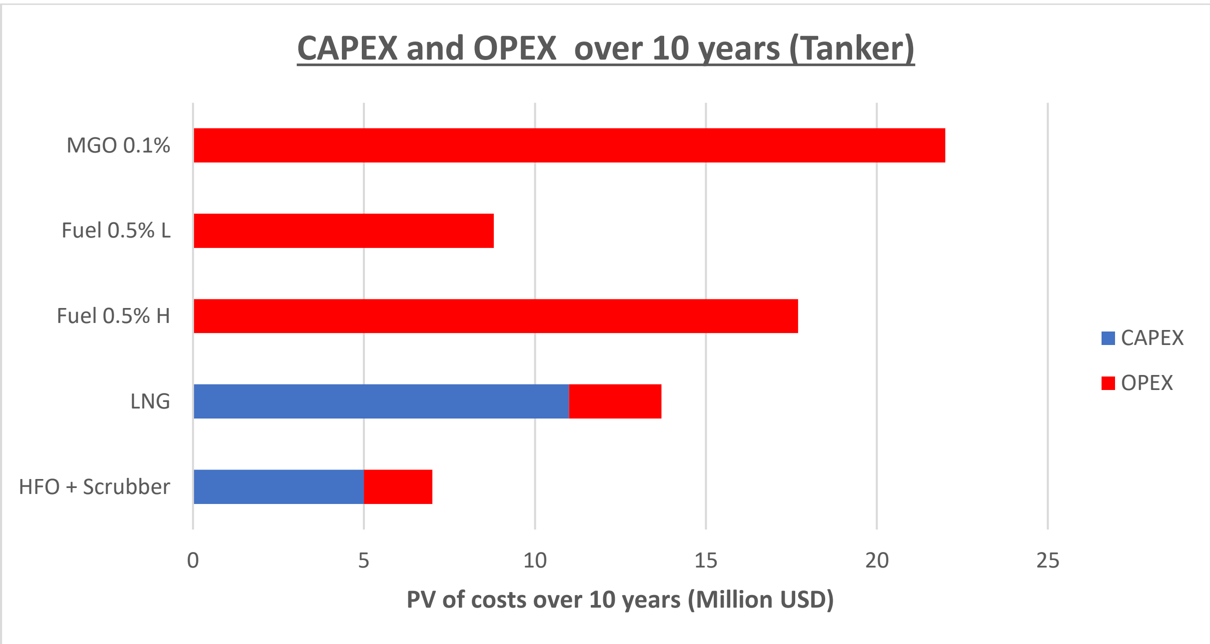

Chart 2: Tanker CAPEX / OPEX

TANKER #	Tanker 1	Tanker 2	Tanker 3
Age	3	13	New Building
Operating Profile	High Speed 15kts	Low Speed (11 kts)	High Speed 15kts
ECA Exposure	Medium	Low	High
TC / Spot	TC (long term)	Spot	TC (long term)
North America Trade	No	No	Yes
Solution 1	Hybrid fuel 0.5% outside ECA 0.1% in ECA	Hybrid fuel 0.5% outside ECA 0.1% in ECA	Hybrid fuel 0.5% outside ECA 0.1% in ECA + EGR/SCR (Tier III)
Solution 2	HFO + Scrubber 0.5% outside ECA Scrubber 0.1% in ECA	HFO + Scrubber 0.5% outside ECA Scrubber 0.1% in ECA	HFO + Scrubber 0.5% outside ECA Scrubber 0.1% in ECA + EGR/SCR (Tier III)
Solution 3			LNG + EGR/SCR (Tier III)

Table 2: Tanker solution proposal per scenario

The graph shows a comparison between today's situation, running on traditional HFO, and a future case where a scrubber, LNG or compliant fuel is used. For the case of a newly built Suezmax tanker, the initial investment required for a scrubber system is approx. 5.0 million dollars and operations expenses (consumption) will be calculated on base HFO pricing. On the other hand, selecting the LNG alternative, the initial investment is approx. 11.0 million dollars, while operating expenses are comparatively increased. When compared to the compliant fuel option, the payback time, depending on how the compliant fuel cost varies, will be from 2.5 to 6 years for the scrubber. Similarly, if an LNG alternative is chosen, the payback time may vary from 6 to well beyond 10 years. Based on the above, the scrubber alternative makes economic sense for both new buildings and retrofits. Higher initial cost for installing a scrubber system in an existing vessel as a retrofit should be expected given the additional costs required to be installed in a repair shipyard and the necessary modifications in piping and equipment arrangement. The LNG alternative appears to be less interesting for new and existing vessels and should be mainly considered when a time charter party contract is fixed and the freight incorporates these additional expenses.

6.1.1.2. Container Vessel Case

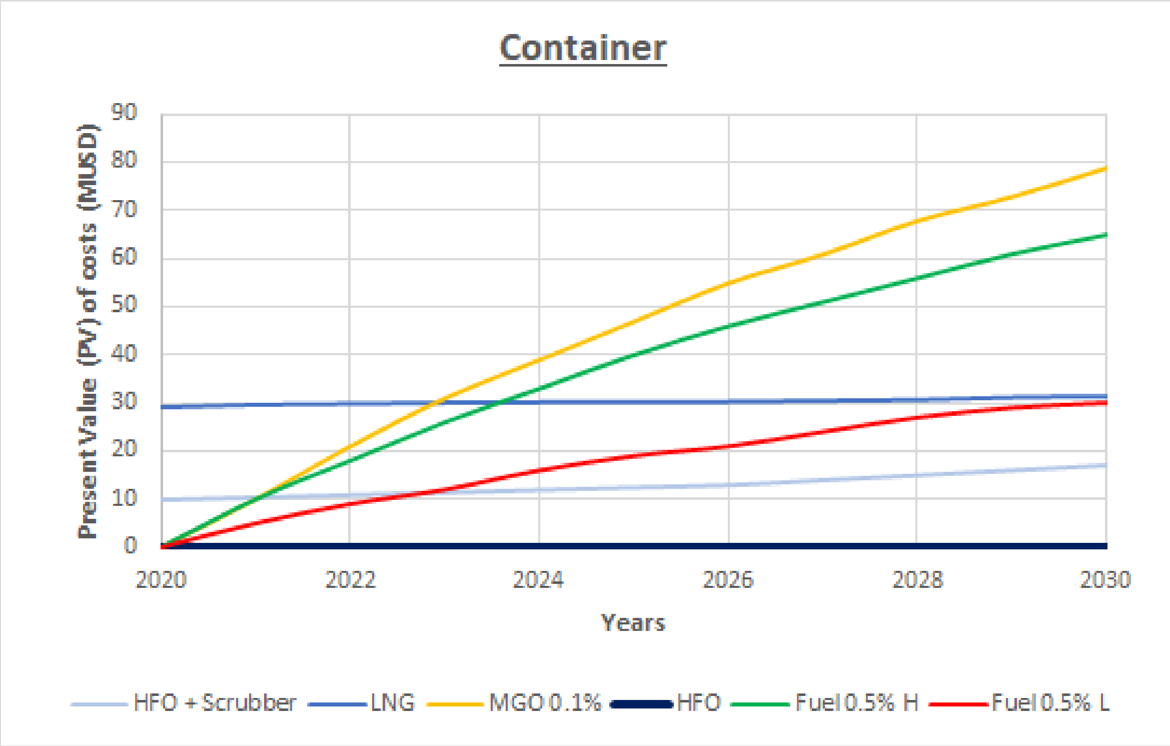

Chart 3: Container costs

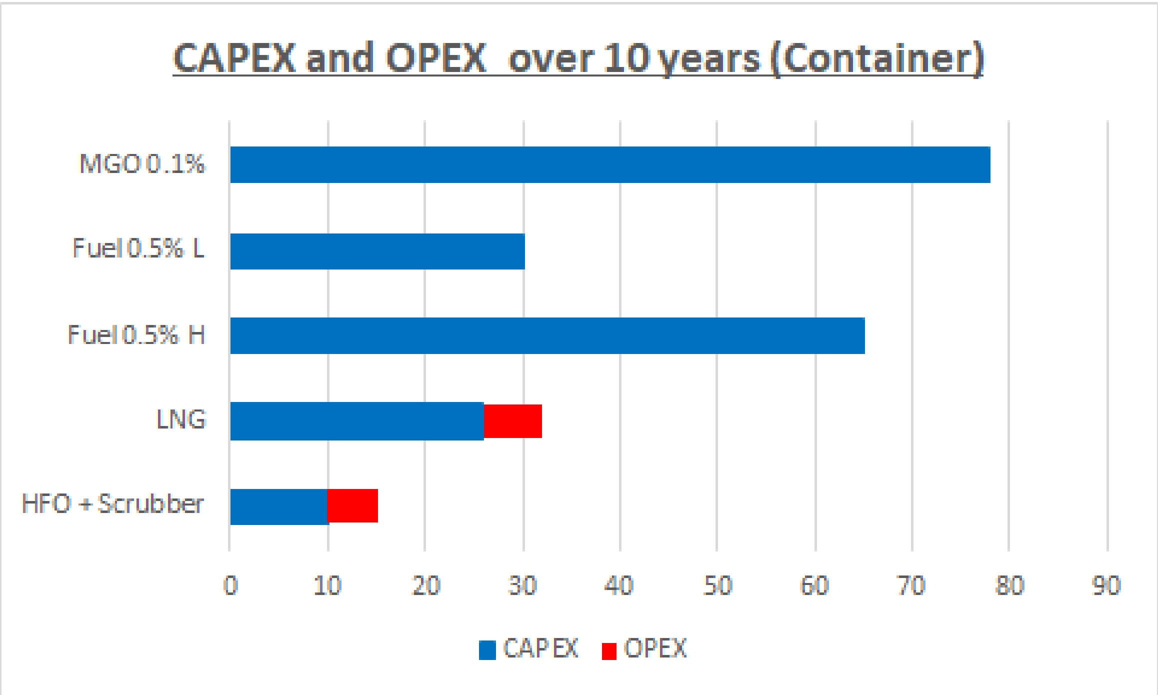

Chart 4: Container CAPEX / OPEX

Container Vessel	Container Vessel 1	Container Vessel 1	Container Vessel 1
Age	3	13	New Building
Operating Profile	High Speed	Low Speed	High Speed
ECA Exposure	Medium	Low	High
TC / Spot	TC (long term)	Spot	TC (long term)
North America Trade	No	No	Yes
Solution 1	Hybrid fuel 0.5% outside ECA 0.1% in ECA	Hybrid fuel 0.5% outside ECA 0.1% in ECA	HFO + Scrubber 0.5% outside ECA Scrubber 0.1% in ECA + EGR/SCR (Tier III)
Solution 2	HFO + Scrubber 0.5% outside ECA Scrubber 0.1% in ECA	HFO + Scrubber 0.5% outside ECA Scrubber 0.1% in ECA	LNG + EGR/SCR (Tier III)
Solution 3	LNG can be evaluated		

Table 3: Container solution proposal per scenario

For the case of a new 12,000 TEU container carrier, the initial investment required for a scrubber system is approx. 10.0 million dollars and operations expenses (consumption) will be calculated on base HFO pricing. On the other hand, selecting the LNG alternative, the initial investment is approx. 28.0 million dollars, while operating expenses are comparatively increased. When compared to the compliant fuel option, the payback time, depending on how the compliant fuel cost varies, will be from 1 to 3 years for the scrubber. Similarly, if an LNG alternative is chosen, the payback time may vary from 4 to beyond 10 years. Based on the above, the scrubber alternative makes economic sense for both new buildings and retrofits. It becomes obvious, when compared to the tanker vessel, that the consumption has a significant impact on the payback period, since these vessels require large amounts of fuel to sail at high speeds. LNG can be a viable alternative and should be considered mainly for new builds. For these vessels, having significant sailing time within current and future ECAs, the LNG as fuel should be considered as it will simplify the vessel’s operation, decrease maintenance costs and achieve the highest results in reducing their environmental impact. Nevertheless, for existing vessel and retrofits, the decision should be purely fuel price based.

6.1.1.3. Bulk Carrier Case

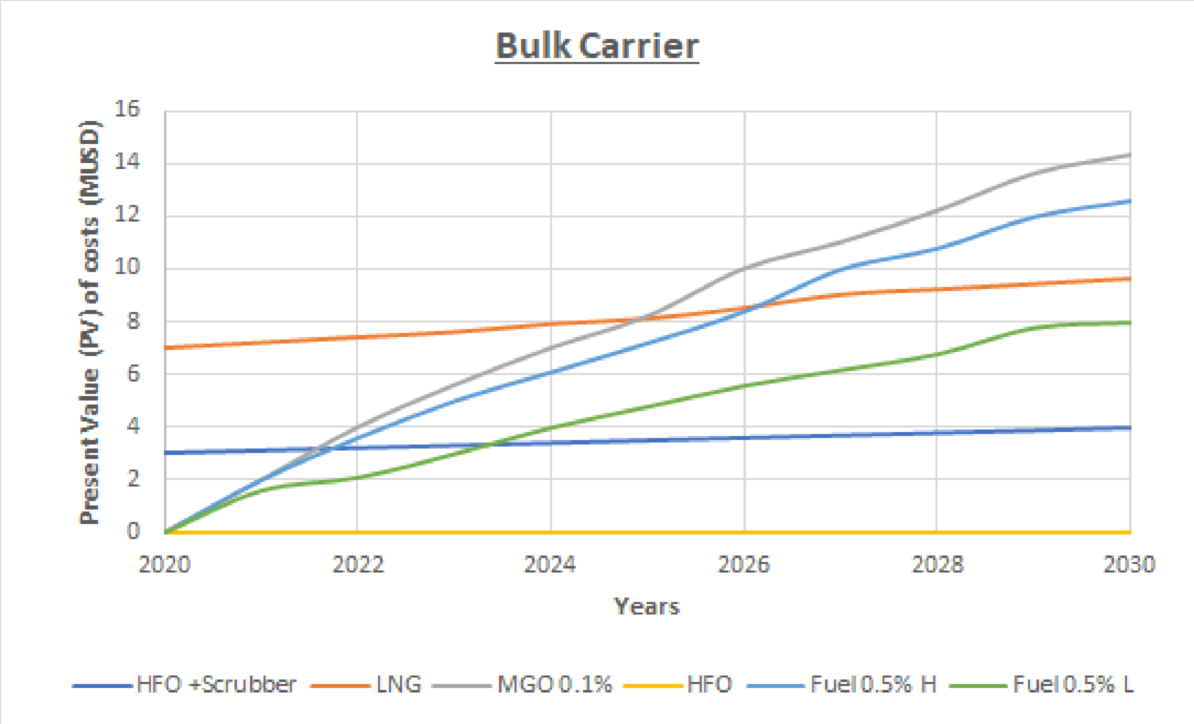

Chart 5: Bulker costs

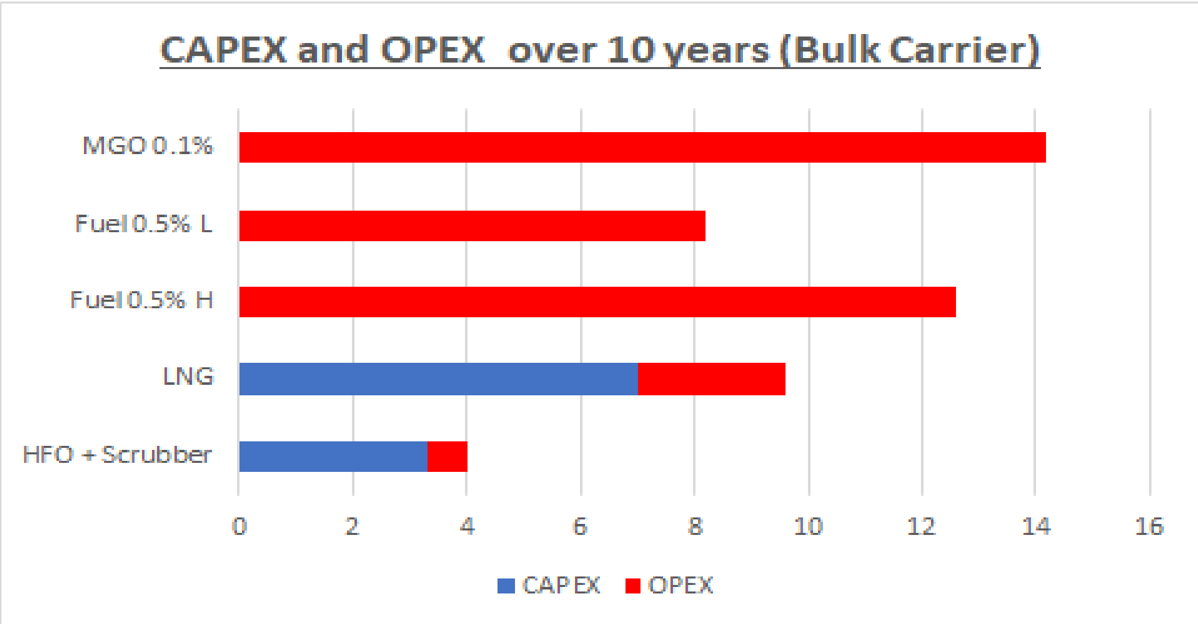

Chart 6: Bulker CAPEX / OPEX

Bulk Carrier	Bulker 1	Bulker 2	Bulker 3
Age	3	13	New Building
Operating Profile	Normal Speed profile	Normal Speed profile	Medium/High speed profile
ECA Exposure	Medium	Low	High
North America Trade	No	No	Yes
Solution 1	Hybrid fuel 0.5% outside ECA 0.1% in ECA	Hybrid fuel 0.5% outside ECA 0.1% in ECA	Hybrid fuel 0.5% outside ECA 0.1% in ECA + EGR/SCR (Tier III)
Solution 2	HFO + Scrubber 0.5% outside ECA Scrubber 0.1% in ECA	HFO + Scrubber 0.5% outside ECA Scrubber 0.1% in ECA	HFO + Scrubber 0.5% outside ECA Scrubber 0.1% in ECA + EGR/SCR (Tier III)
Solution 3			LNG + EGR/SCR (Tier III)

Table 4: Bulker solution proposal per scenario

For the case of a new Panamax bulk carrier, the initial investment required for a scrubber system is approx. 3.0 million dollars and operations expenses (consumption) will be calculated on the basis of HFO pricing. On the other hand, selecting the LNG alternative, the initial investment is approx. 7.0 million dollars, while operating expenses are comparatively increased. When compared to the compliant fuel option, the payback time, depending on how the compliant fuel cost varies, will be from 2 to 3.5 years for the scrubber. Similarly, if an LNG alternative is chosen, the payback time may vary from 6 to beyond 10 years. Based on the above, the scrubber alternative makes economic sense for both new buildings and retrofits. The LNG as fuel option, is considered a very expensive solution for the bulk carrier market given the current low current freight rates. It can, though, be a viable one for large companies requiring securing operation flexibility and compliance to possible future stricter regulations. Of course, the degree of ECA exposure is a significant factor in the selection process.

6.1.2. Recommendation

Any ship owner or operator considering which fuel to use basically has to select among HFO (3.5% S) with scrubber installation; new compliant fuels; distillates and LNG. Each case has different operational issues and are more price sensitive from conventional fuel. The above analysis clearly promotes two options, either the Scrubber Option, which appears to be the cheaper one, or the Hybrid (new complaint) 0.5% Fuel, across all vessel types.

The first option will require from decision makers to proceed with purchasing of the respective equipment and according adjustment of the vessel availability calendar in order to provide adequate period for the works. In the second case, the option is basically plug and play since it requires primarily a simple check of the engine compatibility to fuel type. The below sections illustrate the involved cost which need to be taken into consideration.

6.1.3. Cost saving analysis of promoted options

This section presents a real activity-based analysis using indicative figures of fuel consumption from market in order to provide a cost benefit comparison among the different scenarios, taking into consideration the finding of the CAPEX/OPEX from the analysis above. The criterion is the estimation of yearly savings, following the payback method logic, of related investments on fuels usage which are alternatives to the use of HFO.

Following the analysis above, the option of using MGO seems to be a do-nothing case, which is why it replaces the HFO option, although it should not constitute a solution rather than a benchmark for the other scenarios evaluation. Therefore, the costs of installing scrubber systems will be contrasted with the price differential between 0.5% blend fuel and HFO, permitting the estimation of savings per year for the installation costs and operating costs.

6.1.3.1. Differential cost of Hybrid Fuel over HFO

It is important to further define the adequate % of HFO & distillate, so as to define the exact cost involved for the option of Hybrid Fuel.

Hypothesis:

- Average worldwide Sulphur level of HFO is 2.7%;
- Singapore supplied HFO with average 3.4 % Sulphur content;
- Targeted production of 0.5% Sulphur HFO through blending process

Thus, to determine the % of HFO needed to be mixed with 0.1 % distillates, to achieve the 0.5% m/m, the following formula is used:

$$\mathbf{HFO * X + DSF * (100\text{-}X) = BLF * 100}$$

Where,

HFO = Average level of Sulphur content in HFO

X= the required % of HFO

DSF= the required % of 0,1% S distillate fuel

BLF= the targeted % of Blended Fuel

The above formula gives X at 12 % i.e. 12 % HFO should be mixed with 88 % of 0.1 % distillates to produce 0.5 % blended fuel.

Based on the current Singapore prices, where HFO costs $300 and 0.1% distillate costs $483, the 0.5 % Sulphur blend will cost

$$300 \times 0.12 + 483 \times 0.88 = 461 \text{ USD/MT.}$$

This gives a differential of

$$\$461 - \$300 = 161 \text{ USD/MT}$$

between HFO and 0.5 % blended fuel.

6.1.3.2. Payback calculation

Now it is possible to compare the cost implication of the above two promoted options for each of the vessel types which have been selected. To do so, it is also necessary to define the underlying assumptions:

- Sailing period is 260 days per year for all vessels
- Period of maneuvering and berthing are not examined in all cases
- Consumption level of each vessel are in line with current market statistics
  - Tanker Suezmax vessel 70 MT/Day
  - 12,000 TEU Container vessel 90 MT/Day
  - Bulk Carrier vessel 50 MT/Day
- Cost fluctuation in electrical power and maintenance amongst vessel types is negligible

The saving formula will be the following,

$$(SD \times CONS \times PD) - EPC - MC = CS, \text{ (Function 1)}$$

Where,

SD = sailing days

CONS= consumption in metric tons per day

PD= price differential as found above

EPC= additional consumption due to additional power requirement approx. 3MT/day

MC= additional maintenance costs approx. $300k

CS= yearly cost savings

The following table gives the saving costs in million dollars per year for each vessel type cross the two promoted options

Vessel type	Tanker	Container	Bulker
Savings in USD/year	2.4	3.2	1,56

Table 5: Scrubber savings per year

By using function 1 and factoring in the main variables that affect the decision on scrubber selection (time spent inside ECA areas, fuel consumption and MGO/ HFO spread), then for indicative consumptions and capital investments, we get the following payback periods.

<table>
<tr><td colspan="2" rowspan="2">HFO/MGO spread at 300USD/ton</td><td colspan="5">Consumption (tons per day)</td><td rowspan="2"></td></tr>
<tr><td>25</td><td>50</td><td>100</td><td>150</td><td>200</td></tr>
<tr><td rowspan="4">Time in SECAs</td><td>25%</td><td>10,7</td><td>5,3</td><td>4,0</td><td>3,6</td><td>2,7</td><td rowspan="4">Payback Period</td></tr>
<tr><td>50%</td><td>5,3</td><td>2,7</td><td>2,0</td><td>1,8</td><td>1,3</td></tr>
<tr><td>75%</td><td>3,6</td><td>1,8</td><td>1,3</td><td>1,2</td><td>0,9</td></tr>
<tr><td>100%</td><td>2,7</td><td>1,3</td><td>1,0</td><td>0,9</td><td>0,7</td></tr>
<tr><td colspan="2" rowspan="2"></td><td>5</td><td>5</td><td>7,5</td><td>10</td><td>10</td><td rowspan="2"></td></tr>
<tr><td colspan="5">Scrubber CAPEX (million USD)</td></tr>
</table>

Table 6: Payback calculation for scrubber option

From the table above, we clearly see that the higher the sailing time in SECAs and, mainly, the higher the vessel’s consumption and HFO/MGO spread, the shorter the payback period is, making the scrubber a no brainer solution.

6.1.3.3. Recommendation

From the above analysis it is clear that the optimal decision could be based on the option of the scrubber installation. Such installation involves a significant upfront investment (CAPEX is required prior 2020) and reduced sailing period within 2019 to allow time for the retrofit works to take place. The latter translates also to freight losses due to vessel's unavailability. Nevertheless, it provides at the end higher cost saving over the first 5 years, while the 10-year horizon only increases the profits from this option. The break-even point of Scrubber and 0,5% S fuels is quite important. This factor is necessary to be compared with the vessel's economical life (period till scrap). To further illustrate this the following table provides the decision matrix once the age of the vessel is also included.

Vessel type	Tanker	Container	Bulker
Break-even point	2,5 - 6 years	1 -3 years	2 – 3,5 years

Table 7: Scrubber break-even point

However, there is a lot of speculation in terms of the price differential-spread between HFO and VLSFO in view of January 2020. It is expected that the highest spread will be observed at the inception of the regulations given that the number of scrubbers installed will be limited (expected around 800 units) and the majority of the demand for fuel oil will shift to the compliant VLSFO. Also, the uncertainty in the market during the transition period post 01.01.2020 is likely to encourage the fuel differential to become even wider. However, with time the price differential will inevitably decrease thereafter as there will be more ships installed with scrubbers (as the financials do make sense) thus the demand for HFO will increase and the uncertainty and volatility of the transition period will fade away.

Consequently, the freight market is expected to reach a new equilibrium to reflect the increased bunker expense enabling the net earnings to remain the same. The CIF cargo prices are bound to increase (given the increased bunker expenditure within the freight element). In other words, the increased bunker cost will be, as always, passed to the end consumer through the chain. However, this is not expected to happen overnight.

Chapter 7

Discussion

7.0 Introduction

Strategic decisions should always take into consideration technical challenges that need to be addressed, in order to give a direct competitive advantage to any company's plan. Factors like the NPV of the accumulated costs over a certain period, the payback time, the vessel's type, size and age as well as the trading pattern are absolutely essential in ensuring a successful result. Following the IMO 2020 legislation and the need to burn low sulphur fuels, the determination of these fuels availability, is yet another factor to be considered. Any decision maker needs to understand the specific requirements of their fleet, given the time constraints, and to define the available investment budget. Successful inclusion of all elements above into the decision process will lead to the optimum path forward.

7.1. Results

The cost analysis showed that the Scrubber and the 0.5% S fuel option is relatively more economical than the remaining options in scope. The final decision, on which one to select, will be based mainly on the shipping company's investment policy. Of course, the remaining options may still be viable for certain ship-owners. This is the reason why, three alternative solutions were also proposed in Tables 2, 3 and 4 to account for the diversity in shipping companies' strategy and policies.

Still, above results cannot easily be generalized, since fuel prices may significantly fluctuate. In this sense, the recommendation of this thesis should be considered as the basis for initial plans, providing a substantial ground for further proposals and cost analysis.

7.2. Restrictions and possible future scenarios

One of the most significant constraints, is the readiness of the sources of compliant fuel. It can be a valid concern if the refinery industry could meet the deadline of late 2019 (this was one of the hypothesis of this thesis as well). There could be different scenarios; with most important the one where the bunkering facilities will not be able to source compliant fuels. Thus, there could be compliant fuel unavailability during the first years of the transition. This is the main reason why scrubber orders are increasing significantly and from almost 300 units in 2015, are currently at 1000 units and are expected to reach approximately 3250 units at the implementation time of the Sulphur Cap. On the other hand, it should not be neglected that there is a large number of ships with > 0.50% fuel remaining on board. This fact raises many questions on which should be the best disposal strategy. No one could argue that this uncertainty around 2020 regulatory framework, hampers decision-making by ship owners and operators on fuel selection; making the option of Scrubber installation a preferable alternative.

It can also be the case that the demand for VLSFO will be higher upon 01.01.2020, given that most owners will not have retrofitted their vessels with scrubbers on time. Even though there is no consensus on the exact nature of the VLSFO, the refinery industry is undergoing upgrades to accommodate the production of VLSFO. However, the specification of the VLSFO has not been decided yet and neither its viscosity nor metal content. The above is significant when talking with engine manufacturers, as ship owners are always seeking their approval on the ability of existing engines to burn such fuels. The assumption on fuel compliance to ISO requirements was taken to isolate the possibility of VLSFO variations. This is based on the fact that refineries have already started experimenting with a variety of blending formulations to achieve the desired 0.5% sulphur content. Current laboratory tests have shown, though, differences in compatibility and stability between the blended fuels. These issues are expected to be addressed, though, up to late 2019 as oil majors are heavily working on them. To further justify the above, BP (press release 2018) has already produced 3 different samples of the compliant 0.5% sulphur fuel with different specification and viscosities ranging from 60 to 200 cst. They have clearly stated that they are keen on discussing a contract for both HFO and VLSFO but without giving guarantees for the latter. On one hand, they have confirmed that the supply of HFO will continue as per normal especially in the main hub ports. On the other hand, and from the refineries point of view – BP highlighted the increased risk of instability of the new VLSFO due to blending but has committed to come up with a proper solution.

7.3 Recommendations to ship owners

Additionally, an increased cost of logistics will arise from the need for additional segregation between the different bunker products. Ship owners should have a bunkering strategy in place that considers tank capacity and configuration to the operating profile of the vessel. Apart from technical considerations, it is still important to infer specific commercial considerations on fuel availability as well. Some of the new fuels are only available in one specific region and cannot be sourced in other areas.

Based on the above, supply of adequate fuel might be tight on 01.01.2020 given the expected high demand. Therefore, for ship owners opting into the 0,5% sulphur option, it is imperative to check the supply availability worldwide, lock in contracts ad hoc and have the necessary vessel bunkering arrangements in place.

It is undeniable that the best protection of the environment will be delivered by the shipping industry selecting to burn low sulphur blend and distillate fuels and move away from heavy fuel oils. In this way, the HFO spill risk is avoided and a total reduction in SOx emissions and black carbon is achieved. From the discussion above, it is apparent that the current optimum solutions have certain drawbacks. The scrubber option provides compliance to the air emission regulations at the expense of sea pollution. Compatible and stable blend fuels are not yet available and definitely additional time for tests is required questioning readiness on 01.01.2020. The above, promote the scrubber solution as a preferable solution in the short term until the more stable and compatible blend fuels become widely available.

Chapter 8

Conclusions

The implementation framework of the global sulphur cap has led to numerous debates about future low sulphur fuel availability as well as its possible price development. This makes the forecasting of the fuel price trends a challenging risk. This thesis tried to simplify this unweighted factor, in order to provide clear decision path, ceteris paribus.

The installation of scrubbers involves a major upfront capital investment. This highly depends on the vessel's operating profile, the vessel type, number of engines. But to constitute a viable option, the vessel should be rather young as it makes no sense to invest on a vessel soon to be scrapped. But most importantly, the price differential between heavy residuals and distillates / blends prices is the critical factor as it directly affects the short amortization period of the investment. So, in the case of significant price differences, scrubbers would always be the most cost-efficient option. However, with a short price differential, it is not possible to clearly infer positive recommendations on scrubbers. Nevertheless, the above provides clear incentives to ship owners and assists to promote the options of scrubbers and 0.5% m/m fuel versus distillates.

Bunker analysts suggest that it is highly possible for the prices of distillates to eventually fall, given the new supply and demand equilibrium. The supply of low sulphur compliant fuel will increase significantly post 2020 to cover the increased demand levels and will effectively lead to a price drop. We should clarify that the increase in demand will not be proportional since there will be ship owners either having selected scrubbers (continue to burn high sulphur fuel) or alternative fuels. Nevertheless, the differential between HFO/VLSHFO and low sulphur distillates will certainly remain. This can imply that such solution can provide certain savings in yearly fuel costs, covering the operating expenses of the scrubber, at least in the short term.

Industry analysts, suggest that all ship owners will eventually have to use compliant fuels they are the most effective way to reduce pollution to the environment and should not only concentrate on vessel emissions. While low sulphur fuels tackle the problem of air emissions at the source, scrubbers produce residues from the cleaning process that need to be either treated and stored onboard or discharged overboard. Therefore, there is a valid concern that scrubber residues and black water will be discharged into the sea.

Thus, a solution including the scrubber option can provide short term operational flexibility by enabling ship owners to bunker the widely available HFO and still comply with the new regulations. The high initial investment required, is not consider as a drawback to this option due to its short payback period, while this option allows enough time until the refinery industry is able to cope with the new demand in low sulphur blends and distillates. Therefore, it will assist ship owners to mitigate the risk of compliant fuel unavailability during the first years of the IMO 2020 regulation implementation.

On the other hand, the selection of the 0,5% S fuels requires no significant initial capital investment and only adds to the vessel operating expenses. A number of shipping companies, including Maersk, Hapag Lloyd and Klaveness, have seen the benefits of this solution. Recently they have announced their preference in low sulphur fuels as they believe is the most environmental friendly solution and it will save them from the trouble of installing and maintaining a scrubber that will most probably be decommissioned after a number of years. Further on, Maersk, the world's largest container ship operator, has identified commercial, technical and operational challenges as its reasons for not investing in scrubbers. Additionally, many bunker suppliers have accepted to considerably reduce pricing of such fuels by signing contacts of exclusivity with major shipping companies thus securing their future positions.

Looking into the recent example of the existing SECA areas, ship owners decided to burn fuel distillates (MGO and LSMGO). Their decision was based on the same factors, required initial investment, price differential between HFO and MGO and sailing time within the SECAs. At that time, retrofitting a scrubber was very costly as not many makers were engaged in the market and it was quite risky since this was a new technology. More importantly, the actual sailing time of the world fleet within the SECAs was very limited. Even though the fuel price differential was significant, the costly retrofit of scrubbers and the operating limitations did not justify the expensive investment. The other important lesson learned from this case, relates to the price trends. Although the demand on low sulphur distillates increased, the premium of MGO prices remained rather unchanged. At the same time, the blended 0.1% fuel oil was priced around 10% lower than distillates, so the cost in switching to a lower-grade fuel was an issue. It will be interesting to see which mechanisms will be influencing the prices after the dawn of 2020.

What is clear is that any recommendation, either from literature or past experience need always to be distilled, prior to dictating any final decision making. In this case, it is clear that there could be winners and losers based on appropriate or inappropriate compliance decisions taken. In this thesis it has been presented that the imminent increase of middle distillate demand in 2020 will only force the demand for high-sulfur fuel oil to plummet. In the short term, ship owners and operator that invest in scrubbers will enjoy reduced operating expenses and fuel flexibility given the current uncertainty in complaint fuel availability. Nevertheless, in the long term, switching to 0.5% blend fuels is unavoidable for three reasons. Firstly, stricter regulations are expected to enter into force, supporting a ban on scrubbers due to the technology's impact on the marine environment. Then, international ship-owner associations are now openly supporting a ban on the carriage of fuels onboard exceeding the 0,5% sulphur limit for vessels not equipped with scrubbers. Finally, after some years the price differentials are expected to become such that they will allow efficient and economical vessel operations.

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