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Implications for Shipowners and Charterers of the IMO 2020 Low Sulphur Regulations

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by

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Executive Summary

The objective of this thesis is to evaluate the effects of the implementation of the International Maritime Organization (IMO) 2020 regulations of low Sulphur emissions on the shipping industry. The new amendments to MARPOL Annex VI that came into force on January 1st, has generated as great deal of anticipation and uncertainty for shipowners and market participants.

The choices that shipowners were, and still are, faced with is whether to operate their vessels on more expensive compliant fuel of less than 0.5% Sulphur content or invest in a new technology of onboard exhaust treatment systems (scrubbers) that allow them to operate on less expensive high Sulphur fuel oils. The difference in price between low Sulphur fuel oil and high Sulphur fuel is the determining factor as to the profitability of investing in scrubbers.

Prior studies have concluded that certain types of scrubbers offer a short payback period and can offer a distinct advantage to the owners of such systems. The price difference in fuel types was proving to be profitable for the owners of scrubber fitted vessels during the first months on 2020 until the economic disruption of the Covid-19 pandemic and the ensuing crash in oil prices.

This study aims at analysing the financial presentations that were published by selected shipping companies who invested in scrubber systems and compare them with the current market conditions and possible developments. Another aspect that will be considered, is the speed of vessels operating with scrubbers compared to those that are not.

Fuel consumption represents the largest portion of operational costs for merchant ships. The speed of vessels has an exponential relationship to the amount of fuel that they consume. By observing a sample of vessels this study has found that scrubber fitted vessels do in fact operate considerably faster than non-fitted vessels. At the current low price difference between high Sulphur fuel and low Sulphur fuel, the conclusion of this research is that scrubbers are not a profitable investment at the present time, they do however still hold the potential of becoming profitable if oil demand recovers to pre-pandemic levels in the next few years.

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Implications for Shipowners and Charterers of the 2020 International Maritime Organization Regulations of Low Sulphur Emissions

1. Introduction

The shipping industry is essential to the global economy, raw materials and finished goods need to be carried from production site to where there is demand. Transportation by sea is far less expensive and has a lesser environmental impact compared to air or road transportation. Due to the important volume of transported goods, a focus has been placed on reducing the environmental impact of merchant ships. New regulations put in place by the UN's International Maritime Organization (IMO) became effective as of January 1st, 2020. The aim of the regulations is to reduce Sulphur emissions of ships and thus improve air quality globally. Shipowners have three main options to comply with IMO 2020 regulations, they can either operate their vessels on bunker fuel containing less than 0.5% Sulphur content, retrofit or build new vessels with Exhaust Gas Treatment systems known as scrubbers that allows them to continue operating with fuel of 3.5% Sulphur content, or adapt their vessels to run on Liquified Natural Gas (LNG).
The profitability of installing scrubber systems was a topic of much debate leading up to 2020. A high degree of uncertainty existed prior to the implementation of the new regulations as to the availability of compliant Low Sulphur Fuel Oil (LSFO) post implementation. Most available studies forecasted a large spread in price between more expensive compliant fuel and High Sulphur Fuel Oil (HSFO). Economic disruptions due to the Coronavirus pandemic have added another level of uncertainty as to the profitability of scrubbers.

2. Objectives

The objective of this paper is to examine the parameters that influence scrubber Return on Investment (ROI). An analysis of recorded vessel speeds will be performed on a sample of vessels in an attempt to identify the measurable effects of scrubber investments on average vessel speeds while taking into account the price differential between low Sulphur fuel and high Sulphur fuel. Current market evolutions as well future emission objectives will be analyzed. Finally, the financial statements of sampled shipping companies will be discussed to ultimately attempt to answer the question: Are scrubbers a good investment for shipowners?

3. Literature review

The first studies of the impact and cost of scrubbers on ships were done in 2005 as stated by Shih-Tung Shu (2013). Initial studies done by Ritchie A. et al. (2005) were mostly theoretical as there had been very few scrubbers installed on ships at that time although scrubber tests on ships date back to 1991 according to Ritchie. The conclusions of the study were that over the 15-year estimated lifespan of a scrubber systems the annualized costs would be less than half of those of switching to 0.5% Sulfur fuel.

By 2013 several manufacturers were building scrubber systems and Jens Schipp and Markus Edelman concluded in a report for the European Parliament that Scrubber systems could remove up to 99% of Sulfur from ship exhaust and that they were a viable option until refiners had increased the capacity to produce larger volumes of Low Sulfur Fuel.

Also, in 2013 a study by Shih-Tung Shu examined the life cycle cost analysis of scrubbers that had been installed on existing ships. The 25 known vessels installed with scrubbers at that time were analyzed in terms of the ROI of scrubber type and vessel type. The study modeled the payback of each system under various scenarios and found that open loop scrubbers had by far the shortest ROI. Shu rationally expressed the lowest possible spread between MGO and HSFO as being $133 per metric ton (€ 100). VLSFO is a new development and this bunker type was not available.

In his 2019 research Nishank Sharma conducted a vessel specific investment analysis of the options available to shipowners, his model considered the Net Present Value (NPV) and Modified Internal Rate of Return MIRR and considered the spread in price between High Sulphur Fuel Oil (HSFO), Marine Gas Oil (MGO), and alternate fuels. Similarly, the study done by Shu, his research concluded that the fastest payback comes from investing in open-loop scrubbers, a technology with an associated risk that ports will not accept discharging of wash water from vessels equipped with this type of scrubber. Other forms of scrubbers, hybrid and closed loop, have longer payback periods but vessels equipped with these scrubbers are less likely to be denied port access. Sharma's research does not include vessel speed considerations.

The oil major Shell company puts forward on their website the advantages and issues surrounding the options available to shipowners. The advantages of fitting scrubbers put forward by Shell concur with the conclusions of Sharma in terms of quick payback. Marine Gasoil MGO fuel on the other hand could lead to engine malfunctions as the engines were not initially designed to operate with this lighter distillate grade of fuel. Both Sharma and the Shell company consider the main drawback of LNG to be the current lack of infrastructure for supplying this alternate fuel.

In his research Li (2019) took a different approach using the Analytic Hierarchy Process (AHP) method to analyze the responses of experts working in the industry. By weighing the importance of factors of cost, duration, technical risk, and marketing risk, the AHP method was used by Li to calculate the most favorable option considering the responses of a selected experts. Li concluded that using compliant low Sulphur fuel was a better option compared to installing scrubbers, his research however derives from a very small number of respondents and the results were close, 2 experts favoring the low Sulphur fuel option and the other preferring the installation of scrubbers.

4. Rationale behind IMO 2020 regulations

Marine fuel is known as "bunkers" in the shipping industry, this name dates back to the time when ships were powered by coal, the coal onboard ships was stored in compartments named bunkers. Nowadays, "bunkers", refer to a form of diesel that powers the engines of ships. Bunkers are considered to be the lowest grade of petroleum fuel. Similarly, to diesel powered cars, large seafaring vessels emit fine particle pollutants, such as Sulphur Oxides (SOx) and Nitrogen Oxides (NOx) both of which are harmful to human health when absorbed through the lungs. According to figures published by the UN, the Sulphur emission reduction resulting from the implementation the new norms will lead to a reduction of over 100'000 premature deaths per year and a significant reduction in asthma cases in coastal regions near major ports (IMO, 2020). Cities with major ports tend to be very populated, for example, the largest port in the world, Shanghai, has population of 24.3 million. Singapore, Shenzhen, Hong Kong are other major port cities with significant populations. The largest port in the US in terms of volume of freight transit is Los Angeles, this city has a population of 12.5 million people (World Shipping Council, 2020).

4.1 Brief History of the International Maritime Organization (IMO)

The International Maritime Organization is a United Nations agency that was formed by convention in 1948, at the time of writing in 2020, the IMO organization now has 174 member states. The stated objective when the agency was formed was to "promote maritime safety effectively" (United Nations, 2020). The agency was initially called Inter-Government Maritime Consultative Organization (IMCO). In the early years, the agency was mostly focused on updating the only prior international maritime safety treaty, Safety Of Life At Sea (SOLAS), that dated back to 1914 in response to the Titanic accident.
Following some major oil spills in the 1960's, the focus of IMO broadened to include environmental protection regulations and work on responsibility and liability issues in case of damaging incidents. It was in 1973 that the Convention for the Prevention of Pollution from ships was adopted, the international acronym of this convention is MARPOL. In 1997 MARPOL was extended from a focus on limiting chemicals, waste, and garbage of ships from entering the marine environment to include regulations on atmospheric pollution. MARPOL has 6 technical Annexes that cover specific topics (IMO, 2020). Annexes I and II are mandatory for all countries that have signed the MARPOL convention Annexes 3 to 6 are voluntary (US Coast Guard, 2020). Annex VI deals with air pollution and has been ratified by 97 states as of May 2020, these states account for 96.75% of commercial shipping tonnage (IMO status of treaties, as cited by Čampara et al.,2018)

4.2 List of MARPOL Annexes

- *Annex I, Regulations for the Prevention of Pollution by Oil*
  Contains technical requirements for safe loading and unloading of oil products and requires oil tankers to have double hulls.

- *Annex II, Regulations for the Control of Pollution by Noxious Liquid Substances in Bulk*

Covers the regulations for safe transportation and disposal of residue for 250 substances carried in bulk.

- *Annex III, Prevention of Pollution by Harmful Substances Carried by Sea in Packaged Form*
  Lists the required packing, labelling, and marking standards of transported goods that are not in bulk.

- *Annex IV, Prevention of Pollution by Sewage from Ships*
  Covers the regulations for discharging sewage at sea.

- *Annex V, Prevention of Pollution by Garbage from Ships*
  Lists the regulations for disposing of garbage at sea and specifically forbids the disposal of plastic into the sea.

- *Annex VI, Prevention of Air Pollution from Ships (entered into force 19 May 2005)*

Annex VI deals with air pollution from ships and went into effect in 2005 with a set of regulations aimed at reducing greenhouse gases and ozone depleting gases.

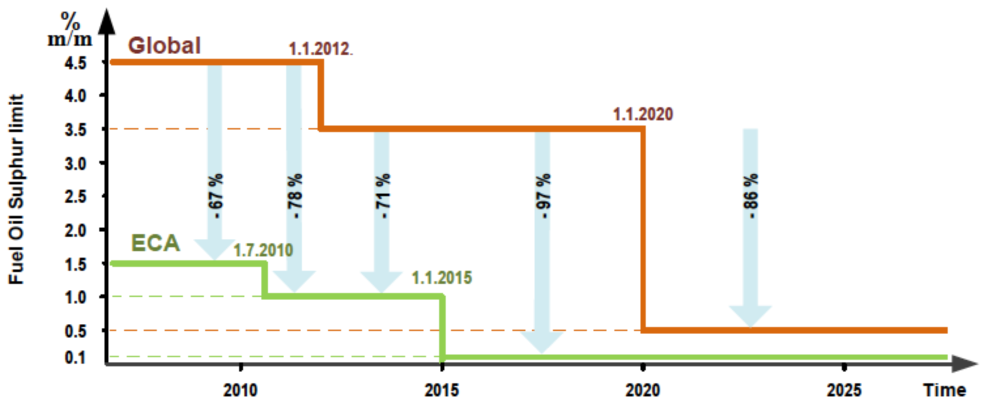
Annex VI specifically focuses on the following main air pollutants emitted by ships (Tay, 2011)

- Chlorofluocarbons (CFCs) and other Halogenated hydrocarbon gases used for the refrigerated transportation of temperature sensitive cargoes. These gases are known to be ozone depleting.
- Nitrogen Oxide (NOx) and Sulfur Oxide (SOx) are emitted during the combustion of diesel (bunkers), these compounds are detrimental to air quality, human health and living organisms, they cause acid rain that can disrupt the pH balance of ecosystems.
- Volatile Organic Compounds that emanate from the holds of oil tankers.
- Emissions from onboard incinerators used to dispose of waste at sea.

As an inter-governmental agency, the IMO does not have direct legal authority to enforce regulations. States remain sovereign for managing their laws and enforcing them. When countries ratify international treaties, they pledge to incorporate the terms into their national laws. Countries can of course decide to impose more stringent rules in their territorial waters.

The EU was the first region to implement SOx Emission Control Areas (SECAs) in the Baltic Sea in 2006, then in 2007 in the North Sea and English Channel, these provisions were included into MARPOL. When entering these areas ships were then required to operate on bunkers containing less than 1.5% Sulphur compared to the global limit at the time of 4.5%. North American Emission Control Areas (ECAs) came into force in 2011 with limits on SOx, NOx and Particulate Matter (PM) with bunker SOx limits of 1% that were also applied in the previously named SECA zones of Europe. In 2015, further amendments to ECA regulations came into force reducing compliant bunker fuel in these zones to 0.1% Sulphur content. MARPOL regulation enforcement for zones outside ECAs were reduced from 4.5% to 3.5% at the start of 2012. The most significant shift yet was implemented on the 1st of January 2020 when compliant fuel went from 3.5% to 0.5% for the vast majority of the world maritime surface.

Figure 1 – Timeline of Sulfur limits implementations



MARPOL Annex VI regulation 14 - sulphur limits for MFOs

Source: (Čampara et al.,2018)

5. Enforcement of the new regulations

The new IMO Annex VI regulations entered into force on January 1st, 2020, shipowners however were still permitted to hold HSFO in their tanks up until March 1st, 2020. The 3-

month period was intended for shipowners to have an adequate period to dispose/sell the non-compliant bunkers at a preferred port.

As mentioned in the section, brief history of IMO, the agency itself does not have jurisdiction to impose fines directly. In theory, ships found to be operating on non-compliant fuel, should be prosecuted and fined by the flag state of the ship.

Philip Roche and Ustav Mathur, two specialized lawyers of the marine industry, describe in their published interview (Oct 2, 2019) for the Argus quotation agency the operational reality of monitoring ships for bunker compliance (Argus, 2019). Roche and Mathur explain that shipowners and shipmasters are unlikely to be fined by the smaller states where many ships are flagged. Because of this, MARPOL authorizes port authorities of any signatory country to detain, prosecute and fine ships that are in breach of legislation of the country where the ship is located.

The primary method of inspection performed by port authorities or coast guards is to verify bunker delivery documents and vessel oil records. New “sniffer” technologies are being deployed in some regions of the world. Sniffer devices are designed to measure the Sulphur content of ship exhaust. The Netherlands, Hong Kong, Denmark and Norway are using sniffer drones to fly through the exhaust plumes of vessels that are approaching their ports. It only takes 3 minutes for the drone to analyze a vessel’s exhaust and to relay the information to port authorities. If the readings are non-compliant, port authorities will proceed to take physical samples from the fuel tanks of suspected vessels (Wittels, Koh, 2019).

Penalties and fines are not defined under MAPOL, they are however, recommended to be sufficiently dissuasive. States, therefore, decide on penalties within their laws. The US authorities for example have imposed fines of $1.5 million to a shipowner and operator for falsifying bunker records, the master was banned from entering US waters for three years (Argus, 2019). In Singapore, two years of prison can be imposed for IMO 2020 infractions, and 6 months in Hong Kong (Wittels, Koh, 2019).

Shipping companies have the added incentive to comply for reputational reasons. If a company is caught cheating, they could lose important customers that want to protect their own reputation. In the modern age of hyper-connectivity, reputational standing has become ever more important for retaining customer loyalty. Shipping companies as well as their charterers are faced with an increased level of oversight that is creating a need to make long term strategic decisions.

6. Shipping industry background

In 2019 the shipping industry was consuming +3 million barrels a day of High Sulphur Fuel Oil (HSFO) to operate 90'000 vessels (IMO, 2020). In order to comply with IMO 2020 regulations, shipowners were faced with the options of either installing exhaust cleaning system on their vessels (scrubbers) or to operate their ships on Low Sulphur Fuel Oil of less than 0.5% Sulphur content. It was estimated that approximately 10% of the global large vessel fleet by tonnage had installed scrubbers by the end of 2019 (Kinch, Fox, 2020). Leading up to 2020, there were concerns that oil refiners had not prepared for the shift in demand from HSFO to LSFO. Availability issues coupled with the higher cost of low Sulphur bunker fuel were issues that forced shipowners to make strategic decisions as to whether they would invest in the unproven technology of scrubbers or whether they would choose to run their fleet on low Sulphur bunkers. The hypothesis was that vessels not equipped with scrubbers would operate at lower speed compared to vessels that had been fitted with scrubber systems. An overall slower global fleet would lead to a reduction of capacity and in turn would lead to higher freight rates. Scrubber fitted vessels would benefit from the ability to operate on less expensive bunkers and thus operate at higher speeds. Before the Coronavirus disruption to the economy and the crash in oil prices in March 2020, the option of installing scrubber systems, was proving to be a profitable decision for shipowners.

7. Shipowner revenues

Freight vessels generate revenues for owners either when utilized or when they are sold. While in possession of a vessel, shipowners are naturally looking to maximize operational revenues. Depending on market conditions, bargaining power may either be in the hands of shipowners or charterers. In a tight market where there are few available vessels shipowners will have the upper hand in terms of negotiating contracts in their favor, the converse is true when there is an overabundance of available ships on the market. As will be discussed in following section, shipowners have brief periods in an average 8-year cycles to profit from their investments.

7.1 ***Shipping market cycles***

Economic cycles have been observed for centuries in all industries and have led to the development of specific and macro models by economists. Martin Stopford the author of the textbook *Maritime Economics* is recognized as one of the foremost economists of the merchant shipping industry.

In his book, Stopford demonstrates that periods of high freight rates (peaks) are followed by periods of low freight rates (troughs), over time, rates climb back up to a peak from a trough. The period from peak to peak (or trough to trough) is known as a cycle. Peak periods are profitable for shipowners whereas troughs, when rates are low, shipowners struggle to stay in business.

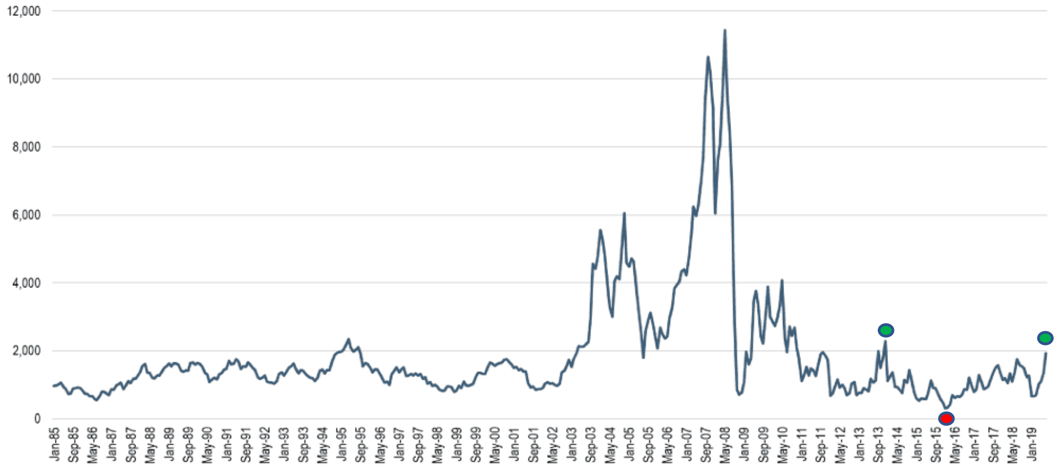
There are also cycles within cycles, long cycles as found by Stopford, last between 20 and 50 years and are driven by changes in technology and geo-political shifts. Short shipping cycles last 8 years on average, the duration can vary and there is no definite rule. The shortest cycles are seasonal, they occur within a year, as the name implies, and are dependent cargo type.

Short cycles are of most importance for shipping companies as they affect the strategic decision of fleet management. When shipowners are earning high revenues during peak periods, they have the cashflow and incentive to order new vessels. A peak (or plateau) can last several years, with many new vessels being ordered and put into service, this eventually creates an oversupply and a subsequent collapse in rates that leads to the trough period of low rates.

The historical data of the Baltic Dry Index represented in Figure [2] is an indicator of freight rates for dry bulk cargo. Besides demonstrating the high level of volatility of the shipping industry, the wave-like pattern of peaks and troughs is apparent, although the pattern is compressed by the massive rate surges between 2003 and 2008. The huge peaks starting in 2003 are a result of the boom in Chinese infrastructure construction (Stopford, 2009).

In figure [3] published by UNCAD we see a representation of vessels on order for construction in the period 2000-2019, the peaks in vessel construction follow the peaks in freight rates with a time lag of between 1 and 2 years. The period of impressively high freight rates between 2003 and 2007 led to a surge in new vessel orders that went from 2006 to 2012. When new vessel orders were still at peak levels in 2012, freight rates dropped to dismal levels. This lag is a well-established difficulty in the shipping industry, the construction of new vessels takes between 6 months and 2.5 years depending on shipyards (Pires Jr, Lamb, Souza, 2009). Shipping companies having ordered a new ship at the highest point of 2008 rates would have taken delivery of their vessel when rates had dropped by up to a staggering 1000%. By the time the last vessels ordered during the order surge ending in 2015 were delivered, freight rates reached their lowest levels on record in 2016.

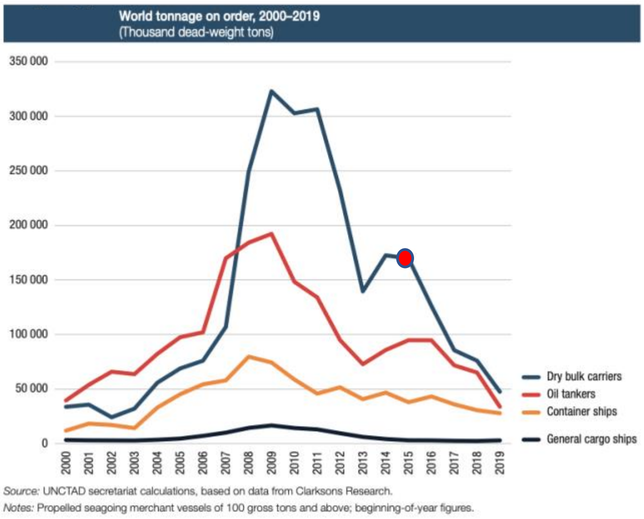
Figure 2 - The Baltic Dry Index, 1985-2019 with markers for latest short cycle



Source: Bloomberg as cited by The Geography of Transport Systems

The oversupply of vessels resulting from the 2006-2014 shipbuilding surge has created a trough of low rates that has arguably lasted from 2014 to 2019. In the dry bulk segment, the global fleet is relatively young because of the excessive orders of the surge period. In fact, the average age of dry bulk vessels was 9.72 years in 2019 compared to an average age 18.87 years for oil tankers (UNCTAD, 2019). Ships have an average life of 21 years between the time they are put in service and the time they are scrapped (UNCTAD, 2019). Although new orders have been declining since 2011, ton-miles of dry bulk and other cargoes has continued to increase over the years and has somewhat balanced the oversupply of vessels built between 2006 and 2014.

Figure 3 – World order for new ships 2000-2019 with marker for record lowest rates



Source: UNCTAD 2019 Review of Maritime Transport based on data from Clarkson's Research

7.2 New and Secondhand market of ships

The market for purchasing and selling ships whether new or second hand, is extremely volatile. Stopford illustrates this characteristic by giving the example of a new 85'000 dwt tanker costing $16 million in 1976, $40 million in 1981, back down to $20 million in 1985, and up again to $43 million in 1990. The secondhand market follows the same price swings as the new building market. In 1986 the price of an 8-year-old VLCC of 250'000 dwt doubled in price from $5 million to $10 million and three years later, the same vessel had a value of $38 million (Stopford, 2009).

Because of this extreme volatility that results from the shipping cycles, the Sale and Purchase (S&P) of ships can be the main profit driver for shipping companies that have bought low during a trough and sold high near the peak. The revenue generated by chartering a vessel may be near breakeven or at a loss during the period of ownership and profits generated only at the time the vessel is sold.

It is of course difficult to predict the duration and nature of each cycle as they are dictated by global events that can occur suddenly and flip a market trend within a matter of days. It requires a cool head, a good amount of nerve, and a sound cashflow policy to buy a vessel during a trough when immediate revenues from the ship will not be profitable. It also demands a high level of discipline to sell a ship when chartering revenues are high. A 2017 Tradewinds article by Andy Pierce lists some of the important indicators for investors that are typical for each phase of the shipping cycle. These indicators are presented in table [1].

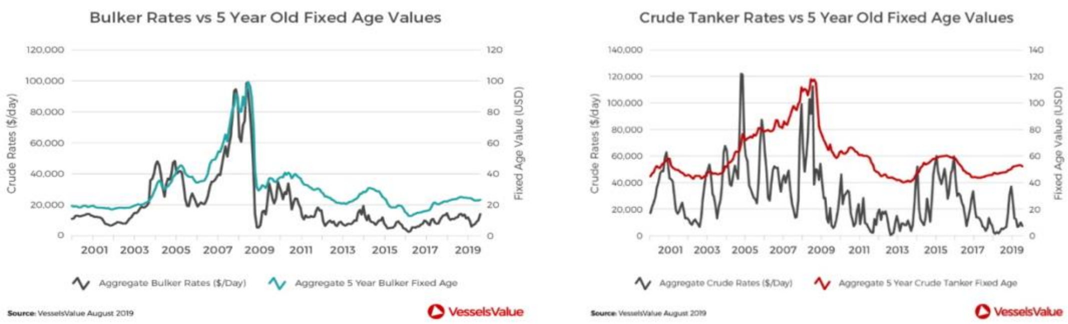
Table 1 – Indicators of the phases of shipping cycles

Trough	Recovery	Peak	Collapse
• Clear surplus capacity • Freight rates at or below OPEX • Tight credit and negative cash flows • Increased demolition	• Supply and demand starting to balance • Sentiment swings between optimism and doubt • Increased liquidity raising ship prices • Prosperous rates	• Rates between 2 and 10 times OPEX • High bank lending • International press coverage • Stock market listings • High newbuilding activity • Talk of new era	• Supply exceeds demand • Economic shock and/or slowing trade • Peak newbuilding orders are arriving • Trading speeds are slowing • Limited sale & purchase activity • Confused sentiment

Source: Information from Pierce Andy, Tradewinds article 2017

Shipping is a unique industry in in terms of potential CAPEX returns. Stopford is quoted in the Pierce 2017 article as stating that a vessel bought in the trough period of 2001 for $18 million could be sold in 2007 for up to $80 million and have generated another $50 or $60 million during high market rates. In other terms a personal capital investment of $3.5 million (20% of 18 million) could be turned into $120 million in the space of 6 years (Stopford as cited by Pierce, 2017).

Figure 4 – Value of 5-year-old vessels 2000-2019



Source: VesselsValue posted on Hellenic Shipping News Worldwide

Such extraordinary returns on investment may have been a once in lifetime opportunity corresponding to the rapid development of the Chinese Economy. Nonetheless when looking at the following cycle 2010-2015 in figure [4] we can see that a 5-year-old tanker went from a value of $40 million to $60 million in only 2.5 years and could still generate significant profits for those who bought low and sold high.

Sound operational management of a vessel (including bunker consumption management) can arguably be considered to be a strategy to ride out a trough period until the next rise in the market when the vessel should be sold to lock in a solid profit.

7.3 Operational revenues

Types of Maritime Transportation Contracts

Contracts between charterers and shipowners fall into a set of 4 categories: voyage charter, contract of affreightment, time charters, or bare boat (Whal, Kristoffersen, Tenold, 2012, Stopford, 2009).

Each type of contact is briefly described below:

Voyage charter
The shipowner takes the responsibility and risk of the voyage for an agreed upon price based on the current spot price. In this case a faster vessel could command a higher price for the reduced transportation time as well as generating more revenues yearly due to a larger volume of contracts resulting from faster legs.
Loading and discharging risks remain with charterer and the costs of delays at port relating to these operations can be claimed against the charterer in demurrage.

Contract of affreightment
The basis of the contract is a rate per ton carried. Under this type of contract, the shipowner has the highest incentive to adapt the speed of the vessel according to market conditions. The shipowner being paid a flat rate per ton carried, will be looking to optimize operational costs for higher profitability.

Time charter
Is an agreement whereby the charterer takes operational control of a vessel and assumes part of the operational costs and risks for a given amount of time. Vessels that have lower operational costs can command a premium above spot daily rates. Because this form

contract entails shared risks it is a complicated form of contract, the shipowner is entitled to receives a flat daily rate for providing his ship to the orders of the charterer

Bare boat
Is a form of contract where all operational risks and expenses are assumed by the charterer. The shipowner only deals with financing the vessel itself and is not involved in operations.

Table 2 – Cost assignment depending on charter type

Cost	Main Components	Bareboat Charter	Time Charter	Voyage Charter & COA
Capital	Deposit Repayment of loan principal interest			
Operating	Manning Insurance Repairs & Maintenance Stores, spares and supplies Administration & Management			
Voyage	Bunkers Port disbursements Canal & seaway transit costs			

Cost for charterers account
Cost for owners account

: Cost distribution between charterer and vessel owner
Source: Drewry Shipping Consultants Ltd.

Source: Drewry Shipping Consultants Ltd, as cited by Maanum 2015

8. Scrubber systems

Scrubber systems, otherwise known as Exhaust Gas Treatment (EGT) systems are installations that process exhaust gases to remove certain types of toxic particles from being released into the atmosphere. The IMO 2020 regulations placed a cap specifically on Sulphur Oxides (SOx) emissions allowed by seagoing vessels above a gross tonnage of 400 t. The aim of this new regulation is to improve the air quality on a global scale and thus save an estimated 570'000 premature human deaths between 2020 and 2025 (IMO,2020).
There exist 3 main types of EGT technologies: wet scrubber systems, dry scrubber systems, and selective catalyst reaction systems (Shih, 2013).

8.1 Wet scrubber systems

As the name implies, this technology places water in close contact with exhaust gases in order to capture chemical elements. The water containing the captured particles must then

undergo a treatment process either onboard or ashore before the treatment water can be safely returned to the sea.
Within the wet scrubber category there are three sub-types of systems.

- Open loop scrubbers
- Closed loop scrubbers
- Hybrid scrubbers

Open loop scrubbers utilize readily available saltwater that is pumped into the filtering chamber of the system and put into contact with the exhaust. This process has the property capturing SOx into the saltwater, this water is then processed onboard to separate the residue (sludge) from filtered water that can be returned to the sea. The sludge must then be held in a sludge tank and be disposed of at ports with appropriate infrastructure.

Closed loop systems utilize freshwater containing Sodium Hydroxide that is held in an onboard tank. The exhaust is put into contact with the freshwater mixture and then pumped into a processing tank where the sludge is separated from water. The treated water is then pumped back into the holding tank and the sludge is pumped into a sludge tank that must be disposed of at ports having the required facilities.

Hybrid Scrubber Systems can either operate as open or closed loop. These systems are more complex, they require a larger number of conduits, pumps and tanks. The advantage of hybrid systems however is that they allow the vessel to operate as open loop in waters where allowed and switch to closed loop when entering regions with stricter regulation while the ship continues to operate on HSFO. As of January 2020, 28 countries have prohibited or restricted the discharge of wash water in their ports and territorial waters these countries include Australia, Brazil, China, France, Norway, USA (Brittania,2020).

8.2 Dry scrubbers

Dry scrubber systems make use of calcium hydroxide granules. The exhaust is passed through a chamber containing the granules and the SOx is captured into the granules. Similarly, to closed loop wet scrubbers, this technology requires a constant supply of chemical elements. The used granules need to be disposed of at ports where collection services are available.

8.3 *Selective catalyst reaction systems*

There are several types of catalyst reaction systems that use rare metals such as platinum, palladium, or vanadium in honeycomb structures. When placed in contact with exhaust fumes, a chemical reaction takes place and allows pollutants to be captured. This option is not economically viable for most seagoing vessels as the capital expenditure is too high.

8.4 *Scrubber system with shortest ROI*

When considering the total life cycle cost of all scrubber systems that includes initial investment, operating costs (ongoing purchase of chemicals), safe disposal of waste materials, maintenance costs, and end of life disposal, wet open loop scrubber systems offer the shortest ROI (Shih, 2013). Open loop systems are the simplest and do not require a supply of chemical additives, the alkalinity of saltwater is sufficient to capture SOx. Due to restrictions in some areas, shipowners operating with open loop systems can opt to carry a lesser amount of LSFO in separate tanks and switch to this bunker when they enter restricted zones. Recent scientific publications have raised concerns that a wide adoption of open loop scrubbers could lead to the acidification of the marine environment (Endres et al., 2018)

8.5 *Malfunction issues surrounding scrubbers*

Scrubbers on ships are a new technology and there are reported issues with some systems. Sam Chambers wrote in an October 2019 article for the maritime reporting magazine Splash247 that during the month of September 2019 there had been 6 scrubber malfunctions that he was aware of. Because scrubber systems are exposed to saltwater and high levels of Sulphur content, they must be designed to withstand a highly corrosive environment. All the pipes and conduits of scrubber systems must be coated in order to resist damage, the welds of the system must also be of high quality to avoid failures that can lead to flooding of the engine room. Inspection and maintenance of scrubbers is a cost that has been underestimated by some shipowners, Chambers gives the example of one shipowner who budgeted $10'000 per year per vessel in scrubber maintenance and found that the actual cost after 1 year was closer to $100'000.

The difficulty in improving scrubber reliability comes from the reluctance of shipowners in sharing the details of incidents. Because of the natural tendency of protecting maritime operational details, scrubber systems may take longer to improve compared to other products due to little available data.

8.6 The options retrofitting or building vessels to operate on LNG

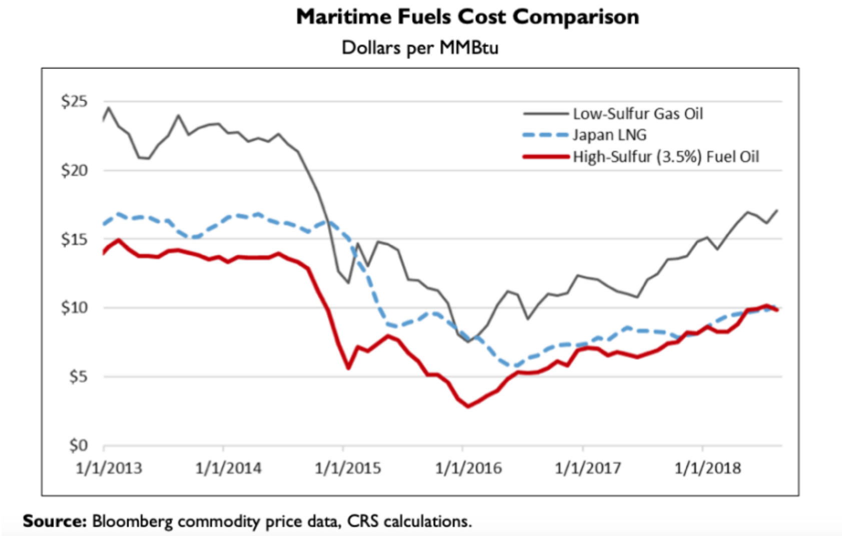
Liquified Natural Gas (LNG) when used as an energy source to power ships or other vehicles emits very little SOx and its price has converged to match HSFO. On the surface these arguments seem to favor this fuel source. The price of retrofitting an existing vessel the size of a VLCC however is prohibitive at a cost of $25 million to $30 million compared to the $6 million to $7 million for installing an open loop scrubber [21]. Newbuildings specifically designed to operate on LNG would cost an extra $5 million compared to a conventional vessel and it is therefore expected that most LNG vessels will be newbuildings.

The infrastructure for supplying vessels with LNG is another major issue for the viability of this option, as of 2020 many ports are not equipped for supplying this fuel type. An investment in LNG only makes sense for vessel types such as ferries that have fixed routes between known ports where LNG is available. Because half of oil tanker and dry bulk fixtures are settled on the spot market, this bunker option is less attractive at the present time because it severely limits operational flexibility.

Recent studies have also cast a doubt as to the environmental benefits of LNG. IMO 2020 amendments to Annex VI regulations have focused primarily on Sulphur emissions. LNG is composed primarily of methane and is therefore a Greenhouse Gas (GHG), any leakage in the supply chain contributes to global warming (Pavlenko et al. 2020). The studies conducted for the International Council on Clean Transportation found that there is no environmental benefit derived from switching to LNG powered ships and that for the vast majority of engine designs, LNG is in fact much more damaging to the environment when compared to VLSFO. For these reasons, LNG is experimental at this time with less than 1%

of global fleet operating with this bunker type and it is mostly used on cruise ships and ferries.

Figure 5 – Historical Comparison of the energy output cost of Low Sulfur Fuel oil, High Sulfur Fuel Oil, and LNG



Source: Cited by US Congressional Research Service

9. Shipping Industry Segmentation

The shipping industry is segmented into several distinct markets, the largest segments are container ships, dry bulk carriers, and oil tankers. Each of these segments are subdivided according to vessel sizes (tonnage), larger vessels make economic sense for longer transportation routes while smaller vessels make more sense for shorter voyages. Market dynamics and the profitability of scrubbers may be substantially different for shipowners that operate in one market or another.

Shipowners earn their revenues either by renting their vessels on a time charter basis whereby the customer charters the vessel for a given period of time or by contracting on a voyage basis where the customer pays an agreed sum for a given route. The choice of contract is a strategic decision that is taken by the shipowner and the charterer given their outlook on the market.

During their operational years, seagoing vessels are essentially in one of five states at any given time, they are either in port, approaching/leaving port, on a laden leg, on a ballast leg, or they are “dry docked” undergoing maintenance, upgrades or repairs. Smaller vessels spend a larger percentage of time in port due to adequacy for shorter voyages resulting from cost reduction in loading/unloading per unit transported (Von Knorring, Styhre, 2015). Bunker consumption of ships is dependent upon their speed and whether they are laden or not.

10. Factors that affect the rational decision of vessel speed

Average vessel speeds are influenced most by three factors (Wahl, Kristofferson, 2012).

- The freight rate measured as daily time charter rate on the market.
- Bunker prices
- Financing costs of cargo

When time charter rates are high, the incentive for charterers is to operate vessels at higher speeds in order to reduce the amount of time the vessel is on hire and thus reduce the incurred costs. Because of the exponential trend between higher speed and fuel consumption the charterer under a time charter contract will want to find the optimal speed at which bunker costs and the chartering duration is optimized. The same logic applies for shipowners under a voyage charter, the rational decision is to find the optimal speed for which bunker costs are minimized relative to the time-value of earnings in market condition at that point in time.

Financing costs of cargo is the third factor to consider. VLCCs can carry 2 million barrels of oil. Even at current low oil prices of $40 a barrel, the value of the cargo is of $80 million. At an interest rate of 3%, this represents a cost of $6’575/day assuming the entire cargo is financed by a loan. This cost must be factored into the decision of voyage speed. Most physical commodity trading firms are financed by banks because margins are very thin and trading companies must leverage themselves to reach high enough volumes. The monetary value of a cargo and the interest rate, therefore, have a significant influence on the optimal speed calculation of vessels for each voyage.

Other factors that influence vessel speed are not necessarily foreseeable and these factors include weather conditions, congestions at ports, canals, or straights. Fouling of the ship hull by sea organisms such as barnacles also affects speed and bunker consumption.

10.1 Slow steaming

In 2005 bunker costs constituted 25% of a ship's operating expenses, in the following decade this percentage rose to almost 70% (Walh, Kristofferson, 2012). In 2007 oil prices skyrocketed, this was coupled with an oversupply of vessels on the market. These difficult market conditions led shipowners to develop cost saving strategies. Bunker consumption constitutes such an important percentage of transportation costs and sailing speed is a determining factor of bunker consumption, because of this, the practice of slow steaming became commonplace in 2007/2008. Vessel speed and fuel consumption have a nonlinear relationship, a speed reduction of 13 % for a VLCC from 15 to 13 knots leads to a reduction in bunker consumption of 35% (Gkonis, Psaraftis 2013).
Slow steaming is considered to be a speed reduction of 15%. It is estimated that between 2008 and 2010 the reduction in steaming speed produced the positive externality of reduced emissions by 11%. Reduced speed is viable for shipowners when bunker prices are above $350 to $400 (Meyer, Stahlbock, Voss, 2012).

10.2 Other factors that affect the rational decision of vessel speed

Optimal speed models were first developed in the 1970's due to the energy crisis that sent oil prices soaring. The first models that aimed at profit optimization were developed by Alderton (1981) and Ronen (1982) as cited by Maanum (2015).
Studies that have compared actual vessel speeds to the calculated optimal speed have found that most vessels operate at speeds that are higher than what is optimal for profit maximization from a shipowners perspective (Maanum, 2015).

Some explanations for this are that charterers and shipowners have opposing interests for cost reduction depending on the type of contract. For a voyage charter the shipowner has the highest incentive to optimize bunker costs, however, there may be minimum speed clauses imposed by the charterer in the contract that are higher than the preferred speed of the owner. In both time charter and voyage charter, a determining factor in vessel speed is the requirement to reach a port during the laycan period.

The periods when ships are closest to predicted optimal speeds in terms of fuel consumption is when they are on ballast legs, waiting for their next fixture. After having unloaded a cargo, if there is no immediate follow-up contract at the same port, a vessel will travel towards the nearest region where demand is high. During this time the vessel is not carrying any cargo, it must however carry water as ballast to stabilize the vessel when cargo is not serving this purpose. Because ships are not earning any revenue during the ballast leg, shipowners or operators will be careful to order optimal speeds for minimal bunker consumption

11. IMO 2030 objectives

With all the immediate attention on the IMO 2020 implementation of amendments to Annex VI there has been little attention paid to the objectives set by IMO in 2008 of lowering carbon emissions by 40% by 2030. This is largely because CO_2 emissions had already been reduced by 30% by 2018 due to slow steaming (Farand, 2020). IMO is set to revise its objectives in 2023 and it is possible that more ambitious objectives will be set. In 2018 the shipping industry pledged to reduce carbon emissions by 50% by 2050 compared to 2008 levels. France and Greece are backing a proposal to limit the speed of vessels as a measure to meet or exceed the 2030 objectives. In a 2019 study for the European Commission it was found that a speed reduction of 20% compared to the 2012 levels could reduce CO_2 emissions between 24% to 34%, this appears to be one of the most effective measures and it does not require shipowners to make large investments. Improvements in operational efficiency standards is the other measure that produces a significant reduction in CO_2. This measure is more complex to put in place and would require a much higher level of monitoring.
Improvements in ship designs can also contribute to CO_2 emission reduction, the main points of improvement are:

- Improvement of the bow design for less drag
- Installation of high-efficiency propellers
- Engine improvements

- Hull coating

As found by the EU Directorate-General for Climate Action, technical upgrades alone are not enough in themselves to reduce GHG emissions as the increased efficiency gained by these improvements incentivizes ships to operate at faster speeds and thus counterbalances the environmental benefits.

Table 3 - Projected Impact of Measures on 2030 GHG emissions

Measure	Impact on 2030 annual CO_2 emissions relative to BAU
Strengthening the SEEMP: mandatory goal setting	0-2%
Strengthening the SEEMP: mandatory periodic efficiency assessment	0-2%
Strengthening the EEDI for new ships	1-3%
Strengthening the SEEMP: mandatory retrofits of cost-effective technologies	2-4%
Existing Fleet Improvement Programme	2-4%
Applying the EEDI to existing ships	1-6%
Operational efficiency standards: AER 20% below 2008	5%
Speed reduction: cap average speed at 2012 level	13%
Required to meet the 2030 level of ambition on the CO_2 intensity	**21%**
Operational efficiency standards: AER 40% below 2008	21%
Speed reduction: cap average speed at 20% below 2012 level	24-34%
Operational efficiency standards: AER 60% below 2008	43%

Source: EU Directorate-General for Climate Action Report (2019)

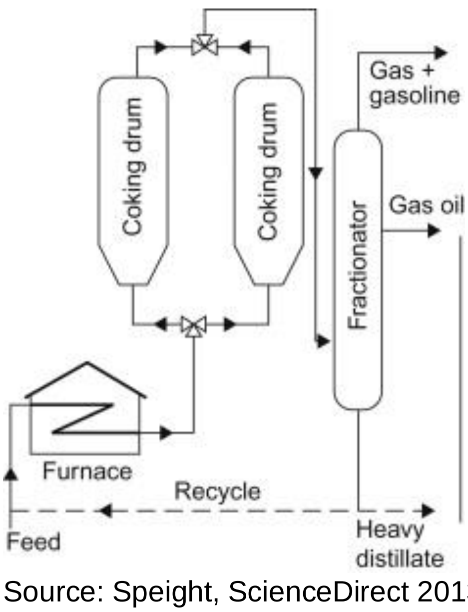
The recommendations for speed reduction by the EU commission could impair the profitability of scrubber systems if they become regulations enforced in the coming years. An important argument for scrubber installation is the possibility for ship operators to navigate vessels at higher speeds at the same cost as ships that are using VLSFO at slower speeds.

As indicated in the EU report (2019), one of the difficulties in implementing vessel improvements incentives, is that the shipowner is the one who bears the cost while it is often the operator that benefits from fuel savings. An interesting proposition is put forward in the report whereby each vessel would act as its own entity and would pay a tax based on the amount of fuel that it had consumed during the year. The collected tax would be invested in green bonds and the shipowner could recover these funds to improve the energy efficiency of his vessel.

12. Implications for the supply of VLSFO

Before IMO 2020 implementation of amendments to Annex VI, a large part of the residuals of the oil refining process were used as bunkers. The move away from HSFO by the maritime industry is requiring oil refining companies to invest in more complex processing units to remove Sulfur. One of the most common methods of refining residual oil is called coking (Speight, 2013). Coking involves heating the feedstock for longer or at higher temperatures compared to the refining process of lighter and sweeter feeds. In what is known as delayed coking, heavy feeds are heated between 480°C and 515°C and sent into a pressurized coking drum where it remains for approximately 24H. The process results in the deposit of a residue called coke on the walls of the coking drum, higher value oil products are passed onto a fractionator. The coke that is left in the coking drum contains a large part of the Sulfur of the feed that was processed. After the 24h the coking drum is cooled, and the coke is removed from the coking drum. There are then 2 main applications for the petroleum coke that is produced it can be used by coal power plants or used as an additive in the steel fabrication process (A Boateng, 2016).
Coal power plants mix the petroleum coke with coal and fire them in their furnaces. Coal power plants themselves are equipped with efficient scrubber systems to remove Sulfur from emissions.

Figure 6 - Diagram of delayed coking process



Source: Speight, ScienceDirect 2013

Installing a coker represents a big investment for refining companies in fact a coker with an output of 40 thousand b/d costs approximately $1 billion (Ramberg, 2014). Oil refiners will only have the incentive to invest in more coking capacity if there is high price differential between HSFO and LSFO. The global coking capacity of refiners was the big question leading up to 2020. The Covid-19 pandemic has postponed the demand spike for coking capacity. When oil demand returns to pre-pandemic levels, coking capacity will play a significant role in the price differential between LSFO and HSFO.

13. Oil tanker insight

In their October 2019 presentation to investors, Scorpio Tankers Inc company stated that they operated the largest fleet of tankers equipped with scrubbers in the world. At the time of their presentation, the company owned 65 vessels equipped with scrubbers and planned to have a total of 114 scrubber equipped vessels by Q2 2020 out of a total of 128 owned vessels [7]. The expected spread between HSFO and VLSFO was based on the Rotterdam forward curves, in October 2019 the spread was between $200-$250 per metric ton throughout 2020 and maintained a spread above $180 through to 2024.
The Scorpio fleet of scrubber equipped vessels is composed of Medium Range (MR) vessels that all have a Deadweight tonnage (Dwt) of around 50’000, Long Range 1 (LR1) vessels with Dwt around 74’000, and Long Range 2 vessels with Dwt around 110’000.

In their presentation to investors, Scorpio Tankers Inc assumed an average spread of $200 of high-low bunker prices in their calculations and arrived at an annual saving of $908K for MRs, $1’017K for LR1s, and $1’221K for LR2s.

The average cost of installing a scrubber is $2 million for medium sized vessels (Ship and Bunker.com 2018), as of mid-February 2020 Scorpio reported a TCE premium for the start of the quarter of $5’400/day for LR1s, $5’300/day for LR2s, and $2’800/day for MRs1[2]. Assuming a 60% “at sea” rate, this translates to a payback period of 20.6 months for LR1s, 20.9 months for LR2s, and 39.7 months for MRs. At the time this article was published, VLSFO was traded at $564 on a global average and IFO 380 at $385 (quotes 17 Feb 20)

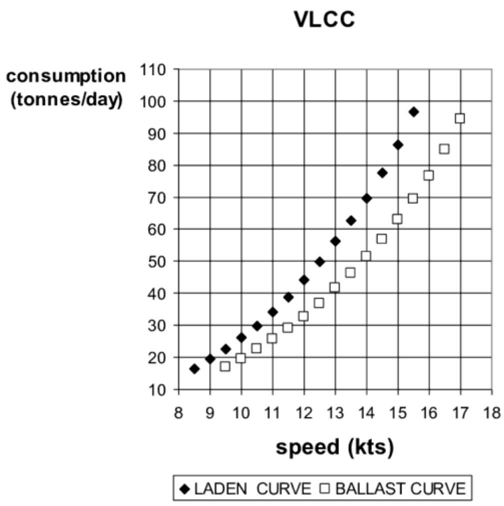
1 MR 35K-60K DWT, LR1 55K-79K DWT, LR2 80K-159K DWT

(Ship & Bunker.com, 2020), this equates to a spread of $179 from collected data on the Ship&Bunker.com website while the Platts quote cited in the article gives a spread of $154.

Considering the TCE premiums cited above, we can notice higher premiums for larger ships although there is a discrepancy between LR1's and LR2's this can be attributed to higher demand for LR1's during this period. The scrubber manufacturer PacificGreen Technologies states on the company website that Very Large Crude Carriers (VLCCs) [2] equipped with scrubbers earned a premium of $16'700/day on average in the month of December 2019 when the high-low Sulphur bunker spread was above $285 in some ports.

Fuel consumption accounts for a large portion of operational costs in the shipping industry. The speed of a vessel has significant impact on the amount of bunker fuel that is consumed in a voyage, shipowners need to calculate the optimal speed of vessels taking into account current bunkers prices at the ports they will travel to and balance this against the current freight rates. The laden bunker consumption of recent VLCCs as illustrated in figure [ ], at 9 knots is approximately 20 tonnes per day, 10 knots = 25 tonnes/day, 11 knots = 34 tonnes/day, 12 knots = 43 tonnes/day, 13 knots = 56 tonnes/day, 14 knots = 70 tonnes/day, 15 knots = 86 tonnes/day (Gkonis, Psaraftis 2013).

Figure 7 – Consumption curves of VLCC's depending on speed



Source: Gkonis & Psaraftis 2013

2 VLCC 150-320 DWT

Argus published an article in December 2019 by Nicholas Watt stating that installation of scrubbers on VLCCs costs approximately $6.6 million including lost revenue due to the dry-docking period of 40 days. Watt assumes that the consumption of a VLCC is 70 tonnes/day at 13 knots. With the average January spread of $234/MT and a 60% coefficient of 13 knots to factor in port time, idle time, and ballast speed, it is possible to calculate a rough estimate of the payback period: $((6'600'000 \div (70 \times 234)) \div 60\% = 672$ days or 22.4 months, the estimation is obtained by dividing the scrubber investment cost by the daily consumption at 13 knots multiplied by the price differential and the result divided by the coefficient of time spent at 13 knots.

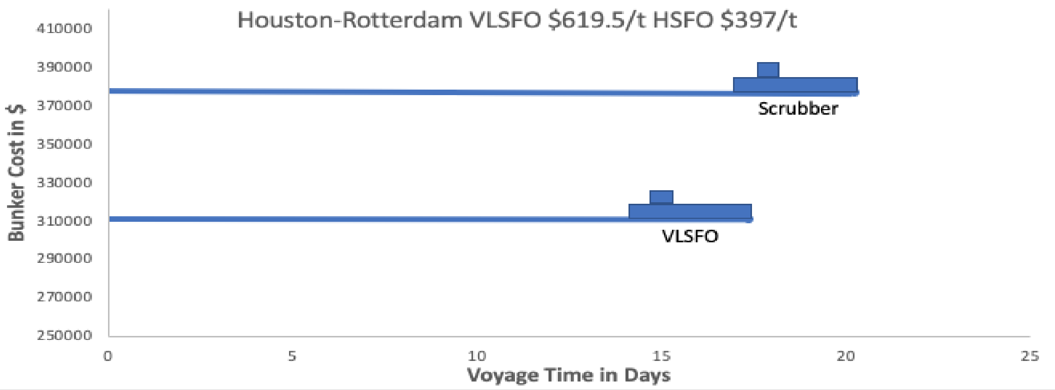
Sandy Fielden in her research published by the MorningStar in March 2019 put forward a much different payback calculation. In her research Fielden puts forward a scrubber installation cost of $2.5 million, this does not appear to include lost revenue from dry-docking during installation. This research includes a more detailed calculation of fuel consumption that takes into account laden time, ballast time, idle time, charging time, and discharging time. The calculation differs from that of Nicholas Watt in terms of consumption when laden, Fielden assumes a consumption of 70 tonnes/day at 15 knots, while Watt assumes the same consumption at 13 knots. Fielden's assumptions resulted in a VLCC scrubber payback of less than 1 year at a high-low Sulphur spread of $180, 2 years at a spread of $65, and 3 years at a spread around $42.

From the sample of collected data from the Marine Traffic website the calculated average speed of VLCCs during the period 16th of February to 16th of March was 12.1 knots for vessels fitted with scrubbers and 10.4 knots for vessels running on compliant fuel. From the Gkonis & Psaraftis study we can see that these speeds translate to approximately a 15 tonnes a day difference in bunker consumption. At 10.4 knots the consumption of VLSFO is around 30 tonnes/day and at 12.1 knots the consumption of HSFO for scrubber vessels is around 45 t/d.

By considering a specific voyage Houston, USA to Rotterdam, Netherlands and by using the online tool available on the website, sea-distances.org, the direct voyage is shown to be of 5052 nautical miles and takes 20.25 days sailing at 10.4 knots and 17.4 days at 12.1 knots. The time difference for VLCCs travelling at these two average speeds is 2.85 days for the Houston-Rotterdam voyage.

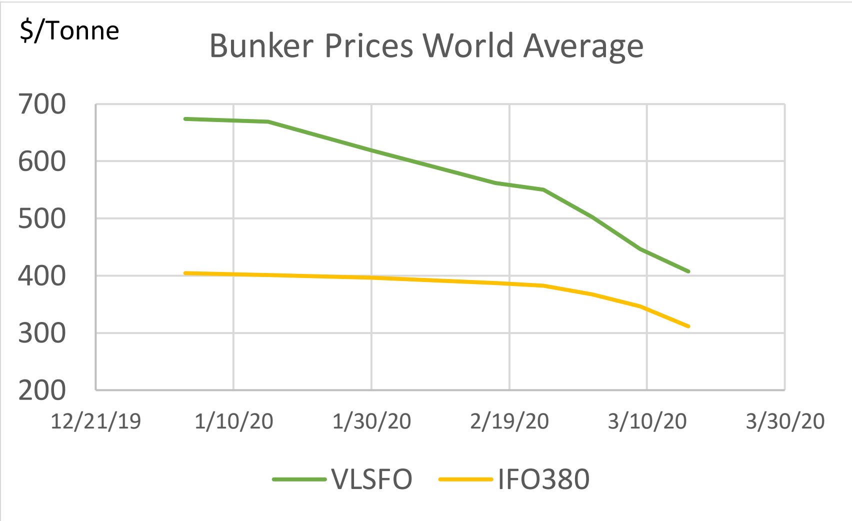
Scrubber installed vessels would consume: $17.4d \times 45t = 783\ tonnes$, and compliant fuel vessels would consume $20.25d \times 30t = 607.5\ tonnes$. On the 30th of January 2020 VLSFO was traded on a global average of $619.5/t and IFO380 at $397/t giving a spread of $222.5. Bunker costs for the Huston-Rotterdam voyage for ships having purchased at these prices and travelling at these average speeds, would have been: $376’346 for compliant fuel vessels and $310’851 for scrubber installed vessels. Scrubber vessels in these conditions therefore complete the voyage almost 3 days faster as well as save over $65k in bunker costs.

Figure 8 – Visual representation of voyage cost and voyage time for a Huston – Rotterdam leg for a VLCC at a spread of $222.5/mt VLSFO to HSFO



As illustrated in the chart below, the spread between VLSFO and HSFO has greatly reduced since the start of 2020. At the beginning of January, the spread was $269.5/mt and by the 16th of March it had narrowed down to $96/mt. With the March 16th bunker prices, the Huston-Rotterdam voyage would cost $247’556 for compliant fuel vessels and $243’904 for scrubber vessels. The bunker cost savings in these conditions is reduced to $3.6K compared to the $65K at a spread of $222.5/mt.

Figure 9 – Spread reduction between VLSFO and HSFO during Q1 2020



Source of data: Ship&Bunker.com

14. Dry bulk carrier insight

In the dry bulk market, Eagle Bulk Shipping Inc company made similar calculations to Scorpio Tankers Inc, according to Eagle Bulk's presentation to investors in October 2018. The cost of installing scrubbers was estimated to be 2 million per vessel (Eagle Bulk, 2018). The Eagle Bulk fleet can be described as "large MRs or small LR1s" with all vessels in the range of Dwt 50K-63K.

Eagle Bulk's business case for scrubbers included an analysis of optimal speeds of vessels operating at the forecasted prices. The optimal speed for a vessel consuming bunker fuel at $650/mt was considered to be 12 knots while at $400/mt it was calculated to be 12.5 knots. Eagle Bulk's projection was that the slower steaming speed of world fleet would lead to a reduced global supply and would therefore also lead to higher rates of hire.
Of their owned fleet of 50 vessels, Eagle Bulk had firm orders to install 19 vessels with scrubbers prior to the 1st of January 2020 and an option to install another 18 after this date. The pay-back period calculated by Eagle Bulk under various price spread scenarios was: 3.9 years at a spread of $100, 2.1 years at a sp. of $200, 1.4 years at a sp. Of $300. This calculation is consistent with the one presented by Scorpio in the tanker market. Both

companies put forward a scrubber installation cost of $2 million per vessel on LR1s. Scorpio estimated the bunker cost savings to be roughly $1 million per year at a spread of $200/mt and Eagle Bulk estimated the payback to be 2.1 years at the same spread level and a market condition of time charter of $12'000/day.

The calculated payback periods do not take into account the NPV of future cash savings and are therefore a rather optimistic projection aimed at investors. The Weighted Average Cost of Capital (WACC) of Eagle Bulk is estimated to be around 11% (Finbox.com, 2020), and the average cost of installing a scrubber has turned out to be 2.2 million according to Eagle Bulk's 2019 Financial statement. Considering this cost of capital, and the revised scrubber initial investment, the adjusted payback period is summarized below under 3 scenarios.

The WACC discounting calculation takes into account the present value of scrubber investments and future savings/earnings that are discounted taking into account interest rates and shareholder expected returns

In the following table that was presented by Eagle Bulk to investors in 2018, we can see a summary of the expected payback periods according to LSFO/HSFO spreads.

Table 4 – Presentation of scrubber payback periods depending on VLSFO/HSFO spread by Eagle Bulk Inc to investors 2018

Compelling financials

- USD 2.0 million investment per ship
- 12,000 USD/day market environment
- Fuel spreads as per below

Short pay-back period

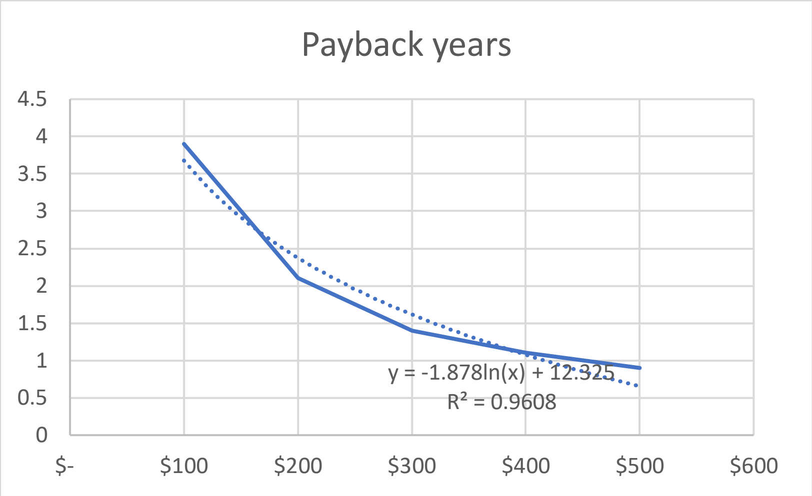
100 USD	200 USD	300 USD	400 USD	500 USD
3.9 yr	2.1 yr	1.4 yr	1.1 yr	0.9 yr

Source: Eagle Bulk presentation to investors October 218

15. Payback Analysis

For further analysis, the information of projected payback periods presented by Eagle Bulk Inc was entered into Microsoft Excel ® in order to obtain a trendline that would allow for the extrapolation of pay-back periods outside of projected spread levels.

Figure 10 – Graph of payback period according to Eagle Bulk Inc 2018 presentation with a line of best fit and equation



From the presented spreads and projected payback periods, a linear regression gives a line of best fit $y = -1.878\ln(x) + 12.325$ with an R^2 of 0.96. Where x is the spread and y the payback period.

By extrapolating this line of best fit below $100/mt, we can assess spreads that were not foreseen in 2018.

Table 5 gives us the extrapolated payback periods for spreads under $100/mt.

Table 5 – Scrubber payback periods with extrapolated values under $100/mt

Spread $/mt	Payback years	Savings/year
$ 40	5.4	$ 272'838
$ 50	5.0	$ 315'684
$ 60	4.6	$ 358'530
$ 70	4.3	$ 401'376
$ 90	3.9	$ 486'640
$ 100	3.9	$ 512'821
$ 200	2.1	$ 952'381
$ 300	1.4	$ 1'428'571
$ 400	1.1	$ 1'818'182
$ 500	0.9	$ 2'222'222

Further adjustments to the 2018 payback projections must also include the 10% higher cost of scrubbers and discounted savings by the WACC. Below are the results of adjusted payback periods for Eagle Bulk Inc under 3 scenarios of spread levels of $200/mt, $100/mt, and $50/mt with a Weighted Average Cost of Capital of 11%.

Spread VLSFO-HSFO of $200/mt

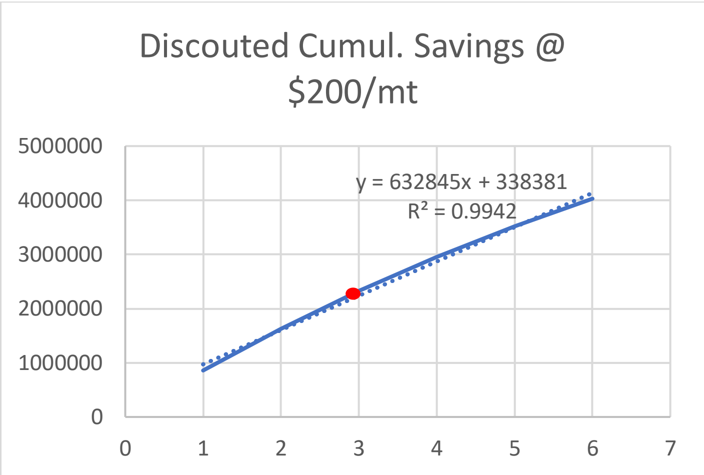
- Investment = $2.2 million
- WACC = 11%
- Discounted savings = $Savings_1 \div (1+11\%) + Savings_2 \div (1+11\%)^2 + Savings_n \div (1+11\%)^n$

  Where $Savings_1$ are the savings in the first year, $Savings_2$ the savings in the second year, and $Savings_n$ a representation of the repetition of the savings for each of the following years.

  The savings/cash flows of each year are discounted by the WACC rate raised to exponent of the corresponding the year.

- Σ discounted savings = scrubber investment $\rightarrow$ **2.9years**

Figure 11 – Discounted savings at a spread of $200/mt and a WACC of 11%



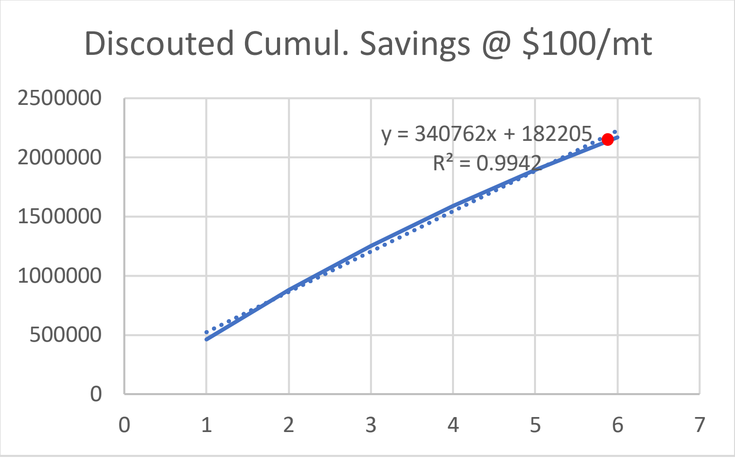
At a spread of $200 the payback period for a scrubber investment of $2.2 mio is 2.9 years compared to the 2.1 years initially presented to investors. The difference is due to the higher cost of investment and the discounted cost of capital.

Spread VLSFO-HSFO of $100/mt

- Investment = $2.2 million

- Σ discounted savings = scrubber investment $\rightarrow$ **5.9years**

Figure 12 – Discounted savings at a spread of $100/mt and a WACC of 11%



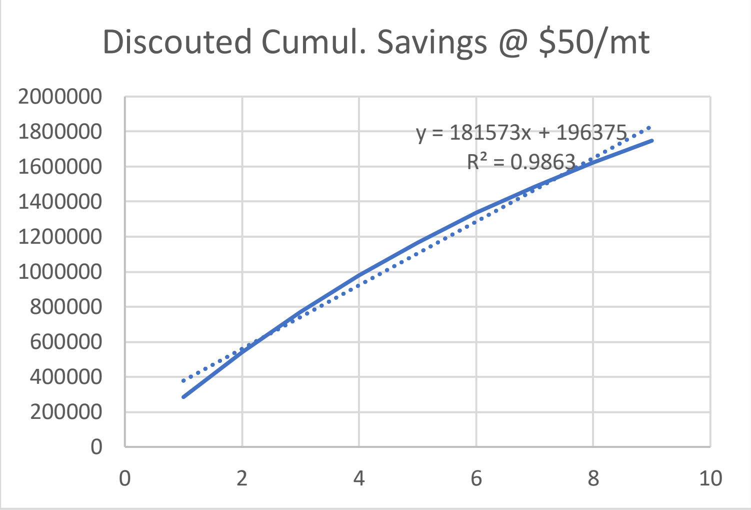
At a spread of $100/mt the payback period extends significantly to 5.9 years compared to the projected 3.9 years.

Spread VLSFO-HSFO of $50/mt

- Investment = $2.2 million
- WACC = 11%
- Discounted savings = $Savings_1 \div (1+11\%) + Savings_2 \div (1+11\%)^2 + Savings_n \div (1+11\%)^n$

- $\Sigma \text{discounted savings} = \text{scrubber investment} \ \rightarrow \mathbf{11 years}$

Figure 13 – Discounted savings at a spread of $50/mt and a WACC of 11%



At a $50/MT spread, the payback period extends to 11, years this timeframe becomes excessive for an unproven technology considering that the average age of 8.7 years for Eagle

Bulk's fleet and the fact that most vessels are sent to demolition after 20 years, a discounted payback period of 11 years does not make economic sense for older vessels if the VLSFO-HSFO spread narrows to $50/mt.

16. Collected vessel speed data analysis

In order to verify and measure the hypothesis that vessels equipped with scrubbers would be operated at faster speeds to obtain a better return on investment, a sample of 90 relevant vessels was selected. The vessels details were collected into a dataset, between the months of February and May 2020, the average speed on of each vessel was recorded on 7 occasions. The average speed was collected from publicly available information on the Marine Traffic ® website, this organization is considered to be a leading company in marine information. Vessel speed information is measured through the Automatic Information System (AIS), a system originally developed to avoid the collision of vessels by making vessels highly visible on radar, the technology has been further developed to track vessels around the world through a combination of onshore Very High Frequency (VHF) receivers as well as the development of satellites capable of tracking the signals of vessels equipped the AIS system. Commercial vessels of more than 300 Dwt are required through the International Maritime Organization to be equipped with the AIS system.

The sample of vessels was selected by investigating company reports and press releases to identify vessels that were equipped with scrubbers and those that were not in order to have a balanced representation of scrubber and non-scrubber vessels in the sample.

Figure 14 - Example of a vessel speed reading (20.08.2020)

Source: Marine Traffic

Table 6 - Recorded Average Speeds for the Dublin Eagle during observation period

VESSEL	Scubber	16.02 Av. Sp	18.02 Av. Sp	23.02 Av. Sp	01.03 Av. Sp	08.03 Av. Sp	16.03 Av. Sp	11.05 Av. Sp
Dublin Eagle	Yes	9.5	9.7	11.1	9.6	9.6	11.2	9.6

Sample description by vessel category:

14 Ultramax vessels, average DWT 63'170, bulk carriers.

- 8 vessels equipped with scrubbers, average year built 2015, owned by Eagle Bulk.
- 6 vessels not equipped with scrubbers, average year built 2015, owned by Genco.

14 Suezmax vessels, average DWT 155'774, crude oil tankers / tankers.

- 7 vessels equipped with scrubbers, average year built 2016, owned by Frontline / SFL.
- 7 vessels not equipped with scrubbers, average year built 2010, owned by Nordic American Tankers.

18 Capesize vessels, average DWT 178'404, bulk carriers.

- 7 vessels equipped with scrubbers, average year built 2011, owned by Star Bulk / SFL.
- 11 vessels not equipped with scrubbers, average year built 2011, owned by Berge Bulk / Navios.

19 Newcastelmax vessels, average DWT 208'251, bulk carriers.

- 12 vessels equipped with scrubbers, average year built 2016, owned by Star Bulk.
- 7 vessels not equipped with scrubbers, average year built 2012, owned by Berge Bulk.

25 Very Large Crude Carriers (VLCCs) average DWT 308'539, crude tankers

- 15 vessels equipped with scrubbers, average year built 2013, owned by Frontline, Kyoei, DHT.
- 10 vessels not equipped with scrubbers, average year built 2013, owned by Euronav, Kyoei.

The average speeds of these vessels were recorded on 7 occasions between the months of February and May 2020. The results of these observations are summarized in the table below.

Table 7 – Average difference of speed (knots) between scrubber and non-scrubber fitted vessels according to size during observation period

Period 16.02-11.05	Ultramax		Suezmax		Capesize		Newcastlemax		VLCC
	Av. Speed		Av. Speed		Av. Speed		Av. Speed		
With Scrubber	10.8		11.3		10.5		10.3		12.1
No Scrubber	9.8		10.2		9.5		8.6		10.4
Speed diff.	1.0		1.2		0.9		1.7		1.8

During the observed period, the sample of vessels equipped with scrubbers did in fact operate at higher average speeds compared to their counterparts not fitted with scrubbers in all size categories. Average speed differential was 1.3 knots for all categories which represents an overall higher speed of 11.9% for scrubber fitted vessels. The largest speed differential was observed in Newcastlemax and VLCC segments. Larger vessels are capable of higher top speeds and their daily fuel consumption increases with size. It makes sense for larger vessels equipped with scrubbers to have higher speed differentials. Without taking into account bunker costs, a VLCC's optimal laden speed is 15.9 knots where the engine is at 90% load. Under these conditions, the bunker consumption is of 92 tons/day (Walh, Kristofferson, 2012). For comparison, a vessel in the Ultramax category that is approximately a fifth of the size compared to a VLCC and has a designed optimal speed of 13 knots and a daily fuel consumption of approximately 30 tonnes/day (Doskocz, 2012).

Table 8 – Normal speed vs "Eco" speed and related bunker consumption for a selection of vessel sizes

Table 2. The main parameters of the analyzed ships

Type	Number of ships	DWT	'Normal' speed	'Normal' consumption	'Eco' speed	'Eco' consumption
Handy 1	3	26,300	12.7	20.0	11.8	18.0
Handy 2	6	33,700	12.5	22.5	11.0	19.5
Panamax	6	73,400	13.4	33.0	12.0	26.5
Kamsarmax	4	79,600	13.8	38.2	12.2	31.2

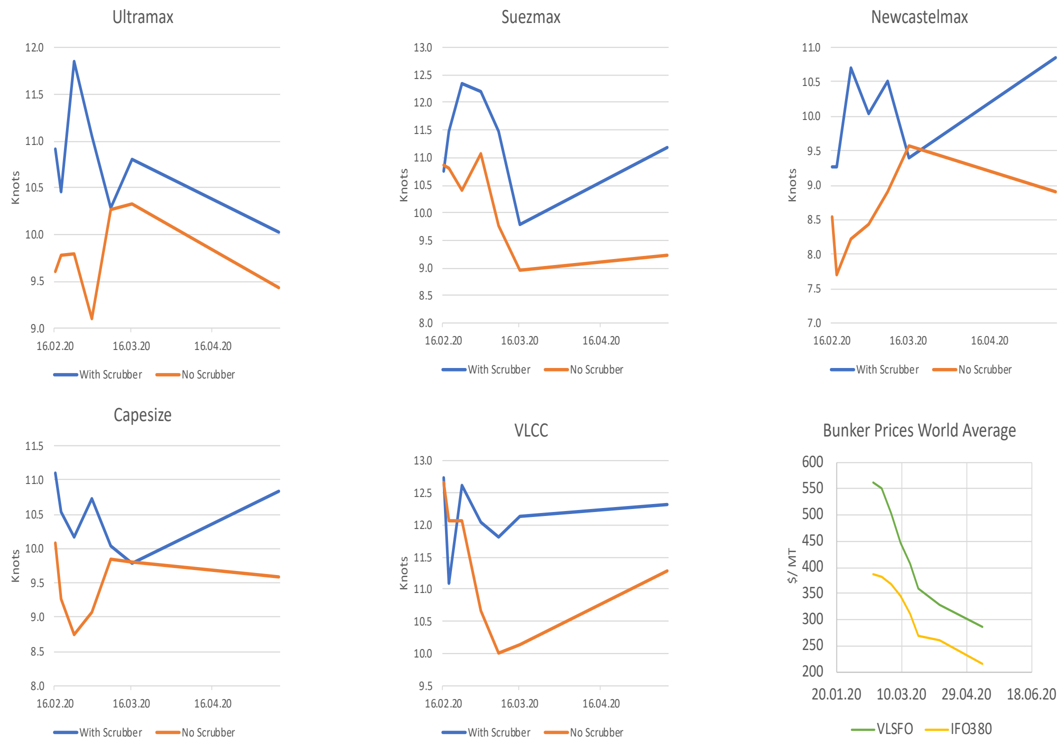
Speed in knots (nautical mile per hour). Consumption in metric tonnes per day.

Source: Doskocz, 2012

16.1 Recorded Speed of Sampled Vessels by Size Category

Figure 15 gives a visual representation of recorded vessel speeds that were recorded during the period of observation. It is interesting to note the general higher speeds of scrubber fitted vessels compared to non-scrubber fitted vessels. Figure 15 also illustrates the drastic fall in bunker prices that is attributed to the global Covid-19 crisis.

Figure 15 - Measured average speed of vessels by size category with a comparison to average global bunker prices



The graphs seem to indicate a relationship between average vessel speeds and the spread of HSFO-VLSFO. Vessels equipped with scrubbers operated at higher speed compared to vessels that operated on VLSFO. In February when the spread was above $150 per metric tonne, Ultramax and Newcastelmax vessels were operating at a 2 knots speed difference for scrubber and non-scrubber fitted vessels. As discussed in the Tanker insight section, this speed difference represents approximately 3 days for a Houston-Rotterdam voyage. Arriving 3 days sooner on a 20-day leg represents a time reduction of 15%. Under these conditions' shipowners can thus charge a premium equivalent to the reduced chartering time.

Considering the stated daily outperformance of $1'724 of Eagle Bulk in Q1 2020 and the market conditions at the time when the contracts would have been concluded in December or January where daily rates for Ultramax vessels were between $10'250/day and $11'000/day, we can see that their outperformance is roughly equivalent to a 15% premium on non-scrubber daily rates. On a side note, the fleet of Eagle Bulk is roughly 2% larger than the reference Ultramax size of 62'000 dwt at around 63'400 dwt and the company can naturally command a higher price equivalent to this size difference.

Table 9 - Index of daily rates mid-December 2019 for mid length fixtures

ALIBRA Shipping Limited

Updated Wednesday 18 December 2019

·Please contact us for rates/charts on scrubbers and eco tonnage.

DRY TIME CHARTER ESTIMATES ($/pdpr)

SIZE	6 MOS		1 YR		2 YR	
PERIOD	ATL	PAC	ATL	PAC	ATL	PAC
HANDY (32k dwt)	8,000	7,750	8,000	7,500	10,500	10,000
SUPRA (56k dwt)	10,500	10,250	10,500	10,000	11,250	11,000
ULTRA (62k dwt)	11,000	9,750	10,750	10,250	11,500	11,750
PANA/KMAX (76k-82k dwt)	14,750	11,750	12,250	11,750	11,875	11,625
CAPE (170k dwt)	18,500	18,000	17,500	17,000	16,500	16,000

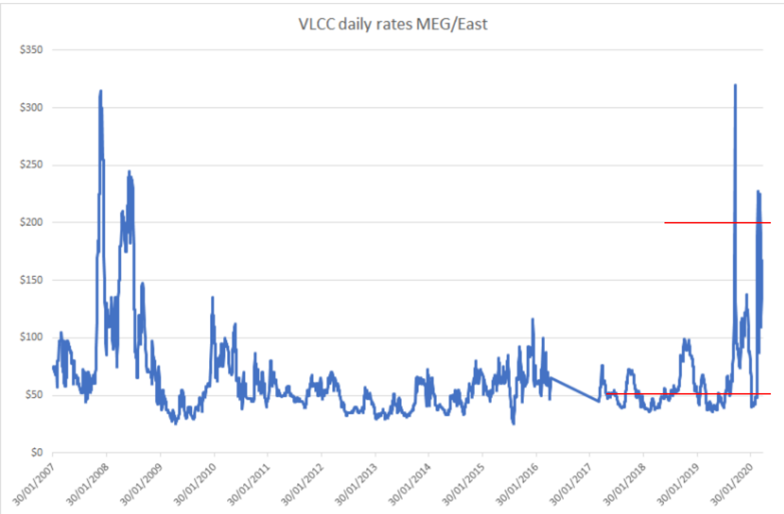
Source: Hellenic Shipping News

Discrepancy in pattern for VLCCs

The observed VLCCs followed a different pattern when compared with the other vessel categories at the start of observations mid-February. Oil tanker demand and freight rates responded in a unique way under specific market conditions. At the start of February 2020, the oil market entered into a contango, meaning that the price on the futures market was higher than the spot price and had upward trend for further months. This situation arises when there is a temporary oversupply of oil on the market and it is expected that demand will recover after a market shock. The Coronavirus pandemic that began in China resulted in much lower demand for oil because of travel restrictions and lockdowns (Dunford et al.,2020). As the pandemic was taking hold, OPEC+ member states failed to reach an agreement on output reductions. Oil prices in Q1 2020 dropped to historical lows due to oversupply and lack of demand.

When the forward curve of futures contract prices steepens the market enters a “super contango”. This super contango situation only occurs when there is an important shock to the market. Prior super contangos occurred in 2008 amidst the financial crisis and then in 2015 when the shale oil boom disrupted the market structure. A characteristic of the oil market is the streamlined nature of this industry with low levels of storage capacity compared to global consumption. Oil traders can benefit from a super contango if they have the ability to secure storage, purchase the physical product, and then sell futures contacts at a higher price. During super contangos, traders will hire VLCCs as storage facilities and might order the vessels to sit idle or travel at extra slow speeds because they are essentially serving a storage purpose. The demand for VLCCs greatly increased during the first months of 2020 and the daily spot rate of VLCCs surged to levels not seen since the 2008 super contango, going from levels around $50’000 per day and skyrocketing past $200’000 a day on some occasions.

Figure 16 - Daily spot rates for VLCCs for Middle East to Asia Route



Source: IG bank

Because of the phenomenon of oil tankers being used as storage, the February discrepancy of non-scrubber fitted VLCCs travelling at higher average speeds compared to equipped VLCCs can be explained. The limited sample size of observed vessels may have contained a disproportionate number of scrubber-equipped vessels that were being hired as floating storage. When the oil futures contracts expired at the end of February and the physical oil had to be delivered, VLCCs responded by operating at speeds that were better suited for bunker cost optimization. Even though the spread of HSFO-VLSFO had narrowed to below $100 in March, Scrubber equipped VLCCs were travelling faster by up to two knots compared to VLCCs operating on VLSFO.

The other vessel categories responded differently to the narrowing of the bunker spread. Dry bulk carriers Utramax, Newcastelmax, Capesize in the sample saw their speeds converge for scrubber and non-scrubber vessels around the 16th of March when the spread fell below $100/mt and VLSFO was down to $408/mt from prices above $550/mt a month earlier.

A cost analysis for Ultramax vessels that had the same average speed of 10.3 knots measured on the 8th of March will follow. Going back to our example route Houston-Rotterdam of 5052 nautical miles, vessels moving at 10.3 knots complete the voyage in 20.4 days. On the 8th of March the bunker spread was $100 with average bunker prices for HSFO at $347 and VLSFO at $447. Assuming that the speed/consumption curve is similar to that of VLCCs presented by Gkonis & Psaraftis (fig 1) and that the 90% engine load speed of Ultramax vessels is 13 knots compared to the 15 knots of VLCCs. A speed reduction from 13 knots down to 10.3 knots represents a decrease in speed of 21%. A speed reduction of 21% for VLCCs from 15 knots to 11.9 knots leads to a reduction of daily bunker consumption of 52.5% from 86 mt/d to 41 mt/d. Applying this to Ultramax vessels that consume 30 mt/d at 13 knots, bunker consumption reduced by 52.5% results in a consumption 14.25 mt/d.

The Houston-Rotterdam voyage of 20.4 days would cost a scrubber equipped vessel $100’873 for bunkers purchased at $347. Vessels not equipped with scrubbers would incur bunker costs of $129’943 for this voyage.

Average charter rates for a 6-month contract in December for Ultramax vessels were $11’000 per day in the Atlantic. If a charterer had contracted at this time and was paying a 15% premium for a scrubber fitted vessel, the daily cost would be $12’650. The total voyage cost of the vessel and bunkers would be $358’933 for an Ultramax with a scrubber and $354’343 for an Ultramax with no scrubber.

In this example we assumed a time charter premium of 15% for scrubber fitted vessels, this would be reasonable for vessels contracted in December 2019 when the bunker VLSFO-HSFO differential was around $300/mt. For contracts signed mid-February 2020, shipowners would command a much lower premium otherwise there would be no cost benefit for the charterer.

It is important to note that at the time when dry bulk scrubber fitted vessels and non-fitted vessel speeds converged, many countries around the world were closing their borders and imposing lockdowns due to the Coronavirus pandemic (Dunford et al., 2020). Because of the sanitary measures imposed by governments, the world economy came to halt in many sectors. Factories, mines, construction sites, stores around the world were forced to temporarily shut down to slow the spread of the novel virus. This sanitary crisis severely affected both supply and demand of commodities on a global scale.

17. Bunker Price Projections for the Years 2020-2030

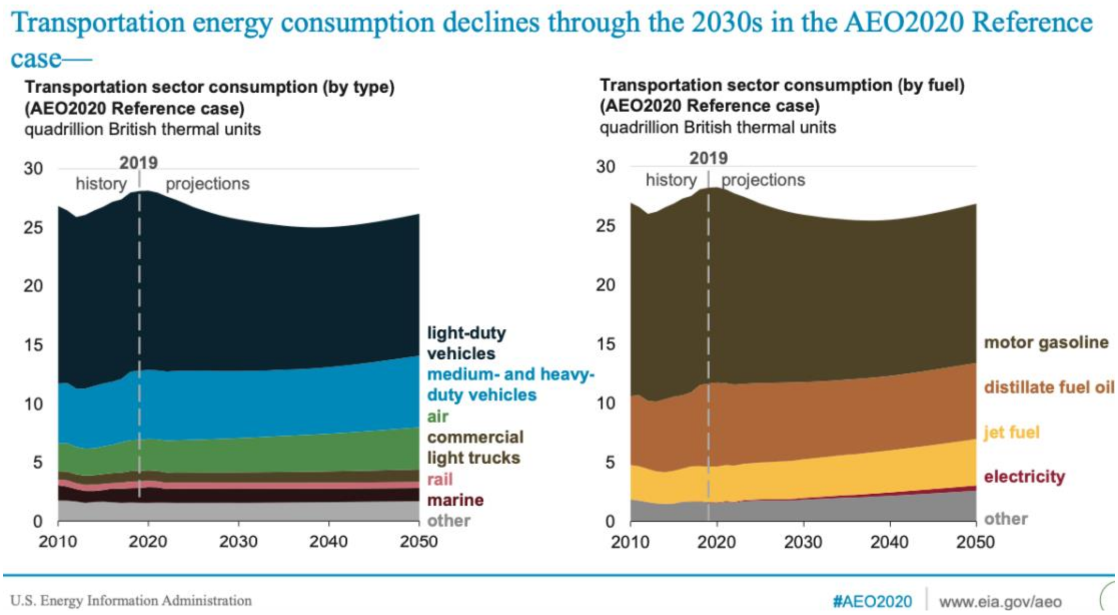
Forecasts are by definition an inexact estimation of future conditions, no one could have predicted the Covid-19 crisis and the devastating effects on the economy. Nevertheless, rational business decisions can hardly be based on anything other than current trends and projected future developments. Bunkers, being petroleum products, have their prices highly correlated to the supply and demand of crude oil.

The International Energy Agency (IEA) reports, are a world reference for oil market developments. In their July 2020 report, the IEA presented the figures of the effects of the pandemic. In the first half of 2020 oil demand fell by 10.75% from 100 million barrels per day (mb/d) to 89.25 mb/d. On the supply side OPEC+ countries have complied to cut production to levels that have balanced the market and stabilized the price of the Brent benchmark around $40 per barrel.

Analysts from the American investment bank Goldman Sachs are quoted in a July 2020 CNBC article as forecasting that oil demand will recover to pre-pandemic levels by 2022 (Meredith, 2020). The analysts predict that gasoline demand will recover first driven by a preference for personal vehicles to protect against the virus. Diesel demand is predicted to recover by 2021 after gasoline. In figure 17 we can see a representation of the ratio of energy consumption by transportation type as of 2019 with projections up to 2050 presented by the U.S. Energy Information Administration (EIA). Because gasoline used for light vehicles (i.e. cars) accounts for over half of transportation energy demand, the projected increase in gasoline demand due to Covid-19 will drive up the prices for more refined oil products.

The price difference between lesser refined HSFO bunkers and VLSFO will likely increase up until 2022. The latest Goldman Sachs analyst projections also contradict the 2019 EIA projections shown in figure 17 in terms of when oil demand will peak, in 2019 EIA projected that oil demand would peak around 2020, at the time of writing, Goldman Sachs analysts now propose that oil demand will peak no sooner than 2030.

Figure 17 - Energy demand by transportation type and energy source 2010-2050



Source: IEA 2019 World Energy Outlook

18. Unsuccessful models for explaining vessel speed

Several basic models were tested to explain the variations in vessel speed as a function of bunker costs, TCE rates, and vessel size. The hypothesis was that shipowners and charterers would have hedged/purchased their bunkers a month prior to the date on which the average speed was recorded, charter rates and the size of ships would be statistically significant to explain recorded speeds. After removing the anomaly of scrubber and non-scrubber vessels having their speeds converge on the 16th on March 2020 due to the assumption that it resulted from momentary of border closures, lockdowns and sanitary measures, no satisfactory model was obtained.

Even the rudimentary assumption that larger vessels with higher design speeds would operate faster than smaller vessels proved to be wrong during this period. In fact, in the dry bulk segment, the smallest Ultramax vessels of dwt 63'170 operated 0.8 knots faster than Newcastelmax vessels of dwt 208'251. The only significant variable influencing vessel speed was whether or not a scrubber was installed. A relationship between vessel speed, bunker costs, and charter rates was not established.

An OLS regression performed on Newcastelmax vessels with recorded speed as dependent variable, IFO380 price and the spread level between IFO 380 and VLSFO has shown no statistically significant relationship between bunker prices and recorded speed. The scrubber dummy variable is significant at a confidence level of 99%. The spread between HSFO and VLSFO is significant at a confidence level of 90%. Bunker price during the observed period, whether on the day or the month prior was a poor indicator of vessel speed.

Table 10 - OLS regression output for Newcastlemax collected data: vessel speed set as dependent variable, scrubber installation set as independent dummy variable, price of HSFO (IFO380 on the day) as independent variable and spread of HSFO to LSFO as independent variable.

```
. reg speed ifo380otd scrubber spread

      Source |       SS           df       MS      Number of obs   =        12
-------------+----------------------------------   F(3, 8)         =     17.73
       Model |  10.1715966         3  3.3905322    Prob > F        =    0.0007
    Residual |  1.53020719         8  .191275898   R-squared       =    0.8692
-------------+----------------------------------   Adj R-squared   =    0.8202
       Total |  11.7018038        11  1.06380035   Root MSE        =    .43735

------------------------------------------------------------------------------
       speed |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
   ifo380otd |   .0144086   .0092509     1.56   0.158    -.0069241    .0357412
    scrubber |   1.653334   .2525047     6.55   0.000     1.071057    2.235611
      spread |  -.0200904   .0093285    -2.15   0.063     -.041602    .0014213
       _cons |   7.340382   1.591389     4.61   0.002     3.670632    11.01013
------------------------------------------------------------------------------
```

Table 11 - Regression without the IFO380 variable

```
. reg  speed scrubber spread

      Source |       SS           df       MS      Number of obs   =        12
-------------+----------------------------------   F(2, 9)         =     21.91
       Model |  9.70758199         2    4.853791   Prob > F        =    0.0003
    Residual |  1.99422181         9  .221580201   R-squared       =    0.8296
-------------+----------------------------------   Adj R-squared   =    0.7917
       Total |  11.7018038        11  1.06380035   Root MSE        =    .47072

------------------------------------------------------------------------------
       speed |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    scrubber |   1.653334   .2717721     6.08   0.000     1.038543    2.268125
      spread |  -.0059397   .0022775    -2.61   0.028    -.0110918   -.0007875
       _cons |   9.703634   .5165024    18.79   0.000     8.535225    10.87204
------------------------------------------------------------------------------
```

For the Newcastelmax segment the predicted speed of a vessel during the observed period can be predicted at a 95% confidence level as being:

$$y = 9.704 + 1.653\beta_1 - .006\beta_2 + \epsilon$$

Where y = speed, β_1 = scrubber, β_2= spread

As is apparent in fig 15, even with a drop of bunker prices for VLSO of 50%, from $562 on the 17th of February to $286.5 on the 18th of May, there is no clear speed increase between the start of the observed period and the end. From these observations, we can say that the factor that influences vessel speed the most is whether or not they are equipped with a scrubber.

19. Effects of Covid-19 Crisis

Due to the observation period having coincided with an unprecedented market disruption, vessel speeds were likely influenced by the extraordinary circumstances. The slowdown of the global economy had a severe impact on the supply and demand of commodities. Taking copper as an example for which the price is often used as a barometer for the health of the economy, we can see in figure [18] the drastic decline in price in the month of march 2020. Copper lost almost 1/3 of its value from the start of 2020 to mid-March despite the fact that some of the largest producing countries including Chile had closed many of their mines (Mining Journal,2020).

Figure 18 - Price of Copper USD/Lbs based on OTC contracts

Source: trading economics.com

The July 10th report by the European Maritime Safety Agency presents the statistics for the year on year variation in ship calls to European ports by vessel type between weeks 15 and 27 (April-July). There was a reduction in port arrivals for all categories except chemical tankers. Bulk carriers decreased their port arrivals by -7% and oil tankers by -5% over this period.

Table 12 -Year on year variation of port calls to European ports by vessel type weeks 15-27 for years 2019 vs 2020

2019 vs 2020														
Ship type / Week	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**15-27**
Bulk carrier	-11%	-10%	-3%	-8%	-18%	-10%	-1%	-5%	-8%	-8%	4%	-7%	1%	-7%
Chemical tanker	25%	24%	16%	30%	10%	23%	17%	23%	31%	22%	27%	-4%	15%	19%
Containership	-13%	-9%	-8%	-6%	-11%	-10%	-9%	-11%	-9%	-13%	-9%	-8%	-6%	-9%
Cruise ships	-91%	-90%	-94%	-95%	-95%	-95%	-95%	-95%	-94%	-96%	-94%	-94%	-94%	-94%
General cargo	-15%	-8%	-1%	-11%	-12%	-13%	-13%	-8%	-14%	-8%	-8%	-7%	-10%	-10%
Liquified gas tanker	2%	-5%	-20%	-16%	-24%	-21%	-17%	-11%	-23%	-5%	-10%	-5%	-14%	-13%
Oil tanker	-5%	-8%	-8%	-6%	-3%	1%	-4%	-3%	-6%	-8%	-1%	-5%	-3%	-5%
Passenger	-93%	-92%	-93%	-94%	-94%	-93%	-91%	-91%	-79%	-72%	-69%	-58%	-39%	-78%
Ro-Ro passenger	-51%	-50%	-45%	-37%	-33%	-32%	-32%	-31%	-23%	-16%	-14%	-8%	-5%	-28%
Ro-Ro cargo	-28%	-27%	-8%	-18%	-14%	-16%	-14%	-10%	-16%	-15%	-11%	-12%	-8%	-15%
Vehicle carrier	-62%	-60%	-54%	-66%	-69%	-60%	-58%	-47%	-47%	-43%	-36%	-28%	-29%	-51%
Grand Total	**-32%**	**-31%**	**-28%**	**-29%**	**-28%**	**-27%**	**-28%**	**-27%**	**-26%**	**-22%**	**-19%**	**-16%**	**-13%**	**-25%**

Table 2: Evolution in number of ship calls per week for different ship types
(most affected ship types indicated in red)

Source: European Maritime Safety Agency

The Covid-19 crisis has also had the effect of limiting inspections by port authorities due to reduced staffing and a focus on sanitary measures instead of bunker compliance. The UK's Maritime and Coastguard Agency, has in fact issued a statement on April 1st, 2020 announcing that it would suspend routine inspections until the sanitary crisis had passed (Turner, 2020). Although port authorities in other countries have not officially made statements about suspended inspections, it is likely that the focus on the pandemic has diverted attention away from strict enforcement of IMO 2020 regulations and that ensuring trade flows has been the main priority. The level of bunker compliance will become clearer once the sanitary crisis has truly passed.

Singapore port authorities have stated that 96% of ships entering their port in Q1 2020 were operating on compliant fuel while the remaining 4% operated with scrubbers (Patterson, 2020). The high level of compliance in Singapore can be explained by the extremely dissuasive penalties for non-compliance. The narrow spread between HSFO and VLSFO has made scrubbers much less attractive and as many as 700 scrubber installations have been delayed or cancelled (Clarkson's, as cited by Patterson, 2020). Shipowners are waiting for the uncertainty created by Covid-19 to be lifted before they proceed with scrubber investments.

20. Conclusion

The decision to install scrubbers on vessels to comply with IMO 2020 emission regulations was set to be a profitable investment up until the Covid-19 pandemic hit the world economy. With price spreads between VLSFO and HSFO at 200$ per metric ton at the start 2020, the payback period would be 2 to 3 years for most vessels had this price difference been maintained. With a spread of 50$ per metric ton, the payback period of 11 years (for 11% WACC) appears to be to too long when considering the lifespan of the average vessel and the level of uncertainty as to the reliability and maintenance costs of scrubber systems. In this study it was apparent that vessel speed was not directly related to the cost of bunkers. The type of contract between shipowner and charterer may be the most important factor for determining the speed of vessels, this study unfortunately did not have access to this information. Further research into contract types and vessel speeds could yield recommendations on policies that incentivize the optimal speed of ships in terms of bunker consumption.

From the observed sample of vessels in this study, it appears that vessels equipped with scrubbers do in fact operate considerably faster than vessels operating on VLSFO with an average higher speed of 11.9%. Shipowners and long-term charterers are understandably attempting to amortize their investments and charter premiums. From an environmental policy perspective, higher speeds and higher bunker consumptions do not align with IMO 2030 GHG objectives.

Scrubber profitability models that favored the installation of these systems, were based on short payback periods. Due to the Covid-19 crisis, the narrow differential between VLSFO and HSFO has made scrubber investment unattractive at a spread level well below $100/mt. If the projections that oil demand will return to pre-pandemic levels by 2022 materialize, scrubbers still hold the potential to generate profits before a plausible new policy on speed reduction enters into force. VLSFO does appear to be the bunker of choice for the vast majority of the global fleet in the near future.

21. Bibliography

A BOATENG, A, 2016. Petroleum Coke - an overview | ScienceDirect Topics. In: *Rotary Kilns* [online]. Second. [Viewed 19 August 2020]. Available from: https://www.sciencedirect.com/topics/engineering/petroleum-coke

ALSGUTH, Marieke and JACKSON, Valarie, 2020. Scrubber option paying off despite dry dock delays: Scorpio Tankers | S&P Global Platts. [online]. 19 February 2020. [Viewed 19 August 2020]. Available from: https://www.spglobal.com/platts/en/market-insights/latest-news/oil/021920-scrubber-option-paying-off-despite-dry-dock-delays-scorpio-tankers

ARGUS, 2019. Q&A: IMO 2020 policing unlikely before March, 2019. [online]. [Viewed 19 June 2020]. Available from: https://www.argusmedia.com/en/news/1988274-qa-imo-2020-policing-unlikely-before-march

BRITTANIA, 2020. LIST OF JURISDICTIONS RESTRICTING OR BANNING SCRUBBER WASH WATER DISCHARGES, 2020. *Britannia* [online]. [Viewed 15 June 2020]. Available from: https://britanniapandi.com/blog/2020/01/27/list-of-jurisdictions-restricting-or-banning-scrubber-wash-water-discharges/

ČAMPARA, Leo, HASANSPAHIĆ, Nermin and VUJICIC, Srdjan, 2018. Overview of MARPOL ANNEX VI regulations for prevention of air pollution from marine diesel engines. *SHS Web of Conferences*. 1 January 2018. Vol. 58, p. 01004. DOI 10.1051/shsconf/20185801004.

CHAMBERS, Sam, October 18, 2019. Scrubber corrosion cases escalate - Splash 247, 2020. [online]. [Viewed 17 August 2020]. Available from: https://splash247.com/scrubber-corrosion-cases-escalate/

DOSKOCZ Dariusz, 2012. "Profitability of Reduction of Speed and Fuel Consumption for Sea Going Bulk Carriers," Folia Oeconomica Stetinensia, Sciendo, vol. 11(1), pages 132-139, January.

DUNFORD, Daniel, DALE, Becky, STYLIANOU, Nassos, LOWTHER, Ed, DE LA TORRES ARENAS, Ahmed and Irene, 7 April 2020. The world in lockdown in maps and charts, 2020. *BBC News* [online]. [Viewed 2 June 2020]. Available from: https://www.bbc.com/news/world-52103747

EAGLE BULK SHIPPING INC., 2018. Investor Presentation: Scrubber Initiative and Amendment Request. [online]. October 2018. Available from: https://ir.eagleships.com/static-files/c0c10603-6127-4c8c-b56a-384a95bf843b

EAGLE BULK BULK SHIPPING INC, 2020. *Eaagle Bulk 2019 Financial Report* [online]. 20 March 2020. Available from: https://ir.eagleships.com/static-files/51371c95-37d5-481a-af07-2afd26233e94

EIA, 2019. AEO2020 - Transportation. . 2019. P. 8.

ENDRES, Sonja, MAES, Frank, HOPKINS, Frances, HOUGHTON, Katherine, MÅRTENSSON, Eva M., OEFFNER, Johannes, QUACK, Birgit, SINGH, Pradeep and TURNER, David, 2018. A New Perspective at the Ship-Air-Sea-Interface: The Environmental Impacts of Exhaust Gas Scrubber Discharge. *Frontiers in Marine Science*. 2018. Vol. 5, p. 139. DOI 10.3389/fmars.2018.00139.

EU DIRECTORATE-GENERAL FOR CLIMATE ACTION, 2019. *Study on the methods and considerations for the determination of greenhouse gas emission reduction targets for international shipping* [online]. European Commission. Available from: https://u-mas.co.uk/LinkClick.aspx?fileticket=R-yNvYMIR-0%3d&portalid=0

EUROPEAN MARITIME SAFETY AGENCY, 2020. COVID-19 Impact on Shipping - EMSA - European Maritime Safety Agency, [no date]. [online]. [Viewed 17 August 2020]. Available from: http://www.emsa.europa.eu/news-a-press-centre/covid19-impact.html

FARAND, Chloé, 11 February 2020. Shipping could raise ambition of 2030 climate target, study shows, 2020. *Climate Home News* [online]. [Viewed 18 August 2020]. Available from: https://www.climatechangenews.com/2020/02/11/shipping-raise-ambition-2030-climate-target-study-shows/

FILDEN, Sandy, 2019. *IMO 2020 Scrubber Payout Extended by Narrow Sulphur Spreads* [online]. MorningStar. Available from: http://research-reports.morningstarcommodity.com/reportpdf/imo-2020-scrubber-payout-extended-by-narrow-sulfur-spreads-FINAL.pdf

FINBOX.COM, 2020. WACC For Eagle Bulk Shipping Inc. (EGLE). *finbox.com* [online]. [Viewed 20 August 2020]. Available from: https://finbox.com/NASDAQGS:EGLE/explorer/wacc

GKONIS, Konstantinos, PSARAFTIS, Harilaos. (2013). Modeling tankers' optimal speed and emissions. Transactions - Society of Naval Architects and Marine Engineers. 120. 90-109.

GURNING, Raja Oloan Saut, BUSSE, Wolfgang and LUBNAN, Mizan, 2017. Decision Making of Full Speed, Slow Steaming, Extra Slow Steaming and Super Slow Steaming using TOPSIS. *International Journal of Marine Engineering Innovation and Research*. 2017. Vol. 2. DOI 10.12962/j25481479.v2i1.2605.

HELLENIC SHIPPING, 2019. The Vicious Cycle | Hellenic Shipping News Worldwide, [2019]. [online]. [Viewed 22 June 2020]. Available from: https://www.hellenicshippingnews.com/the-vicious-cycle/

IEA, 2020. Global Energy Review 2020 – Analysis. *IEA* [online]. [Viewed 20 August 2020]. Available from: https://www.iea.org/reports/global-energy-review-2020

IG BANK, 2020. Oil tanker stocks could surge if lockdowns continue. *IG* [online]. [Viewed 17 June 2020]. Available from: https://www.ig.com/en-ch/news-and-trade-ideas/oil-tanker-stocks-could-surge-if-lockdowns-continue-200417

IMO, 2020. Sulphur 2020 – cutting sulphur oxide emissions.[Viewed 15 June 2020]. Available from: http://www.imo.org/en/MediaCentre/HotTopics/Pages/Sulphur-2020.aspx

IMO, 2020. International Convention for the Prevention of Pollution from Ships (MARPOL), [no date]. [online]. [Viewed 18 June 2020]. Available from: http://www.imo.org/en/About/Conventions/ListOfConventions/Pages/International-Convention-for-the-Prevention-of-Pollution-from-Ships-(MARPOL).aspx

IMO, [2020]. Status Of Treaties. . P. 3. [online]. [Viewed 18 June 2020]. Available from: http://www.imo.org/en/About/Conventions/StatusOfConventions/Documents/StatusOfTreaties.pdf

JI, John S., 2020. The IMO 2020 sulphur cap: a step forward for planetary health? *The Lancet Planetary Health*. 1 February 2020. Vol. 4, no. 2, p. e46–e47. DOI 10.1016/S2542-5196(20)30002-4.

KINCH, Diana and FOX, Jonathan, 3 January 2020. Scrubber installation waiting list "very long" as IMO 2020 kicks in: Wartsila | S&P Global Platts. [online]. 3 January 2020. [Viewed 19 August 2020]. Available from: https://www.spglobal.com/platts/en/market-insights/latest-news/shipping/010320-scrubber-installation-waiting-list-very-long-as-imo-2020-kicks-in-wartsila

KUMAR, Abhay, 2018. A Brief history of IMO (International Maritime Organisation). *MarinerDesk* [online]. 2 September 2018. [Viewed 17 June 2020]. Available from: https://www.marinerdesk.com/brief-history-imo-international-maritime-organisation/

LI, Yirong, 2019. Stakeholder Analysis and Decision-Making of Shipowners Facing the Coming Implementation of IMO 2020 Policy. Universitat Politecnica de Valencia. Available from: https://riunet.upv.es/bitstream/handle/10251/126555/PEA5334866_TFM%20V2.pdf?sequence=6&isAllowed=y

LING LING JOLYN, Tay, 2011. *Air emissions: the effects on the shipping industry and ports: Implications for the port of Singapore* [online]. World Maritime University. Available from: https://commons.wmu.se/cgi/viewcontent.cgi?article=1207&context=all_dissertations

MAANUM, Mathias Owing and SELNES, Henrik Prøsch, [no date]. Determinants of Vessel Speed in the VLCC Market – Theory vs. Practice. . P. 96.

MEREDITH, Sam, 2020. Oil demand to return to pre-pandemic levels by 2022, Goldman says, but unlikely to peak this decade. *CNBC* [online]. 2 July 2020. [Viewed 9 August 2020]. Available from: https://www.cnbc.com/2020/07/02/goldman-sachs-oil-demand-to-return-to-pre-pandemic-levels-by-2022.html

MARINE TRAFFIC COMPANY WEBSITE, 2020. [online]. [Viewed 11 May 2020]. Available from: https://www.marinetraffic.com/en/p/company

MEYER, Jasper, STAHLBOCK, Robert and VOSS, Stefan, 2012. Slow Steaming in Container Shipping. *International Conference on System Sciences*. 2012. P. 1306–1314. DOI 10.1109/HICSS.2012.529.

MINING JOURNAL, 2020. Copper mine closures to bolster prices, says Jefferies. *Mining Journal* [online]. 24 March 2020. [Viewed 17 August 2020]. Available from: https://www.mining-journal.com/copper-news/news/1383565/copper-mine-closures-to-bolster-prices-says-jefferies

PACIFICGREEN TECHNOLOGIES GROUP, 2020. Why Scrubber-Fitted VLCCs Are Earning Big Bucks. [online]. [Viewed 19 August 2020]. Available from: http://www.pacificgreentechnologies.com/articles/why-scrubber-fitted-vlccs-are-earning-big-bucks/

PARFOMAK, Paul W, FRITTELLI, John, LATTANZIO, Richard K and RATNER, Michael, [no date]. LNG as a Maritime Fuel: Prospects and Policy. . P. 28.

PATTERSON, Warren, 21 July 2020. Marine fuels & IMO 2020: So much for all the hype. *ING Think* [online]. [Viewed 18 August 2020]. Available from: https://think.ing.com/articles/marine-fuels-imo-2020-so-much-for-all-the-hype/

PAVLENKO, Nikita, COMER, Bryan, ZHOU, Yuanrong, CLARK, Nigel and RUTHERFORD, Dan, [no date]. *The climate implications of using LNG as a marine fuel* [online]. International Council on Clean Transportation. Available from: https://theicct.org/sites/default/files/publications/Climate_implications_LNG_marinefuel_01282020.pdf

PIERCE, Andy, 2017. Surfing the cycles: what can history teach us about the next shipping market upturn? (Source: Tradewinds). *Cambiaso Risso Group* [online]. 23 May 2017. [Viewed 22 June 2020]. Available from: https://www.cambiasorisso.com/surfing-the-cycles-what-can-history-teach-us-about-the-next-shipping-market-upturn-source-tradewinds/

PIRES JR, Floriano, LAMB, Thomas and SOUZA, Cassiano, 2009. Shipbuilding performance benchmarking. *International Journal of Business Performance Management - Int J Bus Perform Manag*. 1 January 2009. Vol. 11. DOI 10.1504/IJBPM.2009.024372.

RAMBERG, David, 2014. Implications of Residual Fuel Oil Phase Out. *Massachusetts Institute of Technology*. 2014. P. 16.

RITCHIE, Alistair, DE JONGE, Emily, HUGI, Christoph and COOPER, David, 2005. *Service Contract on Ship Emissions: Assignment, Abatement and Market-based Instruments* [online]. European Commission Directorate General. [Viewed 19 August 2020]. Available from: https://ec.europa.eu/environment/air/pdf/task2_so2.pdf

SHARMA, Nishank, 2019. IMO 2020 sulfur cap: green investment in shipping industry. World Maritime University Dissertations. 1126. Available from: https://commons.wmu.se/all_dissertations/1126

SHELL publication. Lower Emissions Partner "A Clear Vision to a Lower Emissions Marine Industry with our Suite of Solutions". Available from: https://www.shell.com/business-customers/marine/imo-2020/_jcr_content/par/relatedtopics.stream/1569544176637/7ab6883caa274810e14c68ca34ff602871ac85e0/imo-2020-brochure-single-page.pdf

SCHIPP, Jens and EDELMAN, Markus, 2013. IP/A/STOA/FWC/2008-096/LOT2/C1/SC10: *Eco-Efficient Transport Interim report: Overview of potentials for an increased eco-efficiency in maritime shipping* [online]. European Parliament /STOA. Available from: http://www.itas.kit.edu/pub/v/2013/sced13a.pdf

SCORPIO TANKERS INC, 2019. Scorpio Tankers Inc Investor Presentation. [online]. October 2019. Available from: https://www.scorpiotankers.com/wp-content/uploads/2015/04/Scorpio-Tankers-Inc-October-Investor-Presentation.pdf

SEA-DISTANCES.ORG - Distances, 2020. [online]. [Viewed 20 August 2020]. Available from: https://sea-distances.org/

SHIH, Tung Shu 2013. *A Life Cycle Cost Analysis of Marine Scrubber Technologies*. University of Rostock.

SHIP and BUNKER.COM, 2018. IMO 2020: Eagle Bulk Opts for Scrubbers on Up to 37 Ships. *Ship & Bunker* [online]. [Viewed 9 March 2020]. Available from: https://shipandbunker.com/news/world/596499-imo-2020-eagle-bulk-opts-for-scrubbers-on-up-to-37-ships

SHIP and BUNKER.COM, 2020. Global Average Bunker Price Bunker Prices, [no date]. *Ship & Bunker* [online]. [Viewed 9 March 2020]. Available from: https://shipandbunker.com/prices/av/global/av-glb-global-average-bunker-price

SPEIGHT, James G, Coking Drum - an overview | ScienceDirect Topics, 2013. [online]. [Viewed 19 August 2020]. Available from: https://www.sciencedirect.com/topics/engineering/coking-drum

STOPFORD, Martin, 2009. *Maritime Economics*. 3rd edition. Routledge. ISBN 0-203-89174-0.

THE GEOGRAPHY OF TRANPORT SYSTEMS, 2020. The Baltic Dry Index, 1985-2019. *The Geography of Transport Systems* [online]. 6 December 2017. [Viewed 20 August 2020]. Available from: https://transportgeography.org/?page_id=5619

TRADING ECONOMICS.COM, 2020. Copper | 1988-2020 Data | 2021-2022 Forecast | Price | Quote | Chart | Historical, [no date]. [online]. [Viewed 17 August 2020]. Available from: https://tradingeconomics.com/commodity/copper

TURNER, Julian, 11 August 2020. How Covid-19 is impacting the enforcement of IMO sulphur regulations, 2020. *Ship Technology* [online]. [Viewed 18 August 2020]. Available from: https://www.ship-technology.com/features/imo-sulphur-regulations/

UNITED NATIONS, 2020. The Role of the International Maritime Organization in Preventing the Pollution of the World's Oceans from Ships and Shipping. *United Nations* [online]. [Viewed 17 June 2020]. Available from: https://www.un.org/en/chronicle/article/role-international-maritime-organization-preventing-pollution-worlds-oceans-ships-and-shipping

UNITED NATIONS CONFERENCE ON TRADE AND DEVELOPMENT, 2020. *REVIEW OF MARITIME TRANSPORT 2019*. UNITED NATIONS. ISBN 978-92-1-112958-8.

US Coast Guard, 2020. MARPOL, 2020. [online]. [Viewed 18 June 2020]. Available from: https://www.dco.uscg.mil/Our-Organization/Assistant-Commandant-for-Prevention-Policy-CG-5P/Inspections-Compliance-CG-5PC-/Commercial-Vessel-Compliance/Domestic-Compliance-Division/MARPOL/

VON KNORRING, Hannes and STYHRE, Linda, 2015. Increased energy efficiency in short sea shipping through decreased time in port. *Transportation Research Part A Policy and Practice*. 2015. Vol. 71, p. 167–178. DOI 10.1016/j.tra.2014.11.008.

WAHL, Martine Erika Biermann and KRISTOFFERSEN, Eirik, 2012. *Speed Optimization for Very Large Crude Carriers (VLCCs): Potential Saving and Effects of Slow Steaming* [online]. Norwegian School of Economics. Available from: https://openaccess.nhh.no/nhh-xmlui/bitstream/handle/11250/169979/Wahl_2012.PDF?sequence=1&isAllowed=y

WATT, Nicholas, 2019. Scrubbers save $700,000 on US-Asia crude move. *Argus* [online]. 12 October 2019. [Viewed 19 August 2020]. Available from: https://www.argusmedia.com/en/news/2031773-scrubbers-save-700000-on-usasia-crude-move

WITTELS, Jack, KOH, Ann, 21 May 2019. Sniffer Drones: Sniffer Drones Will Start Patrolling the World's Busiest Shipping Ports. [online]. [Viewed 19 June 2020]. Available from: https://www.bloombergquint.com/technology/super-sniffer-drones-and-jail-regulators-get-tough-on-shipping

WORLD SHIPPING COUNCIL, 2020. Top 50 World Container Ports | World Shipping Council, [no date]. [online]. [Viewed 15 June 2020]. Available from: http://www.worldshipping.org/about-the-industry/global-trade/top-50-world-container-ports

ZHDANNIKOV, Dmitry, 4 February 2020. Oil flips into contango, indicating months of surplus, 2020. *Reuters* [online]. [Viewed 4 June 2020]. Available from: https://www.reuters.com/article/us-china-health-oil-contango-idUSKBN1ZY2TH