MARITIME ENERGY CONTRACTING FOR CLEAN SHIPPING

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To reduce the Sulphur emission from shipping and ensure clean shipping, a number of Sulphur Emission Control Areas (SECA) were enforced in special areas around the globe. From 2015, in SECA, ship owners are not allowed to use fuel with more than 0.1% Sulphur content. One of the major concerns for the SECA regulation is that maritime stakeholders have had to take into consideration the costs as well as the tolerable risks of their compliance investment options. Besides that, low freight rates have increased the competition and had caused financial pressure on ship owners so that lower capital reserves and low credibility levels limit the manoeuvring space for investment activities.

The indications from BSR after 2015 showed that the low fuel price has eased the economic effects of the SECA regulation and as a result, most ship owners have delayed their investment decisions. Even though the postponement of emission abatement techniques seems to have reduced the compliance expenses for SECA, they, however, did not improve the position of shipowners relative to their competitors. Consequently, new policy instruments to stimulate innovation, to raise competitiveness and to comply with the new environmental regulations are needed. It would have been easier to hedge fuel price volatility and offer maritime logistics services for a lower price, but to be able to ensure sustainable results in long-term, maritime stakeholders must be ready to device astute strategies that can propel them to unparalleled advantage.

This research first appraised the investment risks and payback period associated with the scrubber using different capital budgeting methods. It further illustrated the Maritime Energy Contracting (MEC) model as a market mechanism for the delivery of a cost-effective emission reduction using the scrubber technology as well as an instrument to realise a competitive advantage for ship operators. The results are empirically validated by case studies from BSR.

Keywords: Investment appraisal, VaR, Scrubber, SECA, Energy Contracting, Business model

1. Introduction

The motivation for environmental regulations is mostly related to improving health and quality of life (Lindstad *et al*., 2015). Shipping activities are responsible for up to 15% of the world's anthropogenic pollution of sulphur oxides (SOx), nitrogen oxide (NOx) emissions and some other harmful elements. These emissions are dangerous to human health and can travel long distances (Abadie *et al*., 2017). SOx emissions specifically cause acid rain and generate particulate matter (PM), which is the root-cause of respiratory and cardiovascular diseases (Notteboom, 2010). This why maritime transportation showing efforts to reduce the impact of health-damaging emissions and ensure cost efficiency in the activities that can curtail it (Lindstad and Eskeland, 2016). Stricter emissions and bunkering fuel requirement regulations by IMO on sulphur emissions was enacted in the MARPOL, Annex 2 where Sulphur emissions from ships are not allowed beyond 0.1% since 2015 (IMO, 2016). SECA regions are about 0.3% of the world's water surface and consist of the North Sea, the English Channel (plus the coastal waters around USA and Canada) and the Baltic Sea region (BSR) (Notteboom, 2010). The sulphur restrictions on another dimension involve a global standard that currently allows 3.5% sulphur content from fuel and ship emissions outside SECA and has stipulated that from 2020, only 0.5% of sulphur emissions will be allowed on all water surfaces worldwide (IMO, 2016). Other sulphur related regulations are the Chinese regulation for coastal waters (published in December 2015 and came into effect in 2016) (North, 2016) and the EU directive 2005/33/EC.

The first two years of the SECA regulation have shown that predictions on the negative implications of the regulation are wrong and the low fuel cost and freight rates have played a huge role in ensuring this (Olaniyi, 2017). Consequently, dependence and pursuit of abatement technologies have declined. Nevertheless, the incoming 2020 global sulphur cap seems to have escalated the urgency of solutions for compliance and clean shipping globally. Stakeholders are now frantic about the options available and economic optimisation of their decisions (Atari and Prause, 2018), although there are speculations that, pushing the 2020 regulation to 2025 will save the maritime industry between $30 billion and $50 billion annually (Platts, 2016). There are also studies that insisted that applying a costly global approach to coastal emission areas might bring more negative result than positive especially in terms of fuel efficiency and increasing CO2 emissions concerns (Lindstad *et al*., 2015). Their argument is

that a continual use of HFO at high sea will ensure the cooling effect of global shipping in a 20 years' perspective and further ensure the 100-year CO_2 equivalent emissions at 35–40% of CO_2 emissions, which can reduce the speculated annual cost of sulphur regulation from 10 billion to 4–5 billion USD. Even at this, the truth is that the sulphur regulations have come to stay and the global limit take-off may not be reviewed forward (Abadie *et al.*, 2017). Maritime stakeholders must now look for innovative ways of obeying the sulphur regulations in the face of possible excess fuel demand that cannot be met by the industry (Wiśnicki *et al.*, 2014) and at the same time ensure reduction of their compliance costs.

Olaniyi and Viirmae (2016) explained that the compliance costs for SECA regulation are expensive and have the possibility of interfering with the production, turnover and profits of the companies involved. With the high unpredictability nature of fuel prices, compliance strategies must involve experimental and revolutionary ingenuity on the part of the stakeholders. In this regard, this study pools two objectives, first, it presented a case study of the Maritime Energy Contract (MEC) business model, a market mechanism for the delivery of emission reduction the scrubber technology that cushions the economic effect of the SECA regulations. Second, because the scrubber technology is an integral element in the MEC model, the study calculated the investment risks and payback period involved in the scrubber technology to validate the scrubber investments and to fill the investments risk appraisal gap for ship owners.

Both quantitative and qualitative data approaches were used to collect data from April 2016 to May 2017 in the frame of "EnviSuM" - Environmental Impact of Low Emission Shipping: Measurements and Modelling Strategies project. Through the study of different cases, the authors seek to answer these research questions. What are the risks involved in scrubber retrofit? How profitable is the scrubber investment for the ship owners? What are the cost and the benefits of the MEC model for the ship owners? Results show that the estimated payback period of the scrubber installation on the ship is short because the use of bunker fuel together with a corresponding abatement solution such as the scrubber will positively influence the payback period as well as reduce the risks involved. The MEC model is a stimulus that can be used for value creation and the realisation of competitive advantage in the maritime industry for a new entrepreneurial process.

Work is arranged in the following way: the next section is the literature review on maritime and SECA Compliance, the Value-at-Risk (VaR) in Investment Appraisal and Energy Service Contracting (ESC). The third section presents the method of data gathering and analysis of results. The next section highlighted the results and the last section is the conclusion.

2. Literature Review

2.1. Maritime and SECA Compliance

There are different approaches to satisfy the SECA requirement. The popular choices for ship owners are fuel switching from heavy fuel oil (HFO) to marine gasoline oil (MGO), the installation of LNG engine followed by the use of the LNG fuel and installation of the scrubber into the exhaust of the ship to remove the sulphur from the emission (Acciaro, 2014; Daduna and Prause, 2017). All these approaches have their pros and cons and different ship owners have built their SECA regulation compliance strategy around one or more of them. Most of their decisions are borne from the contemplation between the capital expenditures and the OPEX of the compliance investments (GU and Wallace, 2017). Mostly, the factors that influence the various compliance methods ship owners make include: (a) fuel prices (b) the area in which the ship usually operates and the regulation it is accountable to (c) the number of days at sea and (d) vessel's lifespan (Abadie *et al.*, 2017).

Fuel cost and ultimately fuel consumption is an integral part of shipping because it makes up to about 50 - 60% of voyage operational cost (Stopford, 2009). Now, the supply and demand of fuel appear to be balanced around the world, but regional surpluses and shortages are projected to occur towards and after 2020 (CE Delft, 2017). Another factor that affects the operational costs of a vessel as stated by Gu and Wallace (2017) is sailing pattern of a vessel e.g. routes, vessel speed and type of vessels. That was why at the onset of SECA, some ships have been replaced by bigger vessels to slow steam, also some routes were also increased or reduced (Olaniyi, 2017; Gu and Wallace, 2017).

Most compliant fuels are in fact blends of several refinery fractions. At the refinery, crude oil is refined to different fractions of oil that are used for bunkering such as Marine Gas Oil (MGO), Marine Diesel oil (MDO) and the Heavy Fuel Oil (HFO) (Brynolf *et al.*, 2014). The MGO and MDO are distillates and more expensive but are SECA compliant. The HFO, on the other hand, is the lower fraction, a residual oil that was the preferred bunkering fuel until SECA (Acciaro, 2014). Even though

through hydrodesulphurisation (partial hydrogenation of the fuel to remove sulphur), HFO can be refined to meet the new requirement, it is a very expensive refinery process and only the mega fuel producers are able to take such investment risk (CE Delft, 2017). The price of bunker fuel fluctuates as a response to supply and demand and are usually determined by factors like short-term expectations from forecasts, production estimation from the oil-producing countries, stock levels, seasonality, accidents, weather and sometimes war (Bergqvist et al., 2015; Hämäläinen et al., 2016).

Another option for SECA compliance is using Liquefied Natural Gas (LNG), to curtail the ship emissions during combustions. The LNG is widely accepted because it also fulfils other regulations such as the CO_2 and the NOx and is the cheapest of the fuels (Bas et al., 2017). However, there are many challenges that prevent a faster development of the LNG fuel such as the availability of the infrastructure for its bunkering, the need to store the fuel and distribute at a particular temperature that requires special storage and costly retrofit and LNG-fuelled ships (Brynolf et al., 2014). All the issues increase the costs of distribution depending on the distance from ports to the LNG import terminals (Bas et al., 2017). Although reports are showing that the LNG infrastructure is developing fast worldwide, for example, according to CE Delft (2017) LNG projects are already increasing in North America and most part of Asia like China, South Korea, Japan, and Singapore. Yet, the LNG is not finding a wider use outside shipping. All these setbacks are said to be related to the regulatory framework, the economic capacity and sustainability, technical practicality and the public-social responsiveness (Bas et al., 2017; Notteboom, 2014).

A third option, scrubber technology, is an option that allows the use of the HFO by "scrubbing" out the sulphur emission from the exhaust of the ship up to 98% (Abadie et al., 2017). With an installed scrubber, the vessel can still run with HFO and remain SECA complaint. Costs of the scrubber installation depend on the ship size, engine size, and an additional cost of fuel for energy, chemicals and waste disposal (Lindstad et al., 2015). The age of the ship is used to determine if an investment in scrubber retrofit is right or wrong (Abadie et al., 2017).

The scrubber technology has two major technologies, which is the dry (popular for industrial use), and the wet scrubber technologies (Wiśnicki, 2014). The wet scrubber has been developed into the open loop, (uses only seawater), closed loop (uses the reaction of caustic soda and fresh water) and hybrid (combined both the opened and the closed technology) (Abadie et al., 2017). The open loop has been demonstrated to be cheaper and smaller making it more desirable because it takes less space for installation but has sparked several debates on the ecological implication of using a device that flushes chemical back into the sea. Running a closed loop scrubber is the most expensive because of the broad treatment of the closed loop circulating water (Lindstad et al., 2015).

The actual costs of the scrubber i.e. its operating costs and maintenance costs depend largely on the ship's size, engine capacity, broiler type and the scrubber technology itself (Bergqvist, et al., 2015, Jiang et al., 2014; Abadie et al., 2017) and ranges from 3 to 6 million € for a ship. Because of its weight, when installing the scrubber, extra fortifications are made to stabilize the ship and ensure the scrubber is in an upright position (Brynolf et al., 2014). Apart from the space, the scrubber itself takes up, extra space is further needed for the accessories like the pumps, tanks, engines and a piping system for the wash water (Bergqvist et al., 2015). It takes between 4-8 weeks for the installation process. Operating the scrubbers increases the fuel consumption rate of the engine at 1-5% (EMSA, 2010). These are some of the contributing factors that discourage ship owners from choosing the scrubber installation option.

According to Atari and Prause (2018), the scrubber lifespan is about 15 years and a payback period (called a breakeven point) of 2 to 5 years. The payback period calculation is one of the methods used to evaluate the worth of the scrubber investment to ensure the payback period is not greater than the scrubber's lifespan (Bergqvist, et al., 2015). This calculation prevents a situation whereby it is impossible to recover the purchase cost after discounting the cash flow (Ross, et al., 2002).

The price difference between MGO (which is a higher) and HFO is called the spread value and this spread is used to assess the economic efficiency of abatement technologies including scrubber investment (Jiang et al., 2014). A higher spread encourages the scrubber installation on the ship. Thus, in the scrubber installation, the cost of the MGO is directly proportional to the ship owner's savings (OECD/ITF, 2016). Olaniyi et al. (2018a, 2018b) projected a high reduction in HFO demand by 2020, along with increased demand for distillates fuels and other hybrid fuel like the ULSFO (Ultra-light Sulphur fuel oil). Another angle of this projection according to WoodMacKenzie (2016) is that the decrease in HFO demand from the 2020 cap could push an increase in the spread from 2020. These predictions are also supported by the International bunker fuel association 2018 report, which has more or less projected the scrubber forward as a more rewarding option from an investment angle.

Many studies have proposed different approaches to making the choice for compliance ranging from the multi-criteria approach (Ren and Lützen, 2015), stochastic programming (Schinas and Stefanakos, 2012), cost-benefit analysis (Jiang *et al*., 2014) and costs function of emission abatement alternatives (Lindstad *et al*., 2015). For the newly built ship, it is most common to make a comparison between the investment annuity and the anticipated fuel cost savings (CE Delft, 2017). While the popular methods, especially for retrofits, is the evaluation of the payback time, Patricksson and Erikstad (2017) put forward sets of reconfiguration possibilities for ship owners whose ships are already running on a low Sulphur fuel with no traffic outside of SECA. They insisted that when a ship is already using SECA compliant fuel and plies within SECA there is no need for an abatement technology installed on the ship. However, they did not do a comparative analysis of the fuel usage on yearly bases nor compare the costs to the abatement costs for such ships. All studies point to one fact, which is that there is still a need for a better way to determine the best choice for regulatory compliance.

2.2. Value-at-Risk (VaR) in Investment Appraisal

To explore the market orientation of the SECA regulation, the authors' estimated and appraised the investment risk associated with the scrubber technology. Aforementioned, investments in scrubber technology are expensive and highly risky for ship owners because the efficiency of a scrubber investment depends on the price spread between MGO and HFO. High price spreads yield short payback periods whereas decreasing price spreads increases payback time and are linked so to higher risks.

Classical instruments for financial investment are studies in the area of capital budgeting and the most important concept represents the Net Present Value (NPV) which can be calculated by using the parameters of the investment (Herbst, 1998):

$$NPV = \sum_{t=1}^{n} \frac{CF_t}{(1+r)^t} - Outlay, \tag{1}$$

or CF_0 yields:

$$NPV = \sum_{t=0}^{n} \frac{CF_t}{(1+r)^t}, \tag{2}$$

where:

CF_t: cash flow during period (t),
Outlay: investment expenditures at period zero,
n: the normal lifetime of n periods of a scrubber (usually 15 years),
r: the annual average interest rate of the investment.

The cash flow of period (t):

$$CF_t = V_t \cdot spread_t \cdot (100\% - e\%) - add\_cost, \tag{3}$$

where:

V_t: annual fuel consumption,
$spread_t$: HFO-MGO spread over a period (t),
e%:   additional scrubber energy consumption,
add_cost_t: additional cost.

An investment is assumed to be favourable if the expected NPV is greater than 0. Based on the NPV approach, the determination of the payback period of an investment is possible by looking for the shortest period n* so that NPV (n*) > 0 (Hull and White, 1998). In both constructions, the NPV as well as the payback period revealed that the results of the investment appraisal depend on the price spread between MGO and HFO during the considered time so there is an associated risk with a scrubber investment, which has to be investigated more detailed.

An appropriate instrument for the control the risk of decisions and investments is through a value-at-risk (VaR) analysis where the VaR shows the capital or percentage of capital loss that should be expected over a particular period with a guaranteed probability or word confidence level (Angelidis and Skiadopoulos, 2008). It describes what loss a particular market volatility will encounter at a certain probability (Linsmeier and Pearson, 2000). Thus, it shows the likelihood and rate at which a loss might occur in any real investment. Using Dowd (2007), the investment in scrubber will be determined by the

price spread between the HFO and MGO along with the spread distribution quantiles analysis from a historical figure. In other words, if the spread means is higher than 500 t€, then a 10% VaR of spread in a span of 2 years connotes a 0.1 probability that a scrubber investment of 5 000 000 €, for example, would increase to a higher value by 500,000 € for that 2 years. The NPV of Net fuel cost savings will determine all investment value associated with the scrubber. The study recognizes that the VaR of scrubber investments will help shipowners assess their investments risk level for example; the VaR will be comparable to the loss of the scrubber investment. This is at the 100s of X percentile level of the normal distribution (Jorion, 2006). In concept, it relates to how the stakeholders look for ways to ensure return on their investment and proportionate to the level of the risks involved (Baker and Haslem, 1974).

2.3. Energy Service Contracting

It is not possible to separate policy from the economic significance of compliance because policy framework determines the economic outcome of any industry (Sys *et al.*, 2016) which makes the investment appraisal and associated risks imperative. As explained by Horbach *et al.* (2012), regulation is a part of the determinants and drivers of environmental innovation - regulatory push/pull effect. Usually it occurs not as the first introduction of a product cut but as a market or technology - diffusion as seen by the scrubber technology where manufacturing companies are adopting a technology used by chemical companies for the ship to expand their perspectives and capture value that would lead to a visible lessening of regulatory burdens (McGrath, 2010). The economic performance of such technology determines the sustainability of the regulation (Plouffe *et al.*, 2011).

The production of SECA complaint fuels involves high risks and investments, the same goes for the costs for abatement technologies. Statistics indicate a decrease in scrubber installations due to low bunkering prices, and low freight rates (Olaniyi, 2017). It is clear that ship owners are unwilling to take a risk that ties down funds that they would otherwise prefer to run their ship. Apart from the unreliable fuel costs and supply, a continuation of this development will likely diminish the impact of a strong stimulus and determinant for innovation and technological push and further lead to the market failure of the scrubber technology (Horbach *et al.*, 2012). Chesbrough (2010) explained that until the monetary value of a technology is available as a form of the commodity in any form, its usefulness would remain dormant.

Energy contracting models (EC) commonly used for energy efficiency and supply in the housing sector and stationary and complex buildings like hospitals (Sorrell, 2007). The adoption of energy contracting models in the maritime sector using the scrubber technology to optimise the scrubber technology is quite new and has been discussed by Olaniyi, Gerber and Prause (2018). This study is particularly positioned to submit a solution to the current negative reactions and criticism regarding the economic implication of the scrubber installation and operational costs among other implications such as the technology itself, ecological and environmental factors of using the technology (Lindstad *et al.*, 2015; Abadie *et al.*, 2017).

EC is a comprehensive energy service model commonly used to optimized energy cycle cost in the housing (Bleyl, 2011) mostly used in Germany, Austria, France, Netherlands, Belgium (Goldman *et al.*, 2005). The common models of energy contract are the Energy Supply Contracting (ESC) that delivers basic needed energy and used in services that are short in capital investments and the Energy Performance Contracting (EPC) that ensures energy savings (Sorrell, 2007). Already some other sectors are adopting this model as seen in water treatment and supply, wastewater disposal, industrial gases supply, service management in telecommunications and security (Bleyl, 2011). Concentrating on the ESC for this study, the energy provider becomes responsible for both the installation of the technology as well as the delivery of the needed energy at a reduced price and the same time reduces the costs of operation for both the provider and the recipient company (Bertoldi *et al.*, 2006). The ESC model is a customized process for singular customers where the total costs are determined by the associated risks or terms of the contract (Goldman *et al.*, 2005).

3. Methodology

The study is established through empirical data from expert interviews, focus group meetings and case studies carried out in the frame of EnviSuM - Environmental Impact of Low Emission Shipping: Measurements and Modelling Strategies project sponsored by the EU regional development fund carried out between April 2016 and May 2017. Data were used to first evaluate the cost constructions of different abatement technologies including the scrubber technology. Through the data gathered, the tendencies and enthusiasms of the ship owners regarding scrubber investments were also determined. From the case

studies involving the proposed model and investments calculations, constructs of real synopsis were projected for readers' conviction as described by Siggelkow (2007). Two case studies were presented.

The first case involved the statistical evaluation of historical fuel price data from 2013 and 2017 and fuel price predictions between 2017 and post 2020 to determine the distribution of the spread between HFO and MGO within these years. The analysis carried out, comprised correlation analysis, the empiric probability distribution of the spread value between HFO and MGO of the last four years and statistical test theory. The observed probability distribution of the spread was used as input data for a Value-at-Risk analysis for the scrubber investments. Each spread was associated with the NPV of a scrubber investment.

The second case described the intricacies involved in the adaptation of the energy contract into the maritime industry. Since there are already several energy servicing companies, a desktop research was first carried out to learn energy contracting and related success determinants. Five ESCO practitioners with retrofit experience of at least 10 years were interviewed. The interviews were made to pinpoint significant features of energy contract and to examine their deportment on the on a successful MEC project or contract. The interview analysis is presented as a description for a model contract based on thematic categorisation by Miles *et al.* (1984) and Kvale (2008). The analysis of the overall cost of the MEC model was then made using current real-life figures.

4.   Results and Discussions

The application of VaR approach requires the determination of an underlying probability distribution. In the case of the scrubber installation, the risks depend on the price spread of the fuel so that a statistical evaluation of historical fuel price data from 2013 and 2017 and the spread between HFO and MGO within these years is done. Based on this analysis, the empiric probability distribution of the spread value between HFO and MGO of the last four years has been tested by statistical test theory.

4.1.   Risks Analysis of Scrubber Investments

The historical time series from 2013 of the fuel prices of MGO and HFO in US$ reveals a high correlation with each other with a positive Pearson coefficient. The spread between MGO and HFO depicts a graph which is shown in Figure 1.
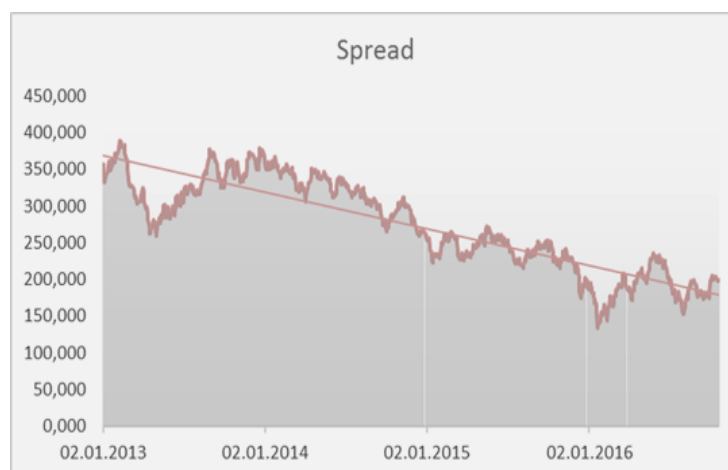

Figure 1. The spread of the HFO and MGO (USD) from 2013 (Computed by Authors)

The histogram of the spread values from 2013 based on 962 values led to an empiric distribution of the spread that has been analysed with the Kolmogorov–Smirnov test as well as with the Shapiro-Wilk test. The results proved that the spread between HFO and MGO is normally distributed with a mean of about 273.5 USD and a standard deviation of about 63.4 USD as shown in Figure 2.
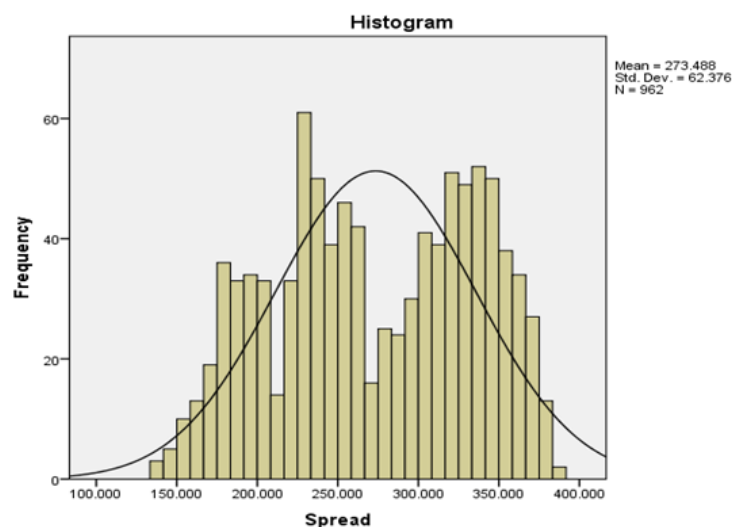
Figure 2. Distribution of HFO/MGO spread (USD) (Computed by Authors)

With the statistical results of the empirical data, it is now possible to conduct a VaR analysis for a scrubber installation on a ship. The property of the spread to be normal distributed allows calculating the quantile which can be used assess the risks of the spread during the investment period. The VaR with definite confidence level α is calculated as $Prob\ (x \leq -VaR\alpha) = 1 - \alpha$. If the distribution is bounded below by –L with probability density function (x) the model yields (Hendricks, 1997):

$$\int_{-L}^{-VaR\alpha} f(x)dx = 1 - \alpha. \tag{4}$$

In order to make the following calculations compatible with Euro calculations the lower 10%, 5% and 1% quantiles of the underlying distribution of the spread are expressed in Euro and correspond to spread values of 155.4 €, 145.53 € and 127.26 €. The applications of these results are studied and empirically validated with the case of a RoPax ferry as follows:

The RoPax Ferry Case

The RoPax ferry enjoys an engine power of 48 MW and a maximal speed of 27 knots that plies Tallinn and Helsinki. From experts' interviews, it was gathered that for this particular ship, a suitable scrubber system would require a power of 15 MW. Calculations were made for suitable open loop scrubber that will cost about 4,984,000 million € with additional installation costs of 0.7 million €. The off hiring days that involves activities such as the scrubber installation, piping, testing, and commissioning will take about thirty days, annual maintenance costs of about 21 t€ p.a. and material costs of around 300€/ton fuel (for chemicals and waste treatment of scrubber residual) were all added and calculated.

Case RoPax ferry has a daily fuel usage of 60t HFO that amounts a yearly volume of 60t x 360 days = 21 600 tons. The HFO – MGO spread within 962 days of oil price data were used to calculate the VaR in the lower 10%, 5% and 1% quantiles of the linked distribution of the spread. In concept, the VaR analysis usually focuses on the left side of the probability distributions. Subsequently, the discounted value method is used to analyse the resultant value of the quantile so that fuel costs saving of n = 15 (discounted value over the 15 years of scrubber lifespan) and r =11% is set as a risk-free value. The results are as follows (Table 1):

Table 1. Quantiles and Present Value (PV) Of Spread Distributions Earnings during Project Lifetime

Historical Data	Days	Annual Savings from difference in Costs of Fuel / Euro	Fuel Spread(Euro)	PV (Euro) in 15 years
10% days	96.2	3 356 640.00	155.4	19,768,031.74
5% days	48.1	3 143 448.00	145.53	18,512,494.59
1% days	9.62	2 748 816.00	127.26	16,188,415.18

Source: Calculations by Authors

Results show that a lower 5% quantile of the spread distribution will lead to a cost of bunker fuel up to 3,143,448 million € per year. The savings that will be made from using the HFO and the scrubber for the ferry with a probability of 95% will yield at least 18 million € within the 15 years scrubber lifespan as against if the ship was using MGO. Furthermore, from the figures, a spread decreased to 127.26 € will yield a lower saving because the lower 1% quantile of the spread distribution was used. If the trend of a higher spread distribution continues to be normal then the saving will increase.

The authors recognised that the NPV used in this study is dependent on two factors: first, the fuel spread and second the HFO price, i.e. NPV = NPV (Spread, HFO) as a function. Accordingly, a linear regression was used to calculate the NPV on the bases of the spread. The R square fit of 93% confirmed a high model fit. This result is on the assumptions that for the scrubber investment not to be risky, the spread distribution must remain normal with the same statistical parameters for the future years.

The Long-Term Fuel Price Scenario

Using a real-life future forecast from the International Bunker Fuel Association report, the authors constructed two different scenarios of savings using the scrubber.

First, from 2019, there is a likelihood of a sharp drop in demand of HFO as bunker fuel together with the expectation of an MGO price recovery up until 2023, when the spread is expected to close up again. Using this forecast, a very high MGO-HFO spread from the 2019-2013 forecasts will be 340 € that will produce a shorter payback period time as presented in Table 2:

Table 2. Scrubber Payback Period from 2019 (Forecasted Oil Price)

HFO	MGO	Earnings from Installation of Scrubber (€)	Scrubber price (€)	Payback Period
526	866	6 060 056	5 684 000	Less than a year

Source: Calculations by authors

Second, according to the same report, in 2024 the fuel price is expected to decrease and the MGO-HFO spread will reduce to 157.25 € which will be approximately around 11% of the VaR quantile. Using the same parameters and calculations, the total savings from using the scrubber technology will be 3,444,767.80 million € per year, a 9% lower value from the from VaR results from the historical fuel price data (Table 3). This also validates the VaR model.

Table 3. Quantiles Value of Spread Distributions with 2024 (Forecasted fuel price)

Forecasted Data	Days	Annual Savings from difference in Costs of Fuel (€)	Fuel Spread (€)
11% days	105	3 444 767.80	157.25

Source: Calculations by authors

The valuation and integration of the NPV and discounted cash flow of the MGO as against the HFO established and validated the Scrubber options as viable investment prospect that is able to yield high returns for the investors. The evolved VaR used with the real-life scenario further helped to demonstrate the high or low-risk time or risk value of the scrubber investment for a particular duration. Forasmuch, as the assumption that the scrubber costs and services remain constant and that the MGO-HFO spread is evenly distributed this model can serve as a classical instrument to measure the value-at-risk of the scrubber investments.

4.2. Maritime Energy Contracting (MEC)

From the investment and risks analysis, the authors confirmed that the scrubber investments have a lot of potentials to be a profitable venture for the ship owners, however, existing empirical data (Olaniyi, 2017) shows a low number of scrubber installations because of the decline in the price of fuel. This has put a lot of pressure on fuel producers who must step up to produce the demanded volumes and types of needed fuel. Unfortunately, a critical challenge for the traditional fuel producers is to cope with the lack of existing production capacity so that they are forced to upgrade their refining process to meet up with their major markets. Olaniyi and Viirmae (2016) highlighted the high investments sums for fuel producers which are needed to produce low sulphur oil. The access to appropriate credits seems to be complicated for the majority of fuel producers due to low oil price and unclear developments in maritime fuel markets.

Even after having recognized the analysis of scrubber investments together with the related risk assessments, the majority of ship owners who are unwilling or even not able to make the financial commitment for scrubber installations which coincidences with the situation of the fuel producers whose product may no longer be marketable. In the end, to reduce the investment risks for ship owners and to ensure business continuity for fuel producers a new business model is thus proffered.

MEC is a revolutionary and feasible new business model for maritime fuel producers that can afford them the opportunity to metamorphose from the everyday fuel producing to energy producing and servicing. This will involve using the concept of the ESC for their energy (fuel) delivery. In theory, it involves fuel producers going into contract with ship owners by pre-financing the scrubber installation, accepting the responsibility of regular maintenance and at the same time supply HFO. In the end, the fuel producers supply energy solutions to ship owners through scrubber installation. All energy service packages are provided at the full expense of the fuel producers in accord to the contract specifications. In return, the fuel company is paid in full for the fuel supplied along with marginal costs of the scrubber costs for servicing and maintaining the scrubber. They guaranty the quality assurance for the use of the scrubber as well. Both companies share the cost savings described previously. The contract will secure energy costs savings that ensure that the reimbursement from the delivered energy during the contract period will comprise of the investment and risk costs already provided by the fuel producers.

Needless say that for the eradication of sulphur emission in shipping, the challenging issue borders on the execution of the compliance objective of the SECA regulation. The BSR has seen admirable compliance actions but because it is related to expensive and risky venture, its achievement is still not 100 percent. This has plagued it with many uncertainties especially as it has to do with the compliance options. Sadly, the low fuel cost has seemingly rendered most of the first investments somewhat pointless. However, with the 2020 global sulphur cap in view, fuel usage will certainly increase along with demand for low sulphur fuel. The maritime sector will likely witness a drastic change in its markets. This change might increase a likelihood of fuel cost or result to a scarcity in low Sulphur fuel supply.

MEC pools two goals: it lowers SECA compliance costs for the ship owners and fuel producers' and ensure SECA compliance. Elements of the MEC implementation consist of a project design (development, planning, contract scrubber installation, fuel supply, maintenance, maximisation, user incentive, quality monitoring and controlling, price bond and risk and technical contracting).

The Long-Term Fuel Price Scenario

In housing, the ESC contracts usually take up to 10 years. This is because buildings are immobile assets so they could be subjected to longer contracts. However, with ships, the conditions are different. First, they are not stationary assets, more so they move from different zone and region to another, which sometimes involves different countries. Under these conditions, circumstances are likely to change significantly, it is therefore suggested to limit the contract duration within 3 to 5 years, adjustable at intervals as well as client specific.

MEC pricing will subsist on two pricing element. (1) The cost of energy (fuel) supply. (2) Financing of the scrubber as an asset that includes supplementary services within the procured contract period also called the adjustment. Each element reviewed periodically (i.e. monthly, bi-monthly, quarterly or yearly) to accommodate arising impelling or unavoidable issues. Thus:

Energy Supply:

$$AP_{HFO} [€/mt] = AP_{0HFO} [€/mt] + FS [€/mt] - FS_0 [€/mt] \tag{5}$$

where:

AP_{HFO}:   Current fuel price at contract time/metric tonne of fuel (€/mt)
AP_{0_HFO}:   Baseline price from official statistics at the period €/mt
FS: Price for fuel supply per metric tonne €/mt
FS_0:   Baseline price for fuel supply in a particular period (i.e. 01-06/2017) €/

Non-Energy (Adjustment):

$$LP [€/a] = LP_0 [€/a] \times \left(0.5 + (0.3 + \frac{I}{I_0}) + (0.2 \times \frac{L}{L_0}) \right), \tag{6}$$

where:

      LP: New fuel price at contract time per annum €/a,
      LP_0:   Baseline fuel price from official statistics at the period €/a,
      I_0:   Current price index for consumer goods taken as the baseline,
      I: Current price index for consumer goods proportionate to I_0,
      L: Average salary index at the contract period,
      L_0:   Average salary index for setting as starting point for the contract.

      The adjustment calculation takes into account the cost of the asset, inflation and modifications in the employee's salary. In principle, every year 50 % of the price is stable, where 30% is dependent on prevailing inflation (consumer good index). The remaining 20% will depend on salary costs build-up, which will affect the provided services like maintenance and monitoring during the contract period.
      Along these lines, the cost of MEC will be as follows:

$$\textbf{\textit{MEC Price}} = Energy\ supply\ +\ Scrubber\ costs\ +\ Adjustments \qquad (7)$$

      In the sequel, the MEC model will be empirically validated with the same RoPax ferry case like in the VaR approach.

MEC Validation

      Using already discussed RoPax ferry ship, the baseline cost is set as the price of fuel (MGO) the cruise was using as at 6th Oct 2017 at 585.08€/t. The annual cost for MGO will be the cost of MGO per tonne multiplied by the daily MGO consumption and multiplied by the number of operating days i.e. 585.08€/mt x 60mt/day x 360 days = 12, 637,796.30 € per year. The cost of HFO is 347.27 €/mt which yields an amount of 7,500,969.99 million €.
      To calculate an adjustment for November 2017, the adjustment costs are based on the current Estonian consumer goods index at 01.01.2017 (TE, 2017a), the average salary index at 01.01.2017 (TE, 2017b) and a fictive fuel price of 450€/mt from 01.01.2017. Totalling 2,062, 592.24 €/a ≈ 28 % of HFO price/mt.
      The annual scrubber costs will be the sum of the 10% additional scrubber fuel/annual (p.a.), 2% additional scrubber service p.a., 15 years depreciation of scrubber p.a. and interest costs p.a. Totalling 897, 881.00 €/a ≈ 12% of HFO price/mt. Thus, the cost savings and sharing is calculated below and is depicted in Figure 3:

$$MEC\ Price/tonne = (347.27\ +\ 41.67\ +\ 97.24) = 486.2€/mt$$
$$Cost\ saving\ for\ Shipowner\ = 585.08 – 486.2\ =\ 98.9€/mt$$
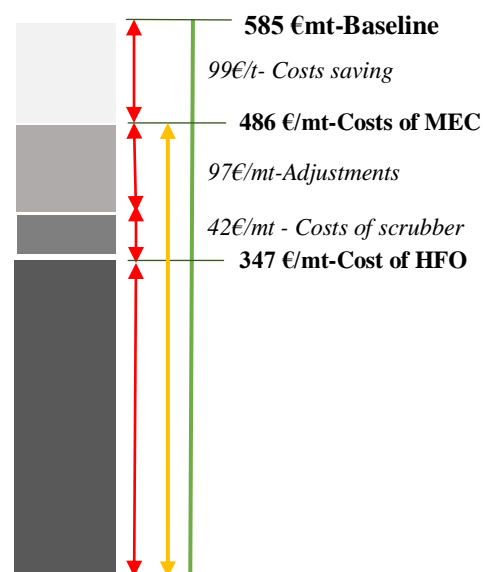

Figure 3. Cost savings in MEC model (Authors' calculations)

By considering the results of the case study it turns out that the shipowner will get the fuel for 99€ per ton cheaper compared to the MGO price whereas the fuel production company will enjoy an additional adjustment of 97€ per ton which generates additional revenues for the fuel company. Another major benefit for the ship-owner is the exchange of the CAPEX to the OPEX that signifies an indirect investment for them. The fuel producer changed his business model from a pure production company towards a service company, which offers now scrubber related services including financing. In comparison to the huge production plant investment for the fuel producing company, the new investments sums for the scrubber installations are smaller and better to handle.

In addition to the financial agreements, a MEC for maritime industry must include other contract conditions in order to become successful. Expert interviews revealed already a list of core points that must be part of MEC agreement between the shipowner and the fuel producer:

- The scrubber as the asset of the fuel producer throughout the agreed contract term.
- Descriptions of financial terms i.e. *Maritime Energy Contracting Price, Scrubber costs, Energy price, Adjustments.*
- Prevailing Interests' rates.
- Provisions for rebates or compensations.
- Terms for penalty and reimbursement for defaults.
- Terms for non-energy elements during the contract period.
- Guidelines for planned or unexpected termination.
- Other matter arising such as *the border of property, Space for scrubber and retrofit, Quality of supply, Additional energy consumption.*

In this regard, using the scrubber option for the MEC concept is a pivotal concept that can be targeted to yield distinctive prospects in the maritime sector because it is practicable and offers a fresh perspective to innovation in an unreliable environment such as the maritime sector. The alliance arrangement will guarantee the following:

(a) SOx emissions reduction.
(b) Scrubber installation costs savings.
(c) Risk transfer to fuel producer such as investment risks, technical risks, market risks, and performance risks, leaving only ''zero risks'' to the ship owners.
(d) Jobs creation.
(e) Lowered operational costs for the ship owner that allows the shipowner to focus on shipping activities, which is transportation (this helps them to remove energy efficiency issue from day to day operations).
(f) Free technology and expert support for the ship owners.
(g) Promises a higher margin for both companies.
(h) Customised contracts.

The MEC concept bears many advantages for fuel producers as well as for ship owners because it allows fuel producers to continue producing their traditional product whereas the shipowner gains a competitive advantage due to lower energy costs in shipping which generates additional margin in the transport competition. Yet, the MEC concept leaves open the question of whether the central desulphurisation in fuel producer's plant is more favourable to the decentralised desulphurisation through the scrubber on a ship from an ecological or economical viewpoint. The financial advantage of the scrubber approach is its scalability, which takes into account the credibility situation in the maritime sector.

5. Conclusion

Compliance with SECA regulation is related to investment decisions for shop owners as well as for maritime fuel producers. In the case of a scrubber installation, the Value-at-Risk model is able to demonstrate the risks associated with the scrubber including changes in payback time. Through the scrubber technology, a navigation can be set to mitigate or reduce the economic effect of the SECA regulation on ship owners or maritime fuel producers who do not have the capacity or the will to invest in refinery upgrade.

The research further discussed the concept of a Maritime Energy Contract as a dynamic market instrument to deliver emission reduction and to generate competitive advantages for the shipowner and the fuel company. Authors recognised the MEC as a decentralised method of the SECA regulation

compliance for the fuel producers who eventually may have to find a way to make refinery upgrade investment in the long term, but would need to be proactive on the short term while they wait for the appropriate time to commit to a much higher investment.

With applicable political support, the ESC model which has been tried over a long period and in different countries can enhance the maritime sector by refocusing the attention of the maritime stakeholders to using the scrubber technology as providing ''energy solutions''. This way, a sustainable private sector in the maritime sector will emerge and score a much-desired technology-push-effect for the EU.

The limitation of the study borders around using only HFO/MGO spread scenario without including other sources of fuels, which can be an interesting angle for further research. There can be a comparative study on the VaR for the LNG, methanol, ethanol, CNG and other types of fuel or air purification technologies used to provide a holistic solution bank for the maritime sector.

Acknowledgements

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