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## ENTREPRENEURIAL COMPLIANCE OPPORTUNITIES FOR MARITIME FUEL PRODUCERS <sup>★</sup>

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**Abstract.** In January 2015, the Sulphur Emission Control Areas (SECA) regulations changed so that ships that ply the Baltic Sea and the North Sea must no longer use bunker fuel that exceeds 0.1%. After the regulation of many compliances, changes occurred in the maritime sector, especially in the BSR. From studies, the impact is still somewhat negative for some maritime stakeholders such as small-scale fuel producing companies who must produce fuel that complies with the SECA requirements. The impact analysis of their compliance options shows that hydrodesulphurisation option is the most viable option with a commensurable investment return rate, but it is highly risky and expensive considering the incessant plummeting of fuel price and the financial status of such companies. However, even though the situation looks bleak for the small-scale maritime fuel producers, a more in-depth probe revealed a chance for exceptional opportunities for growth and profit through a change of business model to the maritime energy-contracting model (MEC). The study zooms in on a case fuel producing company, empirically considers and compares the MEC model (as a decentralised option) and the hydrodesulphurisation process (as a centralised option) and, if either option is adopted by as a SECA compliance strategy to ensure a rounded and robust choice making-process for maritime stakeholders in such situations.

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## 1. Introduction

To increase life expectancy and protect the environment from shipping activities the international maritime organisation (IMO) established a Sulphur Emission Control Area (SECA) in Northern Europe including the Baltic Sea (IMO, 2014). Of which, from 1st January 2015, ships must use low sulphur fuel not exceeding 0.1% v/v adopted by the European Parliament (EP) in the Directive 1999/32/EC amended in Directive 2012/33/EU. The EU shipping regulations on sulphur also include waters, ports and any vessel at the quays in EU ports whether they fall in SECA or non-SECA region. The second clause of this regulation imposes that ships in non-SECA waters can only use a maximum 1.5% sulphur content fuel until 2020 when the allowance is further reduced to 0.5 %v/v (IMO, 2016). This occurrence means that shipowners no longer have to operate in SECA before they pay attention to the sulphur content of the fuel their ships use. OECD/ITF (2016) reported that international shipping produced about 80 times more SO<sub>x</sub> emissions than aviation in 2000. As a reactive gas, SO<sub>2</sub> reacts with other compounds to form secondary particles that have dangerous consequences for the health of the inhalers (Duke Energy, 2016). The IMO and the EU parliament are employing a global strategy to bring this situation under control for a safer world. Regulations such as the sulphur regulations aspire to reduce the acidification damage to ecosystems reduce respiratory and cardiovascular diseases and increase life expectancy (AirClim, 2011).

When companies respond to regulations, they focus primarily on their strategies to reduce their cost of complying. Some of their responses are embedded in activities such as research and development, expansion, equipment upgrade and processes. Since the introduction of the SECA regulations, substantial changes are made with vessels that operate in the Baltic Sea who now use fuel that is low in sulphur content (Wiśniewski, Czernański, Drożdziejki, Matczak, Spangenberg, 2014; Bergqvist, Turesson & Weddmark, 2015).

The compliance rate has been very commendable, and the overall economic impact of SECA has been negligible. However, despite the impressive changes witnessed, the impact may not be the same for all stakeholders, and there is still not a clear-cut conclusion on the most economical options for the shipowners. Moreover, some results show that the effect may be harmful to medium size fuel producers who have to deal with producing low sulphur fuel which is distillate oils and expensive to refine (EfficienSea2, 2016). These fuel producers must make tough strategic business decisions linked to high investments and severe financial risks to remain functional in the maritime fuel markets.

Against this background, stimulating innovation in the maritime sector to ensure a cleaner environment is crucial and technological development may be able to show the way out of some persistent environmental problems. However, technical solutions may not necessarily translate to profit outcomes if innovative choices are not considered carefully. Since successful value propositions are embedded in exceptional business models (Osterwalder & Pigneur, 2009), the SECA regulations could signify the opportunity for innovative responses that are useful for the maritime market. Olaniyi, Prause & Gerber (2017) proposes the Maritime Energy Contracting Model (MEC), a new business model that uses the scrubber installation on ships for fuel producers and shipowners.

However, the concept still leaves a doubt of whether it can bring economic advantage to fuel producers when compared to other methods such as the hydrodesulphurisation process for sulphur removal.

Thus, the core objective of this study is to make a comparative analysis of the capital and the operating costs between the maritime energy contracting (MEC) model – viewed as a decentralised method of sulphur removal process – to the construction of a hydrodesulphurisation plant – viewed as a centralised option for SECA compliance for this study. In this perspective of controlling sulphur emissions, the paper builds on the insights of Olaniyi, Atari & Prause (2017) and Pourmoghaddam et al. (2016) to evaluate the economic parameters of the MEC model and hydrodesulphurisation process for SECA regulation compliance. The research uses the case of Viru Keemia Grupp AS (VKG) an Estonian shale oil (popular as bunker fuel) producer that has a sulphur content that exceeds both the SECA and the global sulphur emissions limit. VKG now faces the challenge of producing the 0.5% or 0.1% sulphur content fuel to meet the demand of the sulphur regulation. On this premise, this study is channelled towards creating an enabling situation for medium-sized maritime fuel producers to make definitive decisions regarding their path of SECA compliance. All research activities were made in the frame of “EnviSuM” - Environmental Impact of Low Emission Shipping: Measurements and Modelling Strategies project.

The structure of the paper is in the following manner; the next section discusses the Sulphur regulations and the activities of the maritime sector stakeholders in their bid to comply with the environmental stipulations and their dilemma when making compliance related investments decisions. Section 3 describes the method used for the research. Section 4 examines the cases of using the decentralised (MEC) compliance model and the centralised (hydrodesulphurisation) business model. The authors highlight the intricacies of each model and their costs as compliance pathways for fuel producing companies. Section 5 draws on the results and discusses the merits and demerits of using the model when compared to the existing knowledge of entrepreneurial opportunities regarding the SECA regulations. The last section concludes.

## **2. Compliance Options for Sulphur Emissions Regulations**

The efforts to reduce the compliance costs forces maritime stakeholders like shipowners, ports and fuel producers to look for innovative ways to adhere to the stipulation of emission reductions and at the same time venture into activities that can increase their capital base and gain new business opportunities (Wiśnicki et al., 2014, EfficienSea2, 2016). Primarily, three paths exist for the shipping industry to comply: one is fuel switch to low sulphur fuels, the other is to alternative sources of fuel, and the last is to install abatement technologies on ships (OECD/ITF 2016).

The low sulphur fuel switch requires that ships use the more expensive and cleaner low sulphur fuel (marine diesel oil (MDO), marine gas oil (MGO) or the ultra-low sulphur fuel (ULSFO) that can be treated to reach a maximum sulphur content of 0.1% (IMO, 2013, 2015). Using low sulphur fuel does not require any significant investments for remodelling ship engines, except for minor adjustment of pipes and other accessories. In some instances, large ships could also choose a hybrid system by installing dual engines that allow them to switch from high to low sulphur fuel whenever they are within or out SECA (Berqqvist, et al., 2015). Seemingly, the easiest solution to the sulphur regulations would be to switch to the use of low sulphur fuel but according to Atari & Prause (2017), the constant erratic fluctuations of fuel price, uncertainties regarding effects of newly introduced regulations such as the 2020 global sulphur cap, makes this option very risky.

The liquefied natural gas (LNG) is a type of non-fossil fuel used as an alternative source of energy for shipping. Its use has been widely accepted as a promising energy source for shipping to solve the sulphur emissions dilemma because the LNG is less costly when compared to the distillate oils and the heavy fuel oil, however, the costs of distributing LNG to ports and ships are very high (Brynnolf et al., 2014). Furthermore installing the LNG engine on ships is quite expensive, so many shipowners avoid this option as their choice for compliance.

A ship scrubber is a cleaning system that washes sulphur from the exhaust of ships that use heavy fuel oil. There are two types of scrubbers, the dry and the wet scrubber (OECD/ITF 2016). The wet scrubbers are of three types, the open loop, closed loop and the hybrid system. The hybrid scrubber integrates both the open and closed-loop systems to function as one. Atari & Prause (2017) explain that the initial investment costs of scrubbers retrofit range from 3 to 5 million € depending on the ship type, scrubber type and size. Besides, operating the scrubbers increases the fuel consumption rate of the ship engine to about 5% (EMSA, 2010). The scrubber needs space for installation and space for equipment for wash water, piping systems and monitoring on the ship making it possible to use the scrubbers only in large vessels (Berqvist et al., 2015).

Compliance with regulations often leads to the dilemma of investment choices and sudden market changes may interrupt a company's usual *modus operandi* which may lead to intensive capital investments and increased operational costs associated to new and changed personnel, materials purchased, legal costs, paperwork and so on (Demil & Lecocq, 2010). Since investments, choices have a significant effect on a company; wrong investment decision can cause adverse setbacks and warrant years of recovery. In other words, strategic actions related to regulatory compliance of an enterprise is very crucial (Prause, 2014).

The endogenous growth theory builds on this premise and suggests that the economic growth of a country is primarily dependent on the decisions made by the actors in the economy—firms and individuals—rather than on external factors (Barro, 1991). Distortions that could adversely affect entrepreneurial activities have great significances for the growth of any economy (Solow, 1994). Thus, the innovation that stems from various compliance activities is a key driving factor for economic growth and social wealth. In this light, the innovative products and services emerge more often because of a cross-sectorial combination of technologies, design and business models (Olaniyi & Prause, 2016).

Jaffe, Peterson & Stavins (1995) argued that regulatory decisions are too time-consuming and are often characterised by litigation and other legal power struggles that could last for decades of reforms leading to high transaction costs. They insisted that regulatory interventions influence investment choices that ultimately have a significant effect on the economy because the build-up of regulations over time often leads to duplicative, conflicting, and even contradictory outcomes. Other work (Martin and Sunley, 1998) agrees that the multiplicity of regulatory constraints complicates and distorts the decision-making processes of companies or stakeholders operating in such an economy.

In contrast, the OECD (2005) refuted these views on regulations and its effects on the premise that even though enterprises are sometimes subjected to series of obligations through regulations, regulations should not be seen in a negative light but be considered as necessary legal impositions needed to control the ways businesses are conducted. Regulations may sometimes bring financial loss, but they also create a type of stability connected to more extensive macroeconomic benefits such as GDP increase, competitiveness and productivity effect and unquantifiable benefits like protection of fundamental rights, social cohesion, international and national economic stability (Renda et al., 2013). Related stakeholders should focus instead on the continuous adaptation and improvement that will evolve in ways that can put their organisations in active stances rather than in reactive states (Eisenhardt & Brown, 1998).

Overall, there is still no academic cut consensus on whether the maritime fuel producers might substantially change their business model and operating strategies to the most viable option with a commensurable investment that maximises the matching return versus risk, about their path of producing SECA compliant fuel and their financial situation. Therefore, addressing this issue is paramount to draw useful regulatory and policy implications regarding the SECA compliance at the shipowners and fuel producers' level, and more particularly to accurately reinvigorate the implementation of new business and management strategies, and assessing their impacts for the industry as a whole.

### **3. Methodology**

The scope of this study is to analyse the differences in the operating costs of the maritime energy-contracting model and the hydrodesulphurisation process, both of which are presented as strategic compliance models for the sulphur regulations compliance using the case of VKG. The analysis will help to determine the merits and demerit of each model for investment choice purposes for medium size fuel producers.

#### **3.1. Survey design and data collection**

All data collection took place between May 2016 and May 2018 in the frame of the “EnviSuM” project. First, document review was conducted to understand the background of the sulphur regulations, the hydrodesulphurisation process of sulphur removal and the energy service-contracting model. This process also substantiates respondents’ reports to provide a rich account of events (Esterberg, 2002). Next, twelve (12) face-to-face structured and semi-structured experts’ interviews were made. Discussions lasted between 1 to 2 hours with notes taking. Where clarifications and validations were needed, follow-up phone calls and emails were made. The interviews made gave room to identify proficient information from experts that Patton (2002) called “key informants” who are familiar with the subject matter and have useful perceptions for full comprehension of events.

Yin (2009) and Stake (2000) said that the triangulation of results is crucial to creating a reliable case study and helps to converge accurately and present experts opinions. In this light, additional data and information were gathered from BSR maritime experts’ focus group meetings and EnviSuM learning café workshops to improve data and create a robust case. Osterwalder (2014) nine-block business model canvas was used to highlight the expected change in the business model of the case company after the adoption of the proposed energy service-contracting model.

Purposeful sampling (Patton, 2002) was used to select top management executives in their respective fields. Patton defined this process as “a selection strategy where particular settings, persons or activities are chosen deliberately to provide information that cannot be gotten otherwise”. This selection criterion for top management executives was drawn because they are involved in everyday decisions and are vast in management experience. The interviews targets three categories of respondents; the managers in VKG who could give the account of their various SECA related activities as well as the economic impact of the SECA regulations on their business performance, the energy servicing managers and consultants, who are familiar with the complexities of energy management and the shipowners who buy the low sulphur fuel.

Data from the interviews, the focus group meetings and document reviews were analysed using Yin's (2009) "five components of effective case study research design," i.e. research questions development; scientific propositions; unit analysis and coding; connecting logic and themes and interpretations of findings.

#### **3.2. Modelling**

##### **3.2.1. Business model design of the MEC package**

Olaniyi et al. (2018c, 2018b) studied the case of the decentralised desulphurisation on a ship with scrubber technology using the MEC modular design, comprising different modules of the ESCO.

$$MEC Price_t = Fuel cost_t + Scrubber costs_t + Adjustments_t \quad (1)$$

Where the MEC costs are calculated within the comprehensive competitive technical solutions and prices offered regarding the functional description of the energy services, scrubber costs as the capital costs of the scrubber installation spread into an amortisation over the lifespan of the scrubber and added to the fuel cost per metric tonne. Fuel price is the consumption of HFO at the current price level related only to the marginal costs defined exclusively in the service contract. Adjustments are the additional margin for running the scrubber comprising of all costs for the scrubber usage such as administration, maintenance, personnel, insurance and management together with entrepreneurial risk, including a profit margin. Adjustments open a negotiation space with the customer and take into account the costs of the asset, inflation and modifications in the employee's salary as well. In principle, every year, 50 % of the price is stable, where 30% is dependent on current inflation (consumer good index). The remaining 20% depends on salary costs build-up that will affect the provided services like maintenance and monitoring during the contract period.

### 3.2.2. Business model design of the HDS plant

In this analysis, the authors devote special attention to estimating the overall annualised cost (OAC) and the final price per metric tonne of low sulphur fuel oil based on the hydrodesulfurisation process of VKG. Recent literature and common practice were used to estimate the OAC using the following equation according to Pourmoghaddam et al. (2016); Coker (2015); Towler & Sinnott (2012):

$$OAC_t = Total annual capital cost_t + Total annual operating cost_i \quad (2)$$

Where, the total annual capital cost (TACC) is the discounted value of the financial cost for year t calculated by including a set of capital investment costs related to the HDS unit, which mainly considers: physical plant cost (i.e. subsumes investment of significant equipment, piping, structures and site development costs), engineering costs and contingency costs. In a similar vein, the total annual operating cost (TAOC) for a given year t sums-up total fixed operating costs (i.e. labour force, maintenance, taxes) and variable operating costs (i.e. fuel, electricity, cooling water). Even though the TACC and the TAOC are observed, they are not necessarily constant over time. Thus, the authors account for time effects by discounting all future costs out-flows resulting from operating the HDS unit.

## 4. Result

### 4.1 Case study: Investment Dilemma of a Fuel-Producing Company

The study uses Viru Keemia Grupp AS (VKG) an oil shale producing company in Estonia, situated in Ida-Viru County, a 148,000 populated area of Estonia a small country located on the Eastern border of European Union (EU) close to the Baltic Sea. Due to the oil shale production, Estonia is the least energy importation dependent country in Europe (Eurostat 2016). The country predominantly uses 78.3% of solid fuels to produce energy - mainly oil shale. Oil shale covers about 65% of the country's needs for primary energy that guarantees the energy independence of Estonia. While the EU imports 53.4% of its total consumed energy, Estonia relied on only 11.9 imports for its energy requirements.

Oil shale industry contributes about 4-5% to the Estonia GDP and about 300M € to the state budget (including employment taxes, environmental taxes) (Eesti põlevkivitööstuse aastaraamat, 2014). As a producer of shale oil, VKG has a significant impact on the Estonia economy. In 2015, VKG's contribution to the state budget of Estonia

was about €35 Million, and the Company's total turnover was €167 million. From the turnover, €87 million was a contribution from shale oil alone. As of 2015, VKG has employed over 2100 employees.

Regrettably, while shale oil has a low sulphur content comparable to crude oil, its sulphur content of 0.8% is still higher than the 2020 global sulphur limit of 0.5%, more, so the SECA limit of 0.1%. VKG has found its self in a position where it must assess the present marketability of its oil products post-2020. A critical challenge for them is how to cope with the existing production capacity that pressures them to upgrade their refining process to meet up with their significant markets. Another is the complication in accessing appropriate credits due to the low oil price and the complicated developments in maritime fuel markets. Other financial problems are related to the high risks involved in financial investments (Olaniyi & Viirmäe, 2016; Prause & Olaniyi, 2017). Because of these magnified and complicated circumstances, having a new business model is critical. Strategic business agility should be taken lightly by VKG if they want to avoid the vicious cycles that could lead to precarious financial performance (Yauch, 2011).

After the introduction of SECA regulations in 2015, the demand for abatement technologies especially the scrubber did not increase as was predicted before 2015 (Olaniyi et al., 2017). According to them, current figures show a decrease in scrubber installations due to low bunkering prices. Most shipowners would instead use the low sulphur fuel reducing the demand for HFO and exerting much pressure on fuel producers like VKG who must come up with compliant fuel to meet the demands of the market for low sulphur fuel.

According to Atari & Prause (2017), investing in scrubber technology have the potential to be a profitable undertaking for the shipowners. However, most shipowners are reluctant to make the financial commitment for scrubber installations, which coincide with the situation of the fuel producers whose product may no longer be marketable. In the end, to reduce the investment risks for the shipowners and to ensure business continuity for the fuel producers, a change of their business model could be a welcome development by both parties.

## **4.2 The Maritime Energy Contracting Package (MEC)**

### **4.2.1 Change in the business model for VKG**

Since the case of VKG reveals that coping with SECA regulation is plagued by high investments risk, Olaniyi, Prause & Gerber (2017) introduced the Maritime Energy Contracting (MEC) using the scrubber technology investment on a ship as a promising new model to overcome this dilemma. The concept of the model highlight how VKG can metamorphose from being fuel producers to also an energy service provider to safeguard SECA compliance. The MEC idea is to deliver the conventional high sulphur fuel to contracted ships, pre-finance the project, and run the scrubber installation. The primary motivation of this model is to lower the transaction (compliance) costs that emanate from SECA regulations of both the fuel producing companies and the shipowners. The proposed model proposes a shift of the fuel company focus towards selling “energy solutions” using the scrubber installations on ships.

The Energy Service Company (ESCO) is an inclusive energy service model used to achieve energy efficiency to optimise cycle cost in building projects (Bertoldi, Rezessy & Vine, 2006). Typically, an ESCO covers the customised service package like design, building, (co-) financing, operation & maintenance, optimisation, fuel purchase, user motivation in place of their customers (Sorrell, 2007). The ESCO also takes on the technical implementation and operational risks in the course of the project term (Bleyl & Schinnerl, 2008). At the initial stage, an energy baseline costs (energy usage before project) is predetermined, and energy is supplied at the agreed price that ensures efficient use of energy and a shared savings assurance. The overall payment guarantees the outcome and the overall costs of services rendered and certifies energy usage and supply that can create the inducement to optimise the use of the supply facility (Goldman, Hopper & Osborn, 2005).

Transferring this concept to the maritime industry using the scrubber installations on ships, the MEC model is developed where the fuel company takes on the implementation and operation of the energy service package at its expenses and risk according to the project specific requirements set by the customer. For its profit, it will receive payment for the energy (fuel) delivered, which depends on the consumption of the ship together with the flat rate costs of service, maintenance and quality assurance. The profit is shared between the fuel producer and the shipowner during the contract lifetime. The MEC guarantees cost savings so that the payback from the cost savings from the fuel supplied throughout the contractual period covers the investment and the risks costs by the fuel company.

By zooming in on the building blocks of Osterwalder (2004) business model, one first thing that would change in the MEC business model are the key partners for the fuel company. This change will mean a switch from bunker traders to financial houses, scrubber producers, maintenance companies, ship operator/shipping company/shipping operators and other fuel producing companies. Next, the key activities will become service driven to marine fuel production, new solution services to sulphur emission compliance, maintenance, and data information exchange and information management. The company's key resources together with the general physical infrastructure like the mines and fuel production facilities will now include the scrubber and intellectual and financial resources, i.e. scrubber experts, service personnel and liquid assets.

Furthermore, the value proposition of the fuel company will change from delivering quality only HFO fuel based on economies of scale concept towards economies of scope. In this case, the production of the traditional HFO will continue, but also, the product portfolio now extends to scrubber related services comprising design, installation and running in the form of a full service-bunkering offer. This full-service bunkering delivers the necessary scrubber to the shipowner including all related services and a cost and risk reduction, which is, related to the investments costs. The costs reduction made for the shipowner will yield financial savings for the fuel producing company and lowers HFO prices due to the removal of intermediaries. The company's significant customers will switch from bunker fuel traders to shipowners.

Customer relationships will become a co-creation alliance between the company and its contractual customers. Services will include personal assistant, maintenance and customised design installation that fit each customer according to their needs. The channel of distribution will remain owned but will involve the use of electronic data exchange (EDI) for inventory and supply management. Cost structure will change from fixed dominated fuel production to more diversified costs due to the new economics of scope activities related to the service offered to shipowners. Finally, the revenue streams related to fuel

#### 4.2.2. Costs of MEC

The analysis of the MEC model raises the question on the costs of the additional costs per ton fuel when using a scrubber aboard. A RoPax ferry ship that plies Tallinn-Helsinki route, with a daily fuel (HFO) usage of 50mt daily, as a ferryboat operates in 340 days a year equalling 17,000mt fuel annual usage is used to calculate this additional cost for this study. The annual scrubber cost is a 10% additional scrubber fuel p.a., 2%, additional scrubber service p.a. and annuity including 15 years depreciation of scrubber p.a. and 6% interest costs. The scrubber cost is considered as the main component of the MEC model, because of the focus on the long-run economic evaluation. Then, taking into account both the operational and financial costs related to operating scrubber, we estimate for each calendar year  $t$  the total scrubber costs, over the lifespan period, as follows:

$$\text{Scrubber Costs}_t = 0.1 \times \text{HFO Cost}_t + 0.02 \times \text{Scrubber Price}_t + \text{Annuity}_t \quad (3)$$

Formally, scrubber costs constitute a forward-looking measure that sum-up the expected stream of operational and financial costs, which characterise a scrubber's expenses-generating potential beyond the total fuel consumption and adjustment cost at the end of year  $t$ . In order to calculate the additional costs for each scrubber cost per tonne, a constant annuity over the overall investment period is inputted. This leads to equation (3):

$$\frac{Annuity_t}{(1+r)^T} \cdot \frac{(1+r)^T - 1}{(1+r) - 1} = \sum_{t=1}^T \frac{oCF_t}{(1+r)^t} - CapEx_0 \quad (4)$$

Where,  $oCF_t$  is the expected outflowing cash flow generated in year  $t$  since only the expenditures have to be considered over the  $T$  investment period (i.e. 15 years); the term  $(1+r)$  is in the finance literature called the discount factor, and  $CapEx_0$  is the capital expenditure, which corresponds to the initial capital investment in a SOx scrubber. By solving Eq. (3) so assuming that the annual fuel consumption for the ship is constant over the years, the division of the annual annuity by the number of consumed fuel tons delivers the additional costs for scrubbing aboard (Ryan & Ryan, 2002; Ross et al., 2004; Di Lorenzo et al., 2012).

Besides, for more realistic quantitative outcomes, the empirical set-up of the equation (2) in this analysis implies incorporating a set of dynamic variables that directly affect the anticipated operating and financial cost valuations over the operating period. Therefore, the pricing of the scrubber costs is built upon the assumptions that the fuel prices (HFO) are exogenous and follow a random walk. All effective costs are adjusted for the annual inflation rate and discounted at a rate of 11% per year, which is defined by disregarding the composition of the company's funding sources. This assumption could strongly influence the project results. Therefore, bearing in mind these, in this case, the results of the project evaluation are reported in Table 1.

Results reveal that the scrubber costs which is the average annual scrubber cost over the 15 operating years discounted by the discounted rate (WACC) will cost costs of 36.25€ per metric tonne for VKG. The cost analysis for the scrubber is shown in table 1.

**Table 1.** Cost analysis for a new scrubber over the entire period

Variable	Value €
Investment costs	5 684 000.00
Average annual scrubber costs	725 667.02
Capital scrubber costs per metric tonne	14.17
Operating scrubber costs per metric tonne	23.02
Scrubber costs per metric tonne	36.25

*Source:* Authors' calculations

Importantly, the differences in magnitudes between the independent results of the first year and the aggregated results over the economic life of the new scrubber (i.e. 15 years) are mainly due to the time effects and the discounted out-flows (costs), as well as the digressive financial annuity scale. The study exclusively considers the scrubber costs as a significant component of the MEC model, because of the focus on the long-run economic evaluation. The authors took into account the operational and financial costs related to the scrubber, the estimate for each calendar year, the total scrubber costs, over the lifespan period was made according to Atari & Prause (2017); Atari, Bakkar, Olaniyi & Prause (2019).

So far, the MEC concept highlights many advantages for fuel producers as well as for shipowners because it allows fuel producers to continue producing their traditional product whereas the shipowners gain a competitive advantage due to lower energy costs in shipping that generates additional margin in freight rate. This concept leaves a doubt of whether a decentralised MEC model through the scrubber installations on a ship could be more favourable than a centralised HDS in the fuel producer's plant from an economic viewpoint.

### 4.3 Hydrodesulphurisation

In a previous study, Olaniyi & Viirmäe (2016) proposed five potential business models for VKG. (1) Upward vertical integration where VKG sells fuel directly to suppliers instead of through an intermediary. (2) Products upgrade by building a new refinery to yield commercially valuable products which would cost VKG about 400 million€ with additional annual 5% depreciation of 20 million€. (3) Products discount where VKG sells at a discounted rate. (4) Process innovation, which is the implementation of an improved production method. (5) Hydrodesulphurisation which will cost the company about 100 - 150 million€ investment.

After the empirical assessment of these investment options, Olaniyi & Viirmäe discovered that out of the five options, only hydrodesulphurisation and the product upgrade would yield a meaningful return on investments but with high risk. Of the two, hydrodesulphurisation option has the highest return on investment and a lower risk making it the most favourable option for VKG. This work accesses the costs of running the hydrodesulphurisation plant to compare to the MEC using the scrubbers.

Hydrodesulphurisation (HDS) is a multi-catalytic chemical process used to remove sulphur compounds from refined fuel used for vehicles, aircraft, ships, after the SECA regulations (Lee, Ryu & Min, 2003). Lin et al. (2010) and Pourmoghaddam, Davari, Moghaddam (2016) linked the earliest production of low sulphur fuel through the hydrodesulphurisation process to China (the mid-1950s) and Japan (early 1960s). Afterwards, different improved processes were developed and even though the catalytic hydrodesulphurisation processes have been the most widely used process, other alternative processes like extractive desulphurisation, extraction with ionic liquids, adsorptive desulphurisation with solid adsorbents, bio-desulphurisation, supercritical water-based desulfurization, and electrochemical desulfurization became popular (Pourmoghaddam et al., 2016).

During the catalytic process, organic sulphur compounds react with hydrogen ( $H_2$ ) to form hydrogen sulphide ( $H_2S$ ) using metal catalysts at high temperature and pressure. According to Erickson (2003), HDS has low operating costs but high capital costs that may be too expensive for refineries that recover less than 20 tons of sulphur per day. This complicated process incurs high material usage because the HDS requires a lot of  $H_2$  so that the production and operating costs are relatively high (Lin et al., 2010) especially for a medium scale company like VKG. Since VKG has a possibility of the building a hydrodesulphurisation plant, particularly with the incoming 2020 global cap, the authors follow the approach of Pourmoghaddam et al. (2016) to perform an economic analysis in a possible case of VKG pursuing this centralised project.

#### 4.3.1. Costs of the HDS plant

The investment analysis was made given a total capital investment of €150 million, a production capacity of 750 000 tonnes of the ultra-low sulphur fuel oil (ULSFO) per year and 330 operating days of per year. Similarly, the authors present the assessments of the aggregated costs estimated for the entire operating period (i.e. 20 years). Using the typical lifetime of an HDS plant of 20 years and assuming an average interest rate for this investment period. While the investment costs of a hydrodesulphurisation plant for VKG range between €100 and €150 million, the authors adopt an upper-value calculation of €150 million as the cut off threshold for calculation. Therefore by assuming the standard VKG's annual production volume of 750 000 tons of fuel, the economic and cost analyses (Table 2).

**Table 2.** Cost analysis for a new HDS plant over the entire period of investment

Variable	Value €
Investment costs	150 000 000
Average overall annualised costs	20 870 000
Capital HDS costs per metric tonne	9.93
Operating HDS costs per metric tonne	17.89
Overall HDS costs per metric tonne	27.28

*Source:* Authors' calculations

By scaling the estimated costs by the annual fuel production, the results exhibit the overall costs of hydrodesulphurisation in term of euros per tonne of ULSFO produced equals to €27.28, while the unit capital cost per ton of ULSFO equals approximatively €9.93, which represents 34% from the overall additional HDS cost. Besides, a transfer of the operating costs calculation of Pourmoghaddam et al. (2016), to the current operating conditions of VKG HDS plant leads to an additional unit operating cost of approximately €17.89 per ton of ULSFO so that in the considered case, it represents 66% from the overall additional centralised hydrodesulphurisation costs. In sum, this analysis provides different exciting insights regarding the additional costs related to the centralised hydrodesulphurisation vis-à-vis the costs for the decentralised MEC model.

## 5. Discussion

The study led to significantly different overall costs (that sum up the operating and capital costs) between the decentralised MEC model and the decentralised HDS process. Hence, the decentralised MEC model costs €36.25 per metric tonne, while the decentralised HDS process represents a cost of €27.28 per metric ton of fuel. By matching the results, the figures gave interesting outcomes as other options have different investment characteristics. For example, the central HDS plant costs about €150 million and enjoys a lifetime of 20 years, whereas the scrubber installation on a ship RoPax ferry costs about €5 million and has a lifetime of 15 years (Olaniyi et al., 2018c, 2018b, 2018a). Also, the additional operating scrubber cost in terms of euros per metric tonne remains significantly higher with regards to the unit operating cost attributed to the HDS plant. However, on the whole, the results are rational, in terms of the scope and the size of the initial investment. A €150 million investment in HDS plant is equivalent to 30 investments in scrubbers for ships like the RoPax ferry suggesting that the scrubber installations on ships are related to lower financial investment volumes and financial risks which are diversified and less when compared to the risk of a single HDS capital investment.

Even though the calculation for centralised and decentralised desulphurisation was done from two specific cases, these results bear valuable insights that will guide decision-makers on the evaluation of the real costs of the sulphur regulations investments options. It will also support the optimal investment choice, thus, aid to argue the optimal financing strategy for the maritime stakeholders. Besides, the decentralised MEC model under the considered circumstances is perhaps more favourable due to the scalability of the investments. A more detailed investment analysis had shown that the payback times for the MEC investment as well as for the HDS plant investment are about 2.5 years (Atari et al., 2019), assuming the current spread of about €150 between MGO and ULSFO. This additional information again supports the scrubber installations using the MEC model due to shorter capital binding periods.

According to Utterback (1994), in situations characterised by a high investments risk where the priority is to minimise costs to obtain greater operational efficiency, smart fuel management and strategic partnership could be

a marketing strategy to handle the challenge. A significant benefit for the MEC model is the exchange of the capital expenditures (CapEx) to the operational expenditures (OpEx) that signifies an indirect investment for the fuel producing company. In comparison to the vast production plant investment, the new investments sums for the scrubber installations are smaller and better to handle.

Similarly, a smart fuel price management will represent a competitive advantage for the shipowners who will also benefit from the MEC model since it has a significant influence on the overall shipping operating costs and influences the margin of freight rates. It also opens the space for negotiations in cargo transportation that might be welcoming in the shipping sector due to low freight rates experienced in recent years (SSE, 2016). In other words, there is an arbitrage for the investor to invest heavily and gain on the operating cost or to reduce investment and enjoy a lesser investment cost, risk, and gain a much lower operating cost.

## **6. Conclusion**

The downward fuel price fluctuations have already adversely affected maritime fuel producing companies. Hence, they must proceed tactically on investments decision they make towards the SECA and the 2020 global sulphur limit. The shipping industry as a whole must find a way to cope with the economic impact of the regulations to ensure the industry's sustainability.

The paper provided answers to some of the concerns regarding abatement technology in maritime. First, it highlighted that the operating costs of both MEC and HDS per metric tonne are nearly the same but with quicker payback for the MEC model using the scrubber technology. Better still, the work showed that the risk of investment in the MEC model is lower due to a reduced and scalable amount of investments. In this situation, the MEC model could pave the way to a win-win situation among the involved maritime stakeholders by combining technical solutions to a business model innovation, presenting a cost-effective and risk minimising route to overcoming barriers to SECA compliance for fuel producing companies as well as for shipowners.

By comparing the MEC and HDS options, the paper presents the opportunities that are both inherent and external to the case company and promotes a viable private sector that targets major maritime stakeholders thereby contributing to regulations driven innovations. It also contributes to the ongoing discussions on the impact of sulphur regulation on maritime business. A pathway for further studies can be towards the systematic exploration of how the MEC is structured from a ship owner's point of view to achieve successful partnerships in the maritime industry.

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