Navigating ECA-Zones

Regulation and Decision-making

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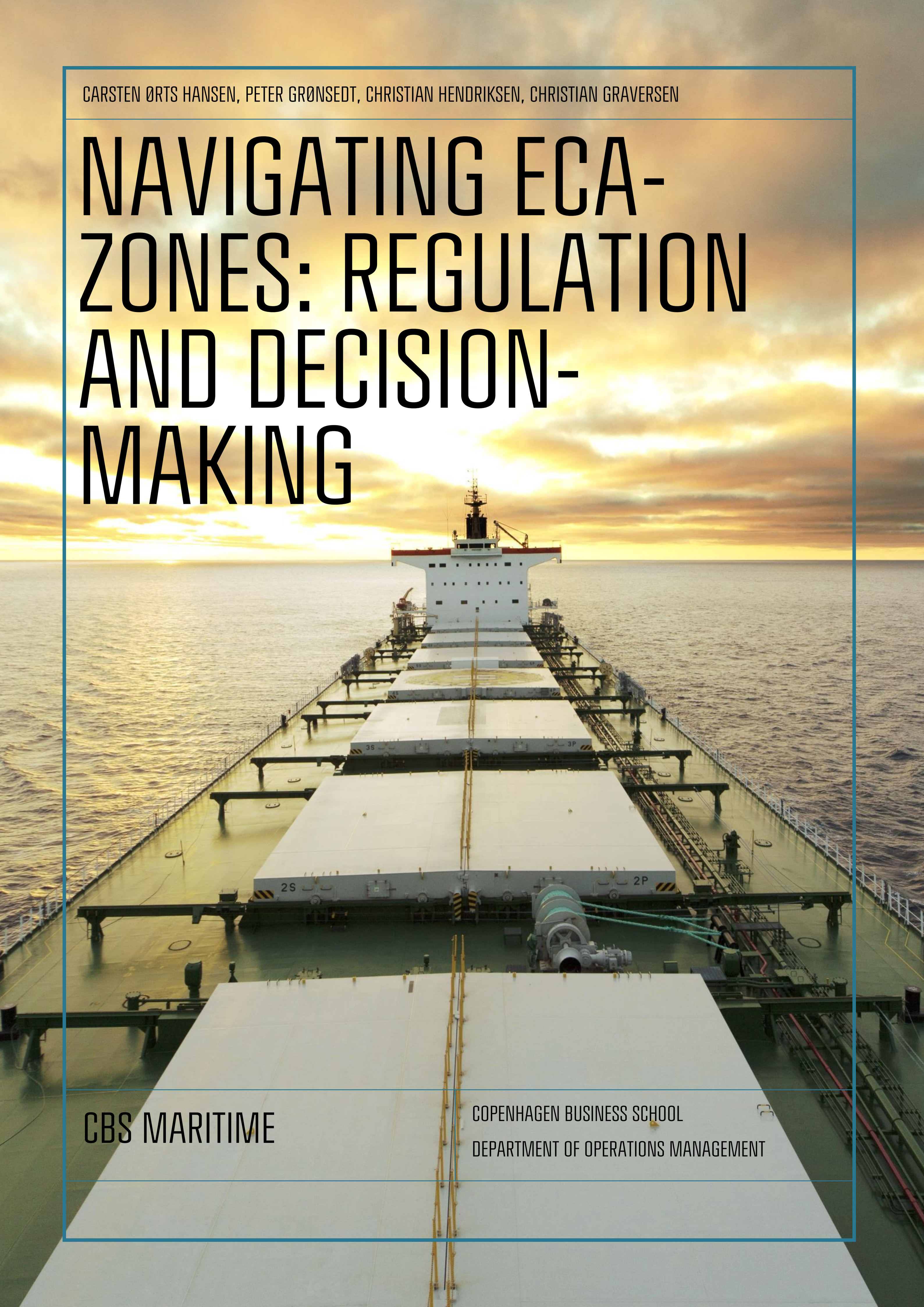

CBS MARITIME

COPENHAGEN BUSINESS SCHOOL
DEPARTMENT OF OPERATIONS MANAGEMENT

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EXCUTIVE SUMMARY

THIS REPORT PROVIDES THREE MAIN TAKEAWAYS: FIRST, THE OIL PRICE PLAYS A CRITICAL ROLE IN THE DEVELOPMENT OF GREEN SHIPPING STRATEGIES BECAUSE IT INFLUENCES WHICH COMPLIANCE STRATEGY IT IS LESS COSTLY TO DEVELOP. SECOND, LOW ENFORCEMENT AND PENALIZATION INCENTIVIZES SHIP-OWNERS TO DISREGARD ECA-ZONE REGULATION. THIRD, THIS REPORT SHOWS THERE IS A POTENTIAL FOR SHIPPING FIRMS SEEKING TO INFLUENCE THE ENVIRONMENTAL STANDARDS OF SHIPPING.

This report examines the effect that ECA-zone regulation has on the optimal vessel fuel strategies for compliance. The findings of this report are trifold, and this report is coupled with a calculation tool which is released to assist ship-owners in the ECA decision making.

The first key insight is the substantial impact of the current and future oil price on the optimal compliance strategies ship-owners choose when complying with the new air emission requirements for vessels. The oil price determines the attractiveness of investing in asset modification for compliance, given the capital investment required. Operating on low-Sulphur fuels remains favourable with a low oil price, as the price spread between high- and low-Sulphur does not outweigh the price of asset investments. Ship-owners who are contemplating future compliance strategies should monitor the developments of the global oil price, and consider how much time their operated vessels navigate the ECA in the future.

The second insight covers the economic considerations of ship-owners, considering the expected enforcement level by authorities and the punishment imposed on violators. The report shows that the rational ship-owner has a significant incentive to not comply with the new regulation when fine sizes and risk of being audited are low. This is an important point for both the ship-owner and the public officials that seeks to enforce the regulation effectively to provide the correct incentives for compliance.

The third insight reveals that ship-owners can play an important role in the formulation of regulation in the IMO. Regulation is not just something that is imposed but rather rules that are a product of those who participate. Three political cases illustrate the power ship-owners potentially can have by being proactive and collaborative in the policymaking process. Coupled with ship-owners insight into how regulation impacts the cost structure of operations, the potential for proactive ship-owners in regulation is huge in creating a future competitive advantage.

From the economic insights, a calculation tool is developed and provided for ship-owners. The calculation tool allows the user to input data about their vessels or fleet, after which the tool provides estimates for the optimal solutions to compliance. This tool should provide guidance for any ship-owner interested in the future of green shipping and determining their optimal ECA compliance strategy.

The calculation tool can be downloaded by following this link.


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1 INTRODUCTION

THIS REPORT PROVIDES MARITIME STAKEHOLDERS THE OPPORTUNITY TO UNDERSTAND HOW DIFFERENT THEORETICAL LENSES CONCEPTUALIZE INTERNATIONAL MARITIME REGULATION. SHIP-OWNERS CAN LEARN THAT ISSUES CAN BE VIEWED FROM DIFFERENT PERSPECTIVES AND HOW TO IMPROVE THEIR OPPORTUNITY AND PROACTIVELY INFLUENCE AND RESPOND TO REGULATION. MEANWHILE, REGULATORS NEED TO UNDERSTAND HOW REGULATION AFFECTS SHIP-OWNERS TO OBTAIN THE CORRECT BEHAVIOUR IN THE MARKET AND HOW DIFFERENT ACTORS INFLUENCE REGULATION.

International shipping is a special industry, as seaborne trade has existed for thousands of years and is a vital part of economic development worldwide. The Viking trade ships bartered along the entire European coast, and vast empires based their power on trade fleets that sailed to and from the New World while the Far East connected to Europe via long sea routes. At sea, dominion over an area could only be enforced by a sizeable fleet, which rendered control and regulation of the high seas impossible.

The basic idea of the freedom of the seas can be traced back to the Dutch jurist and philosopher Hugo Grotius, who first formulated the ideas in his book '*Mare Liberum*' (English: '*The Free Sea'*) (Grotius, Hakluyt, Welwood, & Armitage, 2004) (Vieira, 2003). His argument was that the sea was international territory and all nations could use it for seafaring trade without being restricted by national rules of other countries. This was specifically aimed at the Portuguese empire, which in the early 17th century claimed monopoly over trade routes with the East Indies. Grotius argued that no nation could claim control over international sea routes nor regulate them.

In 1625, a Portuguese priest named Serafim de Freitas published the book '*De Iusto Imperio Lusitanorum Asiatico*' (English: *Of the just Portuguese Asian Empire*). In this book, de Freitas countered Grotius' arguments systematically to eventually conclude that there were moral reasons why the Portuguese empire could control the sea and trade routes. He rejected the idea of 'freedom of the seas' and argued that sea territory could be controlled by states just as land territory could. This position became known as Mare Clausum (Vieira, 2003).

Eventually, the international community came to adopt the idea of Mare Liberum in the spirit of Grotius, but the basic tension between the two points of view still stands. On one hand, the idea of the freedom of the seas is still pervasive and has influenced international treaties and conventions since the 17th century. On the other hand, transnational problems and issues arising from modern challenges, such as protection of the environment or safety, has forced stakeholders to consider how to strike a balance between the Mare Liberum and the Mare Clausum.

This report places itself squarely within this tension. Modern challenges and discussions on international seaborne trade regulation is a constant struggle between those who argue that regulation is legitimate and necessary, and those who argue that regulation limits the benefits of free trade. The latter argue that the market will solve problems more efficiently that state regulation, while others suggest that states must intervene due to negative externalities from the industry.

The basic premise of the report is that decisions to regulate international seaborne trade has real and tangible effects on ship-owners, ship operators and the shipping market in general. However, the report also contends that the view on these tangible effects and the regulation depends on the perspective of the observer. There are therefore possibly infinite ways of looking at regulation and the shipping economy. The report serves two main purposes, providing the reader with different analytical lenses to understand the maritime industry.

First, the report intends to analyse the effect of regulation on the ship operators. Concretely, this analysis will be centred on the recent standards for Sulphur emissions in Emission Control Areas (ECAs) and determine how business actors can respond efficiently to new regulation. The analysis also seeks to elaborate on the inherent problems that are associated with this perception. This is a concrete and quantitative approach to science and it results in tangible recommendations for both industry and governmental actors.

Second, the report illustrates how the substantive regulation agreed upon in the International Maritime Organization (IMO) can be analysed from a social constructionist perspective. Concretely, this will be done by reviewing the process leading up to three major decisions in IMO regulative history, interpreting the process from the analytical position of Actor Network Theory (ANT). The three cases are explained in detail in the next section.

Reading this report should provide a deep understanding of the effects of concrete international regulation on ship-owners and operators, as well as how an analytical position based on theory shapes perception and approach to a given object of analytical interest. This understanding is closely tied to the ongoing discussion regarding the extent of international shipping regulation. This report aims to broaden the readers' perspective on how regulation can be perceived and conceptualized from different angles.

The guiding research questions for this report takes departure in considerations on the regulatory process and the effect the output (i.e. substantive regulation) has on business. The first part of the report, which deals with the substantive environmental regulation, explicitly seeks to explain what the *effect* of *regulatory output* is on business operations. The second part of the report analyses the possibilities for enforcement of the regulation. The third part of the report examines how a *specific theoretical lens* provides a *specific perspective* of international maritime regulation, including how *non-state actors* engage in the process in this perspective.

The report will also explain the economic rationales that exist in favour of regulating international shipping. Using the notions of social cost and social benefit, the first part of chapter 3 explores what conventional economic theory concludes about the need for international regulation. It adds a crucial perspective to the aforementioned tension between freedom of the seas and regulation.

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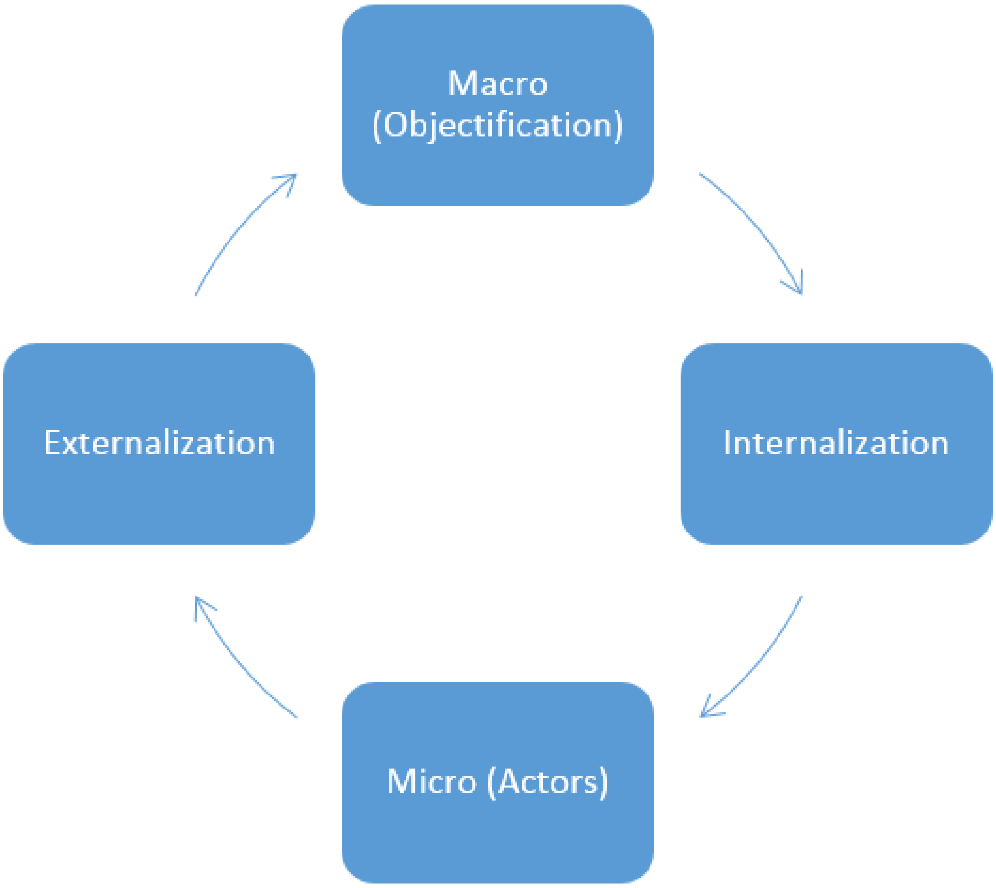


Figure 1.1: Adapted from Berger & Luckmann (1966)

1.1 CIRCULATED APPROACH TO ANALYSIS

The seminal work done by Allison (1999; 1971), in which he examines the same object with different theoretical lenses, inspires the structure of this report. The point of having multiple perspectives is to challenge the idea that there is a 'correct' way to assess regulation and its effects on society. Applying multiple analytical lenses on the same issue provides valuable insight into how we can think about things such as the formation of regulation, the effect of regulation, and the impact of different stakeholders.

In addition to Allison's ideas of multiple perspectives, Berger & Luckmann's (1966; 1991) notion of the "socially constructed reality" has influenced this report. Berger & Luckmann argue that humans construct the idea of reality or the social world. In turn, they argue, humans forget that the social world is constructed and it is taken for granted as reality or, in some cases, as fundamental laws. This accepted reality then affects societal actors, whom take it for granted and act on its premise.

This report takes the perspective that regulation is a process determined by various political actors. Regulation has important effects on shipping, and this 'social reality' is something that firms must take into account when conducting operations.

When a macro level social reality is constructed, it is defined as an objectification, which then has tangible effects on the individual micro level actors; such as firms, states, and persons. This process is called 'internalization', which denotes the fact that actors internalize the social reality, taking it for granted and acting accordingly. Conversely, when actors at the micro level shape and construct social reality, it is called '*externalization*', whereby practices and ideas are raised to object reality. In our report, we consider regulation or international rules for shipping as the macro level reality, and individual actors are states and firms. Internalization is the effect that regulation has on firms and states, and externalization is the process in which actors shape new regulation or amend existing.

Using this perspective, we are able to say something substantive not only about the way regulation affects actors and how regulation is formed, but also about the overall way of understanding regulation of international shipping as something that is continually constructed, objectified, taken for granted, and acted upon, eventually feeding in to how new regulation is formed.

1.2 CHOICE OF POLITICAL CASES

To examine the process of establishing regulation, three political cases that unfolded within the IMO arena have been chosen for analysis using the network perspective, as this perspective allows us to understand regulation as a process. Even though the scope of the report applies to all ECA-zones across the world (or regulation that imitates the effect of an ECA) the empirical study takes departure in the Baltic and North Sea ECAs.

The cases chosen are *definition and geographical scope of SOx regulation*, the *allowed pH-value of wash-water discharge from scrubbers*, and *the effective date of NOx limits in ECAs*.

The political cases are included because they all represent different aspects of regulation. The case of substantive SOx limits tells the story of the spatial scope of regulation, detailing the battle between those who wanted uniform global regulation and those who wanted stricter rules inside ECAs. In this case, a significant number of actors are active and present, ranging from groups of states to individual firms.

The case of effective dates for NOx ECAs is about time rather than space. This is a story about how the timing of regulation was contested and how states and firms scrambled to influence the process to push the temporal element of regulation in their favour.

Finally, the case concerning wash-water discharge values was chosen because it is a technical aspect of regulation that has huge impact on the industry. This is a story of how science plays a political role and how seemingly technical details can be politicized and drawn out due to deliberate actions by involved parties due to the effect on them respectively.

The three themes – spatial, temporal, and technical aspects of regulation – together form a basis on which a central argument is built: Regulation is constructed in the political process and all elements are politicized because of the conscious strategies employed by involved actors. By using the lens of Actor Network Theory in all three cases coupled with an excavation of the actual processes, it becomes clear that regulation is not automatic.

This is why the central tension between Mare Liberum and Mare Clausum is still relevant. Even though there may be good cases for regulation or de-regulation from economic point of view, the actual regulation only emerges after countless actions taken by those involved. Incremental shifts toward Mare Clausum or Mare Liberum are thus not automatic in any sense, but a result of the strategies employed by those benefiting from one or the other.

1.3 UNDERSTANDING ACTORS

There are many actors in the world of shipping. Conventionally, actors are the different stakeholders relevant to a firm or a specific operation and are grouped as such. However, given that this report takes departure in the idea that the same object can be viewed from different theoretical angles, we contend that actors can be many things depending on your point of view.

When we view actors from the market perspective, we consider them either sellers or buyers in a market setting. Actors are grouped in categories that correspond to one of these market positions. When we view actors from the hierarchical perspective, we see instead regulators and those being regulated. Actors are then either those who create and enforce rules, or those who have to decide whether and how to comply. Finally, from a network perspective, we think of actors as embedded in networks across categories, creating alliances and collaboration to achieve certain goals regardless of categories. The figure below illustrates these different layers of understanding.

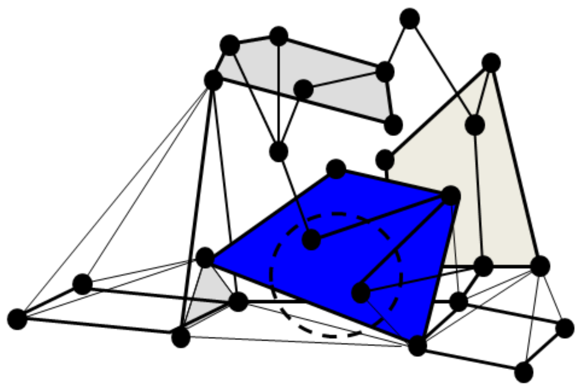


Figure 1.2: Actors from different perspectives
The figure illustrates how the actors (black dots) can be viewed as belonging to certain category or as establishing network links to other actors.
Adapted from Hansen (2005a)

2 READERS GUIDE

THIS CHAPTER OUTLINES THE STRUCTURE OF THE REPORT. THE REPORT TAKES A DIFFERENTIATED ANALYTICAL APPROACH TO A CENTRAL EMPIRICAL OBJECT. THE FIRST PART OF THE REPORT EXAMINES THE ECONOMICS OF REGULATION AND THE FINANCIAL IMPACT NEW REGULATION HAS ON THE INDUSTRY. THE SECOND PART EXAMINES MARITIME REGULATION FROM A HIERARCHICAL PERSPECTIVE, HIGHLIGHTING THE EFFECT OF RULE ENFORCEMENT. THE THIRD PART EXPLORES THE POLITICAL BACKGROUND BEHIND THREE NEW POLICIES DISCUSSED BY THE INTERNATIONAL MARITIME ORGANIZATION.

The empirical object of this report is the regulation of ship emissions in the Baltic Sea, as well as the conditions for competition that are derived from this regulation.
The principal point of departure is the idea that different paradigmatic approaches applied to the empirical object imply different conclusions and implications. Elzen (Elzen, Geels, & Green, 2004) identify three approaches to regulation: Market-based approaches, hierarchical approaches, and network-based approaches. We employ the market perspective first, because it is much more useful for the reader to grasp the economic effect of regulation before discussing how to enforce it.

Market-based approaches assume that the world is best characterized as an efficient market place, where state interference is inherently undesirable. Actors are assumed to be efficient and rational, and instead of a principal-agent relationship between regulator and regulated, market approaches examine financial incentives to determine to what extent regulation changes behaviour.
This paradigm originates from neo-classical economics associated with the Chicago School of Economics and the work done by Stigler, Friedman and other economists (Friedman, 2009; Stigler, 1971). In the economic analysis of this report, we approach the empirical object using the idea of an 'economic man' – an actor that is perfectly rational and maximizes profit. The economic man responds to financial incentives regardless of moral or societal considerations, and only acts to maximize the profits of the firm. This means we treat ship-owners and the decisions they face from a purely economic perspective, examining how new regulation changes their optimal strategies. The economic analysis is carried out in chapter 3.

The hierarchical approach to regulation originates in the peace of Westphalia where nation-states with clearly defined boundaries became the dominant actors in international politics. Hierarchical approaches thus tend to see regulative issues as principal-agent relationships, where the principal (the state) regulates non-state actors (the agents) through formal rules. This perspective is borne

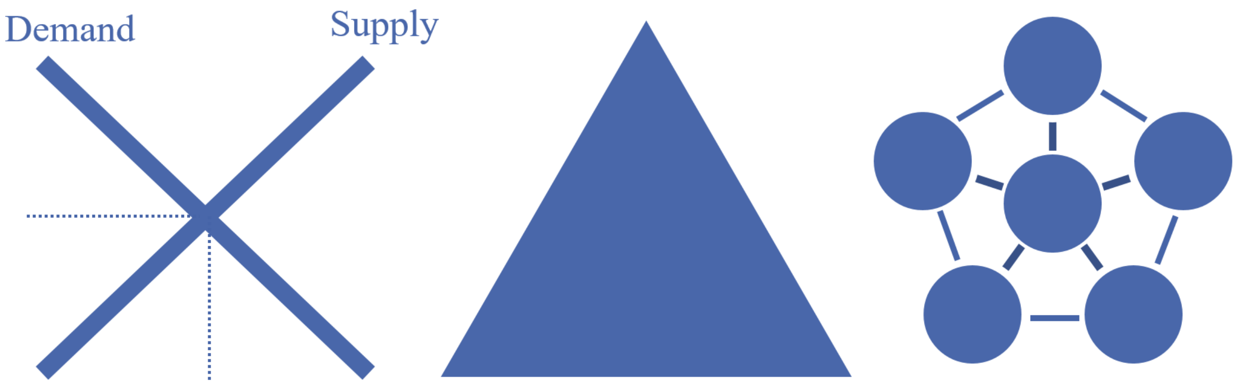


Foto 2.1: The market, hierarchy, and network perspectives illustrated

out of the classic political science literature such as Max Weber. Newer approaches within sociology, political science, and economics break with this paradigm, but it is important to understand the traditional view to appreciate the theoretical developments since then.

Network-based approaches constitute newer academic thinking about regulation. Building on hierarchical, state-centric theories, more recent work emphasizes how state and non-state actors work together to establish systems of governance (Abbott, Genschel, Snidal, & Zangl, 2012; Abbott & Snidal, 2009; Lister, Poulsen, & Ponte, 2015a). Others examine the influence on policies using strategic networks and alliances, and seeks to understand how individuals and professionals impact policymaking and regulation (Carpenter et al., 2007; Seabrooke & Tsingou, 2015; Seabrooke, 2014).

Based on this network approach, this report examines how networks of actors give identity to regulation and regulative entities. This is done by using the framework of Actor Network Theory (ANT) and applying it to three political cases, as described in the introduction (Latour, 1987, 2005). This will be presented in the last chapter of the analysis. Finally, the implications of analysing across perspectives and the impact this has on the regulation of

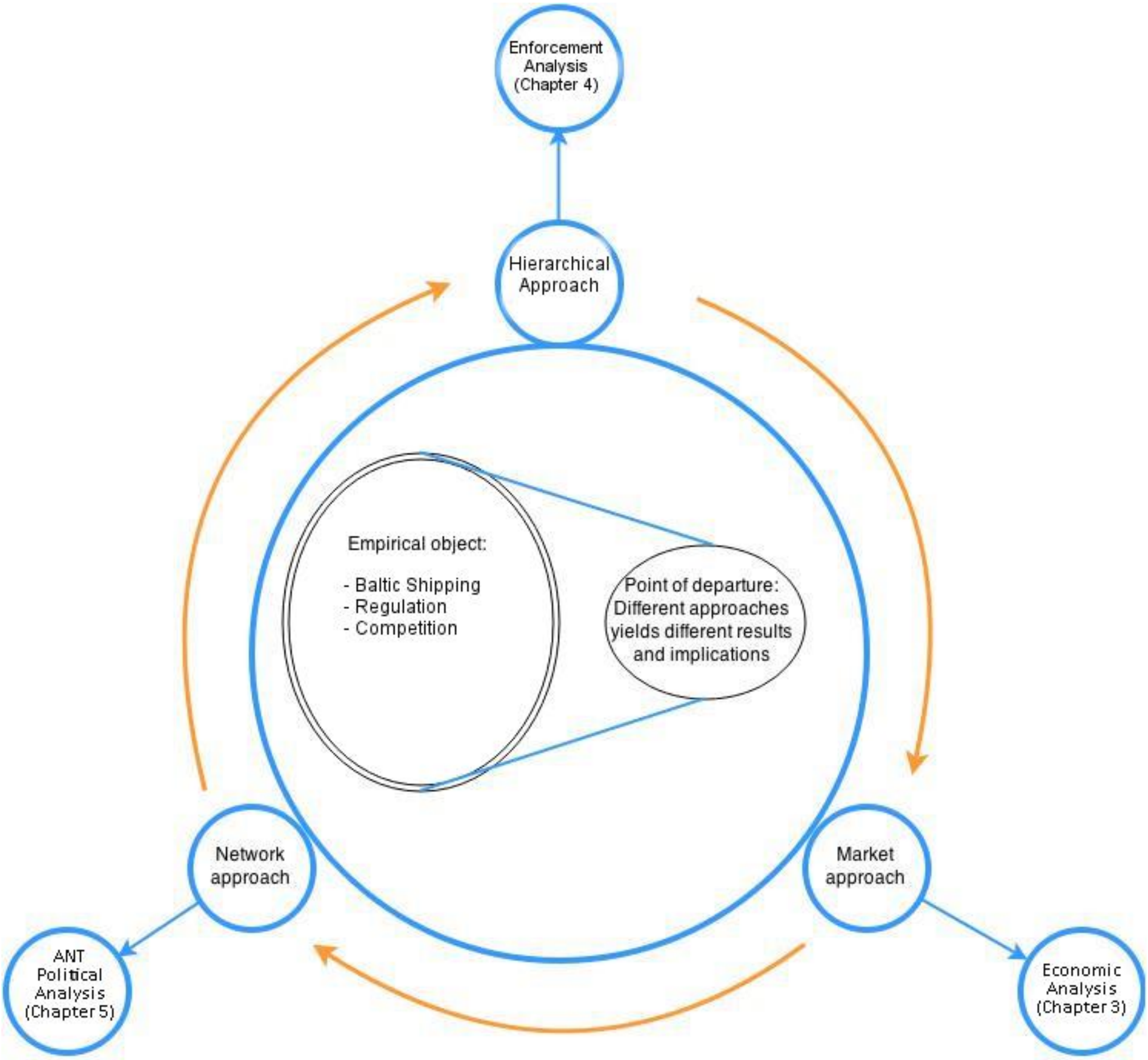


Foto 2.2 Different Theoretical Approaches to the Same Empirical Object
A figure to define the structure of this report.

international shipping is explored in the final chapter of this report.

2.1 OVERVIEW OF THE ACTORS

Following the above logic that different perspectives entails different realities and societal structures, it depends on the deployed perspective what kind of actors we perceive. However, to assist the reader in understanding the world of shipping the report will introduce the most important organizations in the regulative mesh. These organizations are examples of the ones affected by regulation as well as the ones that affect regulation, and as such, the actors are referred to at various points throughout the report. It is important to keep the introduction in mind and be prepared to view these actors from different points of view.

When defining all stakeholders for the regulation of the Baltic Sea it is useful to operate under a framework of the following five sub-categories: Bodies of international/regional co-operation, Industry Organizations, Firms/Owners/Operators, Suppliers and Non-Governmental Organizations. Due to the very nature of these stakeholder types, overlaps in membership will be defined within each stakeholder section. The overlapping memberships will focus only on those relevant for this study. Oil and bunker companies are omitted from this list as their operations are ad-hoc linked to case-by-case demand, thus there is a high mobility of these assets traversing in and out of the SECA. At the same time this is not a complete overview, given the very nature of how to define stakeholders.

2.1.1 Bodies of international and regional regulatory co-operation

The International Maritime Organization

The IMO is the specialized agency of the United Nations, where states cooperate to provide standards related to vessel security, safety and environment. It is the only institution with the governance mandate to adapt global regulation for vessels, yet it relies on individual states to implement regulation. Thus, states have to ratify, implement and enforce legislation of the IMO. Ensuring a level playing field for the maritime industry is thus tied up on successful negotiations within the IMO and that states implement the agreed legislation in an effective manner.

The decision-making of the IMO is based on a system of consensus, allowing for maximum implementation with member states. Measures adopted should have a wide impact, and not only be secluded to a narrow segment of states wanting high standards. Therefore, the IMO should be seen as a maritime organ securing minimum standards, given the regulatory space and its member's power. Influence within the IMO is limited to national delegations, yet they can invite any stakeholder deemed relevant for the delegation (IMO, 2015). The IMO has agreed upon multiple conventions since its inception in 1959. the three major ones being the International Convention for the Safety of Life at Sea (SOLAS), the International Convention for the Prevention of Pollution from Ships (MARPOL) and the International Convention on Standards of Training, Certification and Watch keeping for Seafarers (STCW). In recent decades, IMO has started to tackle problems arising from pollution and has amended MARPOL to reflect these new policy objectives (IMO, 2015).

European Union (EU)

The economic and political partnership of the European Union has a high regional mandate, due to the regulatory powers of the commission. It is based on the rule of law, with voluntary and democratically treaties providing binding targets for member states. The single market in the union is an example of the mandate allocated to the EU, and the harmonization of countries. It can therefore be defined as a catalyst for uniform interpretation and enforcement of Sulphur regulation by Baltic EU member states, as seen in Directive 2012/33/EU (European Parliament & Council of the European Union, 2012). The EU Commission is an observer in IMO with no voting power, but retains the ability to submit documents and proposals.

HELCOM

The Baltic Marine Environmental Protection Commission is the governing body of the Helsinki Commission (HELCOM). Its members comprise of the states around the Baltic Sea, where the commission seeks to increase intergovernmental cooperation to protect the marine environment. Efforts by HELCOM to further increase environmental protection have recently been halted by Russian policy makers, who disagreed that HELCOM should support further international restrictions in the Baltic Sea. This is the case of NO_x emissions and how stringently SO_x has to be enforced (International Maritime Organization, 2008).

2.1.2 Industry Organizations

ECSA

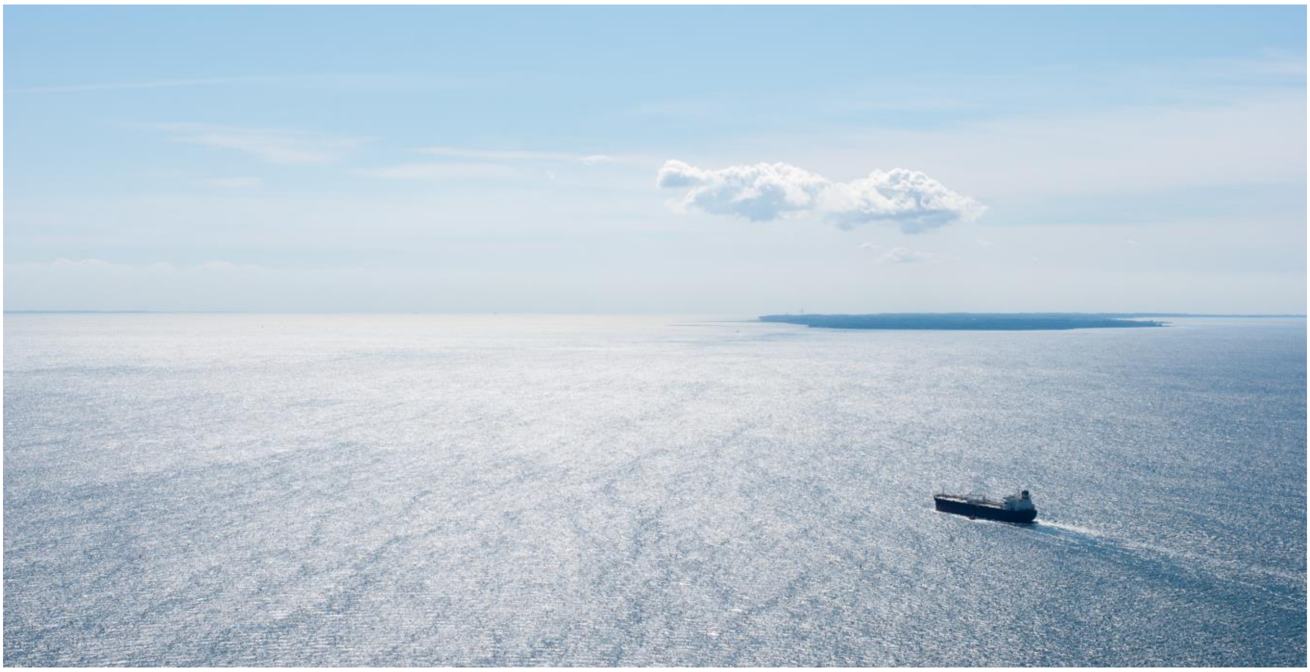
The European Community Ship-owners Association is a member association consisting of 21 national associations, within the EU and Norway. ECSA provides policy inputs to EU from different internal committees and working groups, containing representatives from the national organizations and industry experts. They have ten working group committees covering different topics within shipping policy. It is notable that ECSA has a task force only concerned with Sulphur regulation and coordination between members (ECSA, 2015).

BIMCO

The Baltic and International Maritime Council (BIMCO) is the world's largest international shipping association, with 2300 corporate members representing 65 percent of the global tonnage. Members include firms and organizations from across the industry: operators, brokers, agents, managers and ship-owners. The core objective of BIMCO is to facilitate ease of commercial operation through promotion of harmonisation and standardisation of all shipping related activities. Fair business practices are important to the organization, seeking to achieve open access to all markets. BIMCO is an active member of IMO, and frequently submits papers to the committees in achieving this objective (Baltic and International Maritime Council, 2015).

ICS

The International Chamber of Shipping (ICS) is an international trade association for the shipping industry, representing ship-owners and operators in all sectors. Its members include national ship-owners association's across the world, covering 80% of the world's merchant tonnage. The ICS is concerned with all maritime questions involving technical, legal, employment or regulation. They strive for an international regulatory framework that supports safe and environmentally sound ship operations, opposing unilateral or regional schemes. The ICS represents its members in various intergovernmental bodies, including the IMO, and have a regional partnership with ECSA (ICS, 2015).



Source: Scanpix / Iris

World Shipping Council (WSC)

World Shipping Council (WSC) is an industry trade group with 28 members, representing approximately 90 percent of the global liner shipping capacity. Their aim is to provide a coordinated voice for the liner shipping industry, by working with other industry groups and policymakers. The primary focus is maritime security, but they are also involved in the development of international container standards, environmental stewardship and an efficient transportation infrastructure (Worldshipping, 2015).

INTERTANKO

International Association of Independent Tanker Owners (INTERTANKO) is a forum open for all independent tanker owners and operators. As of January 2014, INTERTANKO had 212 members with a combined fleet of 3040 tankers. On top of this, they also have 300 associated members, which are all directly or indirectly related to the tanker industry. The goal of the forum is for the industry to meet and create statements based on policies on a local, regional and international level. They are perceived as an NGO within the IMO, and are active within the UN Conference on Trade and Development (Intertanko, 2015).

EUROMOT

The European Association of Internal Combustion Engine Manufacturers (EUROMOT) is a European organization for producers of internal combustion engines, yet they are also active worldwide in affecting different industry frameworks. EUROMOT's mission is to communicate the added value of internal combustion engines. They seek to develop the right level of regulation for the minimal impact on the local and global environment, by providing technical input for policy discussions. Marine engines make up a sub-section of EUROMOTs focus, as they are also working with road, non-road and stationary engines (EUROMOT, 2015).

INTERFERRY

With a global scope, Interferry represents the ferry industry worldwide, with 225 members from 38 countries. The association was created to allow members to network and provide a forum for learning synergies across markets. Importantly it represents its members in the IMO and within the ECSA; in both organizations as a consultative member. It supports high safety regulation, open competition, consistent shipping regulation and adherence to environmental regulations (Interferry, 2015).

TRIDENT ALLIANCE

A coalition of 31 shipping operators and owners that specifically focuses on the enforcement of Sulphur regulation in Northern Europe. Trident seeks to create a robust enforcement mechanism in the region eliminating the incentive for non-compliance. Enforcement and compliance are seen as crucial in ensuring a level playing field for all operators. Despite being a smaller actor internationally, they try to position themselves as a regional lobbying group regarding Sulphur regulation, due to the member's high activity level in the Baltic. Their mission is to raise awareness, ensure transparency of member's compliance and encourage innovation in enforcement technology. Members include: Stena, Unifeeder, Maersk Line, DFDS, Hamburg Süd and Wallenius Wilhelmsen logistics (Trident Alliance, 2015).

2.1.3 Firms/Owners/operators

MAERSK

The Maersk Group conglomerate works with logistics and maritime operations on a global scale: Maersk Line, APM Terminals, Maersk Shipping Services, Maersk Drilling and Maersk Oil. For a company with so many maritime assets, there is a high interest on how regulation influences the OPEX of their operations. For SOx regulation in the Baltic and North Sea specifically, Maersk has to consider implications of navigating within the SECA zone and the extra cost of compliance, which deviates a lot within the different business areas. Maersk Line only operates marginally within the SECA, thus having to choose a compliance strategy suitable for this need. On the other hand, Maersk Shipping Services, Oil and Drilling operates purely inside the SECA during their operational years. The prospect of the expansion of the SECA to other regions, Mediterranean and parts of Asia increases the interest for how regulation is operationalized. Maersk themselves are highly active within the regulatory framework, active in WSC and BIMCO. At the same time, they have high demands for their suppliers, creating a demand for certain assets in their pursuit of environmental and efficient transport solutions (Mærsk, 2015).

DFDS

Provider of shipping and ferry services primarily, within the SECA, DFDS has a large exposure to the new regulation. Operating 55 vessels, it is a challenge to define what the optimal compliance strategy is, given multiple vessel types and routes. The DFDS fleet is predominantly composed of Ro-Ro vessels, approximately 80% of the revenue generated by goods transport in 2014, and approximately 20% generated by its 6 million passengers (DFDS, 2014).

STENA

The Swedish ferry operator Stena line has a slightly different profile compared to DFDS, transporting 14.6 million passengers with a fleet of 35 vessels in 2013. Thus Stena is geared more towards passenger transport, compared to the DFDS' focus on Ro-Ro activities. The regulatory exposure of the two operators is very similar, as Stena also has a well-developed network in the SECA and activities around the British Isles (Stena Line, 2015b).

UNIFEEDER

Operating a network of vessels in the Baltic, Unifeeder has the same exposure to the change in regulation as the two other major regional vessel operators, Stena and DFDS. As opposed to the other actors, Unifeeder operates as a short sea shipping service in the Baltic – using a network of feeder ships, trains, and trucks. This allows them to utilize the modular mode of transport, potentially shifting volumes from shipping to land based transport. Their network is also highly active in the Mediterranean, where a future SECA is also proposed, providing them an incentive to be a part of creating the Baltic SECA (Unifeeder, 2015).

2.1.4 Suppliers

MAN DIESEL & TURBO

Within the market for low and medium speed marine engines, MAN is a lead designer and manufacturer worldwide. They cover approximately 50% of the power needed for all world trade covering engines, auxiliary power and turbochargers. Diversified with in the maritime industry, MAN provides power to vessels of many segments: container, cruise, tanker, support, and offshore services. The regulatory interest of MAN is how power plants can be modified directly or indirectly to provide compliance to the SECA and still deliver the same product to its customers (MAN Diesel & Turbo, 2015).

WÄRTSILÄ

Wärtsilä is a global producer of complete lifecycle power solutions for energy markets and the maritime sector. They produce scrubber exhaust cleaning systems for both these markets, allowing them to diversify the application of their technology. This allows them to be a "one-stop" solution for providing a SECA-compliant power solution for new vessels, and compatibility with vessels using their power solutions. For suppliers like Wärtsila, sudden changes in regulatory requirements are costly, so naturally these firms are engaged in the policy process (Wärtsila, 2015).

ALFA LAVAL

Alfa Laval focuses on saving energy and protecting the environment, with technological expertise in fluid handling, heat transfer, exchangers, separation and pumps. Alfa Laval is present in multiple industries, having three core focus areas: "Energy & the Environment", "Food & Pharma" and "Marine & Diesel". Within the Marine and Diesel area, their product portfolio contributes to virtually all elements of vessel operation. Like Wärtsila, they are also interested in how the regulation affects the overall performance of vessels, and the effect on the market for scrubbers, as this affects their asset portfolio (Alfa Laval, 2015).

2.1.5 Non-Governmental Organizations

CLEAN SHIPPING COALITION

A global environmental organization specialized exclusively on shipping issues. Their objective is to protect and restore the marine and atmospheric environment. This is achieved by developing operational standards for vessels that are sustainable, safe and make social and economic sense. CSC is supported by their wide knowledge base from their eight European climate NGOs. They have status as observer at the IMO since 2010, providing their member NGOs access to the global mandated organization. The CSC actively seeks to allow smaller environmental groups to access to the IMO, as it sees the IMO as having an under-representation of environmental group (Clean Shipping Coalition, 2015).

TRANSPORT AND ENVIRONMENT

Their mission is to promote policies that facilitate sustainable transport and minimize the impact and on the environment. The organization represents around 50 environmental groups and campaigns (including the World Wildlife Foundation), working on national, regional, and local level. It provides ideas and knowledge for the members, by providing scientific and evidence based research for its members. The policy focus of the organization, and its members, is primarily processes on the European continent. They are members of the Clean Shipping Coalition, making up a majority of CSC's the delegation to the IMO (Transport and Environment, 2015).

GREENPEACE

Greenpeace is known for its activist approach to questions of environmental protections. In the maritime world, Greenpeace often takes a more radical position compared to other NGOs, such as Transport & Environment, utilizing their global array of activists and three activist vessels. Their main mission is built around the protection of wildlife in the ocean, as well as the sensitive ecosystems and habitats of marine animals. Greenpeace retains an observer position at the IMO which includes the ability to submit papers and proposal, but not voting rights (Greenpeace International, 2016).

3 THE MARKET PERSPECTIVE: FIVE STRATEGIES FOR SHIP-OPERATORS

ALTHOUGH THE PRODUCT OF POLITICS, THE SULPHUR REGULATION INTRODUCED IN 2015 IS BASED ON ECONOMIC PRINCIPLES OF REDUCING COSTS TO THE SOCEITY INCURRED BY POLLUTANTS FROM MARITIME OPERATIONS. CONSEQUENTLY, THE MARITIME INDUSTRY FACES A COMPLEX SET OF DECISIONS OF HOW TO MINIMIZE THE COST INCREASES FOLLOWING THE TIGHTENING OF ENVIRONMENTAL STANDARDS. THIS CHAPTER THOROUGHLY ANALYSES THESE CHALLENGES.

In the first part of this chapter, the microeconomic foundations behind regulation of the industry are introduced following an elaboration on why such regulation has been introduced to the maritime industry. The second part introduces the reader to the different strategies ship-owners operating in the Baltic and North Sea can adopt in response to the introduction of the Sulphur regulations. Thus follows a quantitative study further examining the strengths and weaknesses associated with adopting each of these strategies.

3.1 THE ECONOMICS OF REGULATION

The economics of regulation is a large and essential factor in determining when and how to regulate emissions and consumer behaviour in a modern society. Several different methods of regulation exist and forming the right level of regulation is essential in maximizing the societal utility[1]. In most cases regulation is introduced when negative externalities are associated with the consumption or production of a god in a society, but before continuing to a review of the economics behind an efficient regulative framework, an introduction to the economic concept of externalities is required.

3.1.1 The dilemma of externalities

An externality is said to occur when an actor produces or consumes a certain good, which has a negative, or positive effect on the utility or profit of another actor in a way, which is not directly, intended (Perman, Ma, McGilvray, & Common, 2003). In the context of this study, externalities transform into the adverse effects on the environment and health of society resulting from emissions from international ship traffic in the Baltic and North Sea. While the primary purpose of the ship-owners is the transport of goods, the pollution is therefore a by-product of this and consequently an externality. Negative externalities, such as pollution, are common amongst price actors in sectors such as transportation and production industries. Measured monetarily, the effects associated with these externalities may amount to huge sums. A vast majority of such private actors in these industries are profit maximizing and therefore aim to operate using the technologies that provide the lowest costs to the firm.

In a scenario with no regulation, these external costs to human health and the environment from pollution are passed on to the public. This creates an economic burden for society in the form of loss of life, loss of quality of life, and increases in healthcare expenditure. For the international maritime transport industry, this means fuelling the ship with highly polluting heavy fuel oil and passing the associated costs on to the populations of the coastal states situated near the shipping lanes. Regulative measures are therefore needed in order to minimize the costs faced by populations exposed to negative externalities created by pollutants. While the emissions from ship traffic are an example of negative externalities, positive externalities may also arise during the consumption or production of a good. An example of these is the pollination of nearby plants from the bees of a nearby apiary.

[1] Utility is an economic measurement of the welfare of the public. That is, a higher level of social utility will improve the welfare of the society. Welfare is often measured in monetary terms but may also take unmeasurable terms such as happiness.

In the context of Sulphur emissions in the Baltic and North Sea, government intervention is required in order to minimize the social costs incurred by the emission of pollutants, from maritime traffic. This regulation must shift the costs, so that the polluter instead of the polluted bears the externality costs. Such a scenario of negative externalities from the maritime industry is exemplified in figure 3.1 below.

In a scenario with a free and unregulated market, the market supply curve labelled "private cost" denotes the supply and therefore the costs encountered by the private maritime industry. If the supplier only takes into account these private costs, all the costs of negative externalities are passed on to society. The initial equilibrium without any regulation is therefore found at the intersection between the private demand and the supply curve labelled "private costs". In this equilibrium, a large amount of goods is produced at a low price, which translates into a low level of freight rates in the Baltic and North Sea.

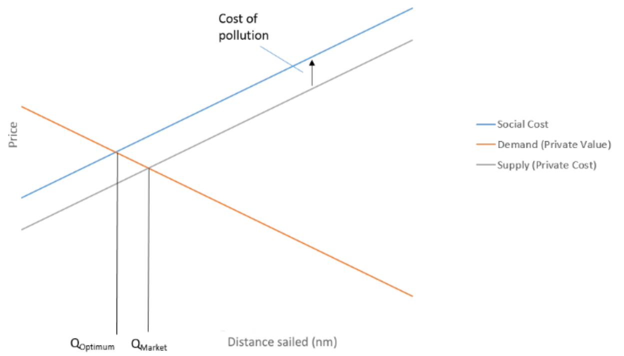


Figure 3.1: Negative externalities and the social optimum
Source: Own illustration

The private costs do not encompass the total costs for society that arise due to industry emissions causing adverse effects to the health of humans and nature alike. These societal total costs are reflected in the cost curve labelled "social costs", which is composed of private costs plus cost of externalities. This implies that the area between the two cost curves denotes the total costs of pollution. The social optimum (i.e. the economically optimal level of production) is therefore found at the intersection of the demand and social cost curve, changing the equilibrium to a point where the price of the good is significantly higher and the amount produced is lower, depending on the price elasticity of demand[2]. The aim for the policy makers are therefore to adopt a level of regulation that shifts the private cost supply curve sufficiently such that the social optimum is achieved, taking potential demand alterations into account as well.

3.1.2 The optimal level of regulation

After establishing that the production of a given industry is causing negative externalities, regulation is required in order to reduce the negative external costs. To do this, it is required that the right level of regulation is determined, which is significantly more complicated. Difficult questions arise: What is the right level of regulation, what determines the social optimum and why not just ban the release of emissions into the atmosphere all together? In order to answer these questions, further economic reasoning and analysis is needed in order to facilitate an effective level of regulation of the industry.

A rational assumption is that policymakers are aiming to maximize social utility and therefore affect either the total supply or demand such that an overall societal optimum is achieved. Such policymakers must therefore aim to strike a balance between the damage done by the negative externalities and the benefits to society created by the good produced. While the pollution in itself does not presents any benefits to society, the primary industry sector emitting the pollution may provide vital services to society and therefore provide an increase in social welfare. In the context of Sulphur emissions in the Baltic and North Sea, international ship traffic plays an important part in the transport of goods between the world's economic regions, thereby bolstering trade and economic growth. Such beneficial and disadvantageous effects of emission abatement along with the socially optimal level of regulation are illustrated in figure 3.2 on the following page[3].

The line labelled "pollution costs" illustrates the societal external cost of the damages to human health and the environment given the level of pollution. Intuitively, a higher level of Sulphur particles in the atmosphere will result in higher costs to society due to the effects of an increasing amount of pollution-related illness. The other line labelled "pollution benefit" illustrates the benefits to

[2] For the shipping sector where such elasticity is low, the reduction in the amount of cargo transported is expected to be insignificant.
[3] For an in debt review of externalities and the social optimal level of regulation see Perman, et al., (2003).

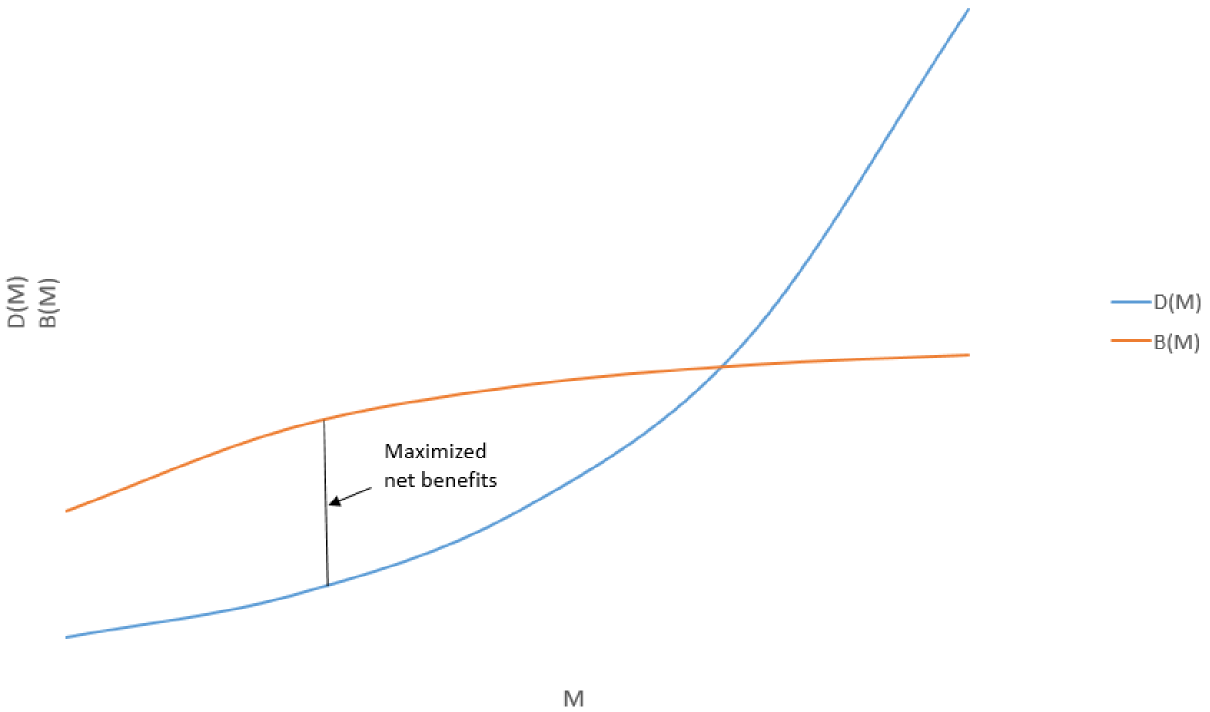


Figure 3.2: The optimal level of regulation
The blue line denoted by "D(M)" illustrates the total damage caused by the pollutant while the red line denoted by "B(M)" illustrates the benefits arising from the polluting industries and activities. The optimal level of pollution is found at the level of emissions "M" where the net benefits are maximized, illustrated by the vertical line labelled "maximizes net benefits".
Source: Own illustrations based on figures from Perman, et al., (2003).

society from the source of the pollution. The benefit is increasing with the level of pollution, converging towards a certain point where an increase in the level of emissions will have no beneficial effect to society. For the commercial shipping industry this makes sense, because an increase in the level of Sulphur beyond the current level of 3.5 percent would not provide larger profits nor lower the operational costs of the shipping firms. Conversely, regulating the level of Sulphur content very strictly will incur significant cost to the ship-owners, in turn resulting in higher freight rates and reductions in sea borne trade. A decrease in seaborne trade leads to a decrease in societal utility.

Because policy makers aim to maximize the societal utility, the optimal level of emission abatement is found where the vertical distance between the benefit and damage function reaches the greatest value. This point, known as the societal net benefit of pollution, therefore maximizes the social utility of pollution in similar ways as a firm profit maximizes its profit margin.

Another and more convenient way of interpreting the societal net benefit of pollution is to use the notion of "marginal damage" and "marginal benefit" functions, respectively, as presented by the lower graph in figure 3.3. The "marginal pollution cost" function is increasing with the level of emissions while the "marginal pollution benefits" function is decreasing to the point where an increase in the level of emissions will not result in an increase in benefit[4]. The optimal emission level, where the societal benefit is highest, is found at the intersection between the marginal damage and marginal benefit curves. This is indicated above, where the marginal costs of abatement equals the marginal damage as illustrated by point E.

Another important implication from the cost curves is the explanation of why a total ban on emissions will not always be beneficial to society. From figure 3.2 it can be seen that as the emission level is reduced to a level close to

[4] In a scenario with an unconstrained emission level, the firms, assuming they are profit maximizing, will pollute at the point where the marginal benefits equal zero resulting in a high level of damage to the society and low costs to the firms (Line A). In such a scenario all the costs associated with reductions in human health and environmental damage is passed on the public while the firms experience low costs and a potential high profit margin.

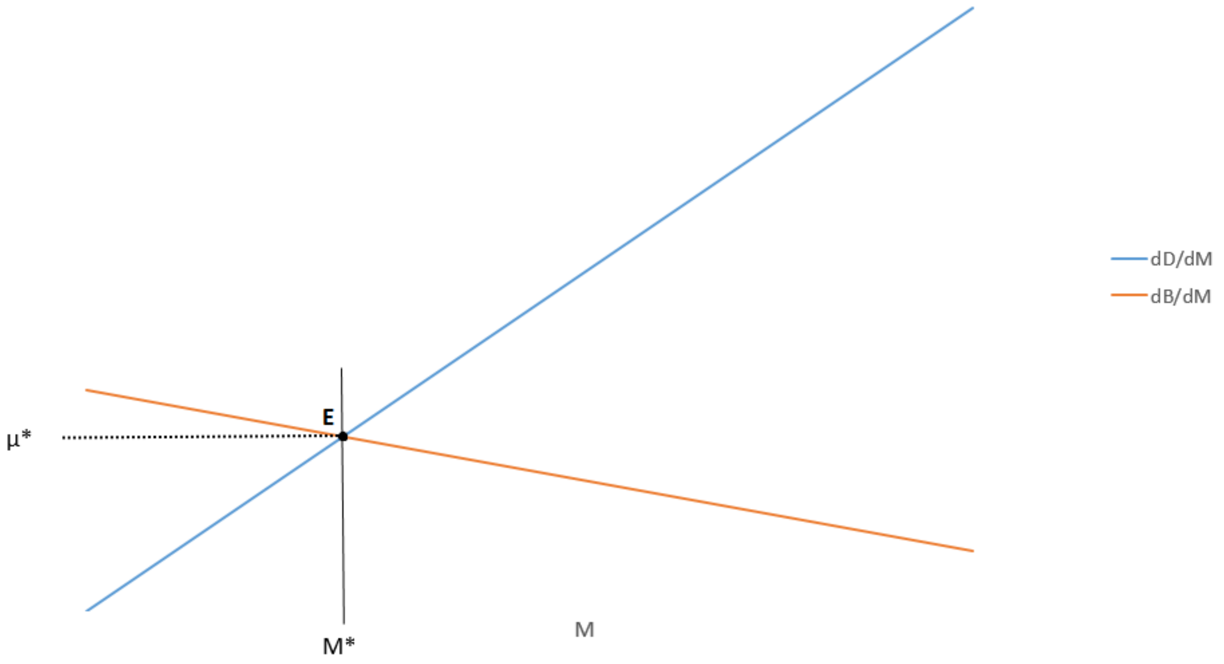


Figure 3.3: Alternative determination of the optimal level of regulation
The blue line denoted by "dD/dM" illustrates the marginal damage caused by the pollutant while the red line denoted by "dB/dM" illustrates the marginal benefits arising from the polluting industries and activities. The optimal level of pollution is found at point E where the net benefit of the pollutant is maximized.
Source: Own illustrations based on figures from Perman et. al., (2003).

zero, the benefits of pollution far exceeds the total costs of pollution resulting in a social efficiency loss. The fact that society may actually benefit from negative externalities such as pollution goes counter intuitive and explains why policy makers does not ban the emissions of Sulphuric oxide all together. Why is this the case and how can pollution be beneficial? In the case of the shipping industry, a complete ban on Sulphur particles in fuel would increase the operational costs of ship-owners to a level that would cripple individual firms until alternative technologies, such as LNG, matured.

Such a scenario would not only force firms below the shutdown point, but also severely hinder maritime transport of goods, causing shortages and drastic freight rate increases and, consequently, a large societal loss. Finding the appropriate level of regulation of pollutants is therefore a significant requirement in order to reduce the adverse effects to human health and the environment, while at the same time ensuring that it remains feasible for firms to stay in business.

It is important to note that the functions illustrated in figures 3.2 and 3.3 are standard emission curves and therefore reflect a general interpretation of the costs and benefits of pollution and emission regulations[5] - the concrete effects of pollution in the Baltic and North Sea may, in reality, be different. Further, the cost and benefit curves depicted in these figures only illustrate the societal optimal level of pollution and do not explain how different forms of regulation may achieve a societal optimum. For example, the Sulphur regulation in the Baltic and North Sea is implemented as a technical standard that requires the Sulphur content of emissions not to exceed a specific value (0.1 %), while other environmental standards instead tax each harmful unit of pollutant used or emitted[6].

Although all regulation increases the price of the good produced, thus lowering the amount of the negative externality produced, the way society is compensated for the costs of pollution do, however, differ significantly between the two forms of regulation. For a general emission tax to be effective, the tariff rate must be

[5] The standard emission curves are adopted from Perman et. al. (Perman et al., 2003).
[6] Several other forms of regulations exist such as the cap & trade system of the Kyoto Protocol.

Source / Year	External health related costs from all emissions from shipping on the northern hemisphere (billion EUR)	External health related costs from all emissions from shipping in the Baltic / North Sea (billion EUR)	External health related costs from Sulphur particle emissions from ship traffic on the northern hemisphere (billion EUR)	External health related costs from Sulphur particle emissions from ship traffic in the Baltic / North Sea (billion EUR)
Year 2000	58.4	22.0	27.0	11.6
Year 2011	54.3	14.7	21.0	3.55
Year 2020 (projected)	64.1	14.1	24.3	0.360

Table 3.1: External Health Related Costs in Europe

Illustrated are the total external health related costs from both total emissions and Sulphur in Europe as a consequence of international ship traffic on the northern hemisphere and the Baltic and North Sea in year 2000, 2011 and 2020 (projected). All costs are measured in 2006 constant euros.

Source: (Brandt et al., 2013a)

sufficiently high in order to lower demand to the point of the social optimum. Some of the societal costs are also compensated for due to an increase in tax revenues, which in turn is spent on society. In such a scenario, the firms are enticed to lower their emissions by adapting new technologies or fuel types, in order to reduce the tax burden, but are not required to do so. This contrasts to the Sulphur regulation in the ECA zone, where the adaption of new technological or fuel types is mandatory in order to avoid sanctioning. The reduction in the emissions of Sulphur dioxide may therefore be achieved without a significant reduction in the amount of production; which in this case is the amount of freight that is transported through the ECA zone. Additionally, the form of regulation adopted in the Baltic will it will not generate tax revenue as seen with other forms of regulation. In light of such complexities in the regulation of negative externalities, it is worth noting that the graphs depicted in figures 3.1 to 3.3 are simplified and does not emphasize all the aspects and impacts of the introduction of regulative schemes.

3.1.3 The social costs in numbers

While it is simple to illustrate the optimal level of emissions allowed from the point of theoretical micro economics, calculating both the actual costs incurred and benefits accrued by society is quite complicated as a multitude of factors needs to be taken into account. A recent report by Brandt, et al., (2011) written for the Danish Centre for Energy, Environment and Health examines the adverse effects to human health in Europe, resulting from emissions of air pollutants from different industry sectors. The adverse effects of these emissions are calculated using a combination of air pollution models, data on European population densities and economic evaluation models and converted into both direct health impacts and monetary costs. The results show that the impacts on human health due to air pollution from international ship traffic on the northern hemisphere are predicted to increase between 2000 and 2020 compared to all other industrial sectors where a decrease is predicted. In the study, Brandt, et al., (2011) found that international ship traffic on the entire northern hemisphere resulted in approximately 49,500 premature deaths in Europe in year 2000 and projected this number to rise to approximately 53,200 in year 2020. Measured monetarily, the total European external health related costs from international ship traffic on the northern hemisphere was estimated to be a total of 58.4 billion EUR per year in 2000 and rising to 64.1 billion EUR per year in 2020. The external health related emission costs and external health related costs from emissions of Sulphur in Europe as a consequence of emissions from international ship traffic on the northern hemisphere and the Baltic and North Sea in year 2000, 2011 and 2020 (projected) are illustrated in table 3.1.

Although the external health related costs associated with shipping pollution are projected to increase in Europe, the initial introduction of regulation limiting the Sulphur content of fuel to 1 % followed by recent enhancement of in the Baltic and North Sea will have a diminishing effect on these costs increase. Consequently, the external health-related costs from emissions from international ship traffic in the Baltic and North Sea are expected to drop to 14.1 billion EUR in 2020 from a level of 22 billion EUR per year in 2000 equalling a reduction of almost 30 percent.

Source / Year	External health related costs from all emissions from shipping on the northern hemisphere (million EUR)	External health related costs from all emissions from shipping in the Baltic / (million EUR)
Year 2000	805	627
Year 2011	558	414
Year 2020 (projected)	448	357

Table 3.2: External health related costs in Denmark from maritime activities
Illustrated are the total external health related costs from both total emissions and Sulphur in Denmark as a consequence of international ship traffic on the northern hemisphere and the Baltic and North Sea in year 2000, 2011 and 2020 (projected). All costs are measured in 2006 constant euros.
Source: (Brandt et al., 2013b)

The most extreme drop in these health-related costs is those from Sulphur particle emissions from the Baltic and North Sea. These costs are projected to be reduced by more than 95 percent, from yearly costs of 11.600 million EUR in 2000 to 360 million EUR in 2020 even though the external health related costs from Sulphur particle emissions from international ship traffic on the northern hemisphere is still projected to amount to 24 billion EUR in 2020.

Given its location in the middle of the ECA zone, Denmark, at the introduction of the regulation, will experience positive effect in terms of societal costs. The annual health related costs in Denmark from international ship traffic in the northern hemisphere and the Baltic / North Sea in the years 2000, 2011 and 2020 are illustrated in table 3.2.

From the figure it is clear that previous Sulphur regulation such as the 1 % cap in 2010 already had a large impact on the external health related costs from Sulphur particle emissions. This is evident from the changes between 2000 and 2011, and the projections indicate further reductions in these costs from the introduction of the Sulphur regulations of 2015. The external health related costs from international shipping on the northern hemisphere are projected to decrease from a level of 805 million EUR in 2000 to 484 million EUR in 2020. The annual external health related costs from international shipping in the Baltic and North Sea alone is projected to fall to 357 million EUR in 2020 from 627 million EUR in 2000, equalling a reduction of close to 43 percent.
Although the annual reductions in the external health related cost from the step-wise reductions in the allowed Sulphur content are massive, the emissions from international shipping on the northern hemisphere relative to the total external cost from all emission sources is actually projected to increase in the same time period. Reductions in the emissions from other sectors in combination with a high emission level of NO_x will result in the percentage of the total external health costs in Denmark, incurred by maritime traffic, to increase from a level of 18 percent in 2000 to 19 percent in 2020.

The total benefits of pollution are generally more complicated to calculate. In order to compute an approximately correct estimate, the researcher needs information about how the freight rate affects the total economy of the country. However, the effective level of regulation is generally achieved when external costs of the pollutant exceed the abatement costs of the polluters (Press-Kristensen, 2014). In the context of the Sulphur regulations in the Baltic and North Sea, this means that the external health related costs from the Sulphur emissions must exceed the costs faced by the ship-owners operating within the regulated area.
From Brandt et al. (Brandt et al., 2013b), the total health related external costs from emissions of Sulphur from international shipping in the Baltic and North Sea is 17.5 EUR per kilogram of SO_2 emissions. Comparatively, the removal costs of replacing a ton of the 1 percent bunker fuel, currently used in the Baltic and North Sea, with a ton of 0.1 percent Marine gas oil is approximately 11.5 EUR per kilogram of SO_2 emissions (Press-Kristensen, 2014)[7]. This leaves a cost difference (between the external health-

[7] The 1 percent bunker fuel and the 0.1 percent MGO is in this example assumed to be priced at 480 and 690 EUR respectively.

related costs and the removal costs) of 6 EUR, resulting in a net benefit to society of 6 EUR per kilogram of emissions of SO_2 avoided due to the introduction of the regulation. Conversely a total ban on the emission of Sulphur would cause the removal costs of the emission of a kilogram of SO_2 faced by the polluters to be severe and most likely exceed the external health cost level of 17.5 EUR per kilogram of SO_2 emissions by a wide margin. This cost increase reflects the fact that substitute technologies without SOx are quite expensive.

From the above external health related cost estimations, it is clear that the regulation, on Sulphur emissions for ship traffic in the Baltic and North Sea introduced in 2010, has had a dramatic effect on the external health related costs from shipping in the Baltic and North Sea. Further cost decreases are projected after the introduction of the new Sulphur regulations at the onset of 2015. These results indicate that environment regulations on international ship traffic in other parts of the world will result in major improvements in the health of the nearby population and, additionally, resulting in large reductions of external health related costs.

3.2 INDUSTRY COST ANALYSIS

While the introduction of the enhanced regulation of Sulphur emissions in the Baltic and North Seas causes a reduction in the external health costs of humans and environment alike, the requirements of maintaining a level of Sulphur emissions below 0.1 percent will force the owners and charterers of the vessels operating within the ECA zone to adapt new fuel strategies. Several means of complying with the regulation exist, but common to them all is a significant increase in the costs faced by the ship-operators operating within the ECA zone. The aim of this chapter is to project the costs associated with the different strategies which ship-owners can choose. The difference in terms of markets and route segments within the shipping industry means that the dominant strategy may vary between different vessels, and by deploying these cost projections it may be possible to illuminate which factors determine the feasibility of the different strategies.

3.2.1 The adaptation of five strategies

The different strategies of compliance faced by the ship-owner / charterer required in order to comply with the new regulation can be divided into two categories: Fuel switching or engine retrofits.

Fuel switching strategies revolve around the ship-owner freely shifting between standard heavy fuel oil (HFO) when outside of the ECA zone and ultra-low Sulphur fuels when entering the Baltic and North Seas. These ultra-low Sulphur fuels include the commonly used marine gas oil (MGO), marine diesel oil (MDO) and several other types of fuel currently under development[8]. These types of fuels are significantly more expensive than standard HFO.

The ship-owner can instead decide to adopt a strategy of retrofitting the vessel with a scrubber, which filters away a large fraction of the Sulphur emissions, thereby allowing for the continued use of cheap high Sulphur fuels. Currently, several types of scrubbers exist, including both dry and water scrubbers with the latter coming in both open- and closed-looped form. Another possible retrofit is the installation of engine modifications and pressure tanks to allow the ship to be capable of operating on both LNG and HFO. For a company operating a large fleet of vessels, the introduction of the enhanced Sulphur regulations has the potential to increase the fuel related costs by hundreds of million euros. Selecting the most cost-effective way to reduce the Sulphur emissions to ECA-compliance levels is therefore of immense significance in a market of intense cost-competition.

Due to the similarity of many of the types of alternate fuels and scrubber types, this analysis will only examine three concrete strategies of compliance deemed most likely to dominate the market in the long run: Fuel switching to MGO, retrofitting the ship with a closed loop freshwater scrubber, and finally retrofitting the engine to operate on LNG. Additionally, a strategy of non-compliance is included where the ship-owner continues operating on HFO and take advantage of the lax enforcement scheme

[8] For example, has Exxon recently announced the introduction of a new form of low Sulphur fuel. This new fuel HDME 50, short of Heavy Distillate Marine ECA 50 is compliant with the new Sulphur regulations by containing under 0.1 % Sulphur and the viscosity of the fuel is makes the storage and handling similar to that of HFO (ExxonMobil, 2014). This reduces the risk of thermal shocks to the engine when switching fuel reported on several occasions for vessels switching to MGO. Currently HDME is only produced by Exxon, is only stored at a few ports in the Netherlands and Belgium and it remains to be seen if the price can compete with that of MGO. Exxon has received a lot of interest from the shipping industry and both of the companies Norden and Torm mention HDME as a possible fuel according to Shippingwatch (Raun, 2014b).

Strategy	Strength	Weakness
Scrubber	Can continue operating on HFO No fuel switching	Moderate investment costs
MGO	No investment costs Can continue operating on HFO outside the ECA zone	High fuel spread between HFO and MGO
LNG	LNG fuel is fairly cheap in EU	Large investment costs Lack of infrastructure and refueling capabilities
Non-compliance	No need for retrofit nor fuel switching Current enforcement is limited	Risk of bad publicity and future sanctions

Table 3.3: Strength and Weaknesses of compliance methods

currently reported to exist within the ECA zone. Finally, the ship-owner can decide to avoid operating within the ECA zone at all, either by terminating the vessel or relocating it to other parts of the world (insofar the vessel may continue to generate revenue for the owner). The economic strengths and weaknesses of these five strategies are illustrated in table 3.3 and further examined below.

Scrubber

By retrofitting the ship with a scrubber system, the vessel can continue to burn HFO when operating in the Baltic and North Sea ECA zones, thus keeping the bunker costs at a level not significantly higher than the level before 2015. This especially makes the scrubber an attractive solution for vessels operating a majority of the time within the ECA zone as the price for MGO remains significantly higher than that of HFO. Further, if the more restrictive global Sulphur regulation is adopted by the IMO all vessels must emit a maximum of 1 % Sulphur in all waters from the beginning of the next decade.

Retrofitting the vessel with a scrubber will allow the vessel to continue operating on the cheaper 2.2 % or 3.5 % HFO in this situation. Although it is uncertain when this global regulation will come into effect, this study assumes such a global Sulphur cap by 2020.

The retrofitting costs of installing a scrubber are, however, significant and costs may easily amount to several million USD, depending on the size of the vessel. This is especially a problem for many ship-owners as the industry has experienced a limited access to capital and credit in recent years, due to many banks trying to reduce their shipping-commitments (Stulgis, Smith, Rehmatulla, Powers, & Hoppe, 2014). Additionally, it has still to be determined how policy makers will form the regulation of waste removal from open loop scrubbers, creating uncertainty among ship-owners on what type of retrofit the significant amount of capital required should be allocated.

Due to the capital requirements, a viable strategy for shipping companies is to postpone the decision on whether to install a scrubber, and either operate on MGO or take advantage of the currently vague enforcement procedures in the port states and coastal states of the ECA zone (see part 4). Additionally, a significant fraction of the tonnage operating within the ECA zone is chartered, which reduces the incentive of the ship-owner to allocate the capital on an expensive retrofit when all the operational costs are passed on to the charterer. The problem of moral hazard is further exacerbated as the charterer will have little incentive to pay for the retrofit and thereby make the vessel more valuable, unless the chartering period spans a sufficiently long period such that the investment yields positive returns.

MGO

MGO is an ultra-low Sulphur fuel that makes fuel switching straightforward, since only a few adjustments to the engine are required to configure a former HFO-engine to operate on MGO. Due to the strict Sulphur regulation already being in effect for vessels calling at ports within the ECA zone prior to 2015, these minor extensions to the engine may be assumed to already be installed on a far majority of the vessels operating within the Baltic and North Seas. Additionally, the vessel will still be capable of operating on HFO, and MGO-compliance is therefore the simplest strategy of compliance to adopt. The price of MGO is, however, significantly higher than that of HFO, with a price span as high as 300 USD per metric ton. Adopting the strategy of MGO may therefore be favourable for vessels operating outside of the ECA zone for the majority of the time.

LNG

LNG has the potential to be a big game changer for the maritime industry due to the availability of natural gas on the world market following technological improvements such as hydraulic fracking and the ease of the US export ban. Emissions from LNG contains almost zero Sulphur particles and therefore further helps reducing the negative externalities arising from shipping operations in the ECA zone. For the vessel to operate on LNG, the engine needs to be modified and pressurized fuel tanks must be installed. Depending on the retrofit, the engine will still be able to operate on MGO, creating the possibility of fuel switching in case of LNG price spikes or shortages. At present, infrastructure for refuelling and storage of LNG is severely underdeveloped, which, in combination with the higher costs of retrofitting compared to the scrubber, makes the investment in LNG relatively uncertain. These higher retrofitting costs and infrastructure shortages further exacerbates the current issues of moral hazard and credit constraints mentioned in the scrubber section, as charterers will have no incentives to retrofit the vessel and financial institutions will hesitate lending to risky investments.

Non-compliance

The fourth response strategy is to operate using the cheap high Sulphur content HFO within the SECA regardless of the introduction of the Sulphur regulation. By doing this, the ship-owner avoids paying the price of retrofitting the ship engine and operating on alternative fuels. This means that the only additional costs are the fines and sanctions imposed by the authorities of the ECA zone port city and coastal states (see part 4). The viability of this strategy thus relies critically on the impact and magnitude of the sanctions associated with non-compliance and the frequency of getting caught ”cheating” by authorities. The currently inefficient enforcement scheme adopted by the different coastal states within the ECA zone results, in combination with negligible fine sizes, in non-compliance being an attractive strategy for credit constrained ship-owners.

Termination

The ship-owner has the fifth option of completely putting a stop to operations that take place within the ECA zone. By exercising such a strategy, the ship-owner faces the different options of either relocating the vessel to alternate areas where no Sulphur regulation or enforcement exists, or terminating the vessel completely. The latter option can be done by either selling it on the second-hand market or to a scrap-yard. Such scenarios will potentially incur costs in the form of lost revenue, but may easily be a cost-effective solution for the ship-owner if other areas of the World have an increased transport demand. This is especially true if the price for low Sulphur fuel reaches unsustainable levels, or if the vessel is simply too old for a retrofit to be feasible. The adaptation of such a strategy may only incur extra costs on the ship-owner in the form of opportunity costs stemming from the loss of the market share in the ECA zone and the subsequent changes in the firm’s areas of operation.

The purpose if this study is to identify the most cost effective strategies for the ship-owner to adopt after the introduction of the Sulphur regulation and does not take the revenue aspect into account. The strategy of terminating the vessel, yielding no fuel related costs, is therefore only partially mentioned in this analysis. This is done through a case study on the economic rationale behind the withdrawal of the Stena Line Ro-Ro the “Trelleborg” presented in chapter 3.2.11 later in this analysis.

3.2.2 Observed industry strategies

In 2013 and 2014, the affected firms started considering which modes of compliance to choose. While uncertainties existed with regards to price of MGO, scrubber retrofit, and LNG availability, firms decided on very different compliance strategies in the lead-up to the effective date of the new regulation.

In 2013, the Danish Ro-Ro and Ro-Pax operator DFDS decided to upgrade 11 ships with scrubbers before the end

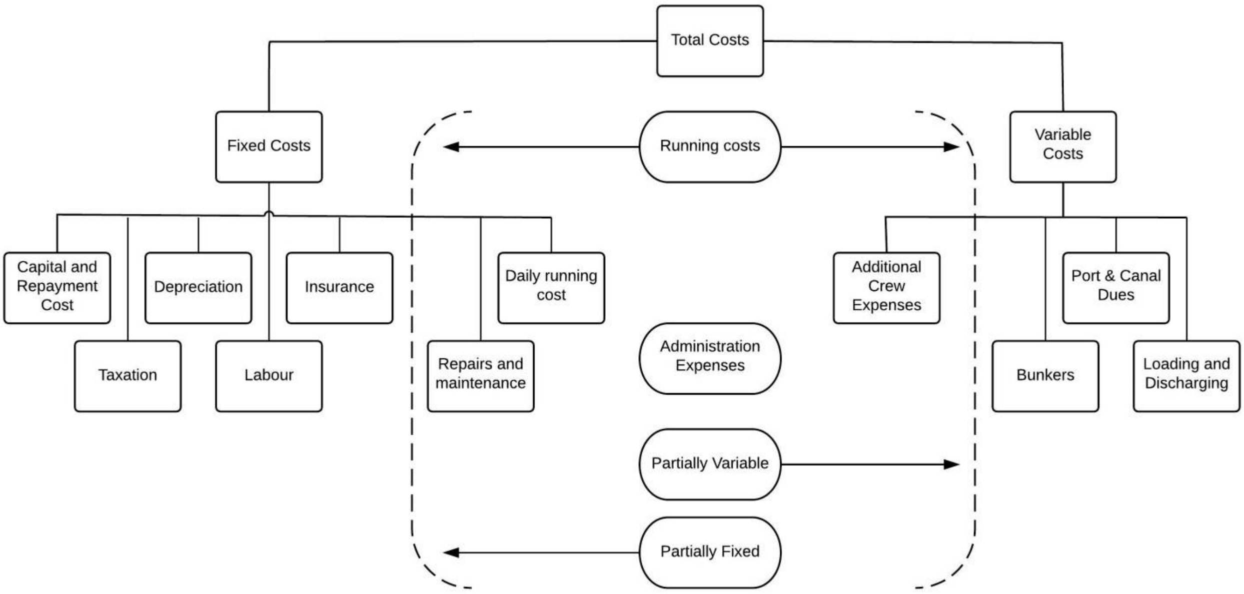


Figure 3.4: The Cost Structure of a Ship
Source: Own illustration, adapted from Stopford (2009)

of 2014 (Knudsen, 2014a). In total, 20 DFDS vessels were technically able to have scrubbers installed. In late 2014, DFDS decided to retrofit all remaining vessels (barring those where retrofit was not technically feasible) at a total cost of 150 million USD. Scandlines, another Ro-Pax operator, also invested in retrofitting a number of vessels (Knudsen, 2014b; Pathak & MEC Intelligence, 2015).

Outside Denmark, large operators such as Brittany and Carnival have invested hundreds of millions of USD in retrofitting their vessels (Jones & Brittany-Ferries, 2015), and an analysis conducted by MEC+ in 2015 showed that at least 14 operators had invested in scrubber retrofitting (Raun, 2015). Common to most of the retrofitting firms were that they operated continuously in the ECA. DFDS and Carnival operate Ro-ro, Ro-Pax, and Pax vessels in loops on short or medium length routes inside the ECA.

Other firms have decided to forgo installing scrubbers and instead followed either an MGO- or LNG-focused strategy. Maersk decided early on to focus on dual-fuel solutions, using MGO inside the ECA and heavier fuel solutions on open sea. In 2014, Maersk stated that this was because most Maersk vessels spent relatively little time in ECAs, and thus the dual-fuel solution would be more economically sound. In addition, Maersk started examining the possibilities of LNG-powered vessels and to what extent facilities in Northern Europe were ready for this (Knudsen, 2014b).

Some firms operating solely within the ECA also decided against scrubbers. Tallink, a Baltic Ro-Pax operator, and Stena, a Swedish RoRo and Ro-Pax operator, both decided to use MGO instead of scrubbers. Stena argued that they could afford to wait to see the scrubber technology develop further and possibly retrofit at some point in the future.

It is evident that different firms have made different decisions, but surprisingly, firms operating under similar circumstances (such as DFDS and Stena) have chosen different compliance strategies. At the same time, operators with very different profiles (such as Maersk and Scanlines) have settled on very different strategies for compliance.

Impact on the cost structure

Regardless of which compliance strategy the ship-owner adopts, the annual costs of operating the vessel will significantly increase. Depending on which of the different strategies adopted, the cost structure of the ship-owner will change in different ways. Figure 3.4 outlies the different cost components that constitute the total costs associated with owning and operating a regular transport ship. The total costs are divided into three segments which, starting from the left hand side, includes the fixed costs, the running costs, and the variable costs. The fixed costs include the cost components that are independent of the amount of days spent at sea, such as capital costs, depreciation, and insurance. These are contrasted with the variable costs, such as bunker fuel costs, that are dependent on the amount of days spent at sea. "Running costs" is an intermediate category that encompasses costs which are partially fixed and partially variable. Examples include components such as repairs & maintenance and administration costs.

Ship-owners complying by running on MGO or MDO will only experience changes in the bunker fuel cost component. According to the current regulation, vessels calling at ports located within the Baltic and North Seas are compelled to operate on low Sulphur fuels, and the small alterations that are needed to operate on these fuels must therefore be assumed to have been installed previously, causing no changes to the capital & repayment cost component. Conversely, adopting any of the other strategies of compliance that involves retrofitting, these cost components change significantly.

The significant costs associated with retrofits of the ship engine causes capital and repayment costs to increase. Furthermore, the complexities of deploying both a scrubber and an LNG engine extension simultaneously may also adversely affect the repairs, maintenance, and daily operational costs. The value of the bunker component may, however, be affected quite differently depending on the retrofit. This is because the continued use of HFO causes the cost component to remain largely unaffected[9]. However, the price spread between HFO and LNG may determine whether the fuel costs increase or decrease if the LNG retrofit is adopted.

The cost component breakdown becomes impractical when allocating the fines to one of the components, as fines are not a direct factor in the typical operational costs of a vessel. If the vessel is caught non-complying several times, the insurer will most certainly charge a higher insurance premium, due to the risk of the vessel being detained, which in turn increases the insurance cost component. As such, it is not straightforward to determine where fines and penalties go in terms of cost components.
Due to the multiple and widely differing options available for the ship-owner when adopting the fifth strategy of withdrawing the vessel from the ECA zone, it is nearly impossible to pinpoint which cost components that may change. If the ship-owner continues to operate in another part of the world both the administration expenses, bunker costs, and port & canal dues may change significantly. Conversely, re-selling the vessel on the second-hand market will effectively cause all the components - except the capital costs – to be redundant.

The different changes in the values of the different cost components as a result of a given strategy does, however, not allow us to infer which of these strategies results in the lowest total costs. A detailed analysis incorporating the different variables and strategies a ship-owner is faced with when operating within the Baltic and North Seas is therefore required.

3.2.3 Literature Review

During the formulation and implementation of the new Sulphur regulation, several quantitative studies on the topic were carried out. The analysis framework of these studies differ widely, ranging from the societal benefits of a reduction in Sulphur emissions (Jiang, Kronbak, & Christensen, 2014) to industry payback periods of retrofits (Andersen, Clausen, & Sames, 2011). Common to all of these studies, however, is the conclusion that fuel related costs placed on the ship-operators increase, as a result of either installing a scrubber or switching to alternate forms of bunker fuel.

The first study addressing the economics of installing and operating a scrubber system was ENTEC (ENTEC & European Commission Directorate General Environment, 2005), investigating the results of the sea scrubber trials of the vessel "*Pride of Kent*". The study was not a direct comparison between the alternative fuel types, but instead an overview of the costs and benefits of installing a scrubber on board vessels operating in the ECA zone.

The Danish Maritime Authority (2012) analyses the potential for both expanding the LNG infrastructure in Northern Europe, and the potential for using LNG as a primary fuel for vessels operating in the Baltics and North Sea. Both the present and future potential for LNG is examined and compared to the potential of operating on MGO and HFO using the scrubber technology.

Similar to the study by the DMA, MAN (Andersen et al., 2011) analyses the advantages of retrofitting a vessel to operate on LNG, contrasted with retrofitting a scrubber or burning MGO when operating inside the ECA zone. In the analysis, five containerships of sizes ranging from 2500

[9] The installation of a scrubber causes the fuel consumption to increase, although by a small margin.

TEU to 18000 TEU are examined with voyage distances increasing with the container capacity. They conclude that for vessels operating a small portion of the time in ECA zones, the payback time for LNG is lower compared to that of the scrubber, but that this discrepancy tends to even out as the relative time spent in ECAs increases. For smaller vessel sizes retrofitted to operate on LNG, payback times may be as low as two years when navigating within an ECA zone more than 65 percent of the time.

In a presentation on the Green Ship Technology conference two mutually exclusive strategies were compared: Either investing in a scrubber or investing in an LNG engine (Klimt-Møllenbach, Schack, Eefsen, & De Kat, 2012). The two strategies were examined and compared to a situation where the vessel uses MGO when operating in the ECA zone and uses HFO when operating outside. The study takes departure in a 38,500 DWT tanker examined for a duration of 10 years by using the discounted payback method with a nine percent discount rate. The study finds that the payback period for both decisions (scrubber and LNG, respectively) is reduced as the price of MGO, relatively to that of HFO and LNG, increases. Additionally, they find that the payback periods are reduced as the proportion of time spent by the vessel in the SECA zone increases. For the vessel examined, they find a payback time of 9 years for both the Scrubber and LNG solution, assuming a 13 percent sailing time within the ECA zone, a HFO-MGO spread of 350 USD per ton and a LNG cost of 550 USD per ton.

Jiang, et al. (2014) investigates the costs and benefits of the different abatement measures available to the shipping industry in order to comply with the ECA Sulphur emission standards in the Baltic and North Sea. Contrary to the studies presenting the optimal strategy purely from a profit maximizing ship-owners perspective, their analysis is extended to include the socio-economic costs and benefits of different strategies. The analysis takes departure in a 5000 TEU containership operating between the ports of Gothenburg and Rotterdam, completing 52 round trips per year. They find that the seawater scrubber system is slightly advantageous to operating on MGO, given that the price spread between HFO and MGO remains above 231 euros. This is due, in part, to the fact that scrubber technology is more efficient in reducing the emission of Sulphur. Jiang et al. conclude that the installation of a sea water scrubber is more advantageous on a new-built ship compared to retrofitting an existing vessel, and that a vessel with less than 4 years of remaining service time is unsuitable for retrofitting a scrubber from an economic point of view.

Holmgren, et al. (Holmgren, Nikopoulou, Ramstedt, & Woxenius, 2014) examines whether the introduction of new Sulphur regulations, and the resulting higher marine shipping costs, will result in a transportation modal shift to transport by truck instead of ship. The study examines the

Source: Scanpix / Iris

transport of goods between Klaipeda, Lithuania and the British East Midlands. In contrast to most other recent studies, Holmgren et al. only analyse this modal shift with respect to a switch to MGO. In order to investigate this, they use the Transportation and Production Agent Based Simulator (TAPAS) – a program used for decision-making and activity in transport chains, and for estimating the optimal managerial choice based on simulations of the decisions of shipments in selected consumer-supplier relations. Holmgren et al. conclude that, although the freight rates will increase from vessels operating on MGO, a modal shift for high value goods on the route examined is not likely to occur as a consequence of the increased bunker fuel costs.

3.2.4 Analysis Framework

In order to analyse how the different variables (such as vessel size, age, ECA zone mileage, and fuel type price spreads) will impact the feasibility of the different strategies examined in this analysis, this study will take departure in three different commercial vessels of various sizes operating on different routes, periodically calling at a hypothetical port situated in the Baltic / North Sea ECA zone.

Ship A is a 1000 TEU feeder ship servicing the route between Gothenburg and Rotterdam and is therefore solely operating within the bounds of the ECA zone. Ship B is a 100.000 DWT Aframax tanker servicing the route between Rotterdam and the major Egyptian oil terminal of Sidi Kerir, implying a limited time spent in the ECA zone - approximately 15 percent of the operational time. The third vessel (ship C) is a 20.000 DWT Handy-size ore bulk carrier, servicing the route between Rotterdam and Murmansk and therefore spending approximately 45 percent of the operational time within the ECA zone. The specifications for each of the three vessels are outlined in table 3.4.

Although the vessels are hypothetical and used for the purpose of this study, the characteristics of the vessels, such as fuel consumption, vessel size, and vessel dimensions, are representative of actual vessels of these types and sizes that operate in the North and Baltic Sea. The specifications are calculated using the ship specification program offered by the Danish Ship-Owners Association[10] (Danish Shipowners' Association, 2015). The route distances and subsequent yearly nautical miles sailed as well as annual ECA zone port visits are calculated using the voyage calculator from seadistances.org (Sea Distances, 2015). The three vessels are selected in order to highlight the differences between the optimal strategies, given vessels of different sizes and ECA zone nautical mileage.

We predict that a reduced amount of time spent in the ECA zone, the retrofit of the engine and installation of the scrubber should provide a relatively larger benefit to Ship A, compared to the other two vessels while operating on MGO. Non-complying might be a more cost effective strategy for ship B, which is spending a majority of the time out-side of the ECA zone and therefore less frequently call at ECA zone ports.

From table 3.4 it is clear that the amount of fuel required for maintaining the average voyage speeds differ, depending on the type of fuel the ships are burning. By operating on HFO, the amount of fuel burned per nautical mile slightly exceeds that of MGO and LNG, while the installation of a scrubber causes a slight increase in the fuel consumption. Consequently, the vessels can cover a longer distance on a full tank of LNG or MGO compared to that of HFO (assuming the fuel carrying capacity stays the same), thereby offsetting the price spread between the alternate fuels and HFO.

In order to investigate the optimal investment strategy of the ship-owner, this study employs the present value method. Although several methods of investment evaluation are currently in use, the internal rate of return as well as the payback method are undesirable when used to compare alternative (i.e. mutually exclusive) investments (Hedegaard & Hedegaard, 2011). Although both the present value and annuity model are useful when comparing investments running over an equal duration[11], the annuity method complicates the illustrations and calculations without significantly changing the outcome of the feasibility of the investment. The analysis is conducted in discrete time, with each period denoting a year from 2015 until the vessel is either resold or scrapped. Thus, period *0* equals the year 2015 while the last operational year of the vessel is denoted as year *n*.

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[10] *By inserting the preferred vessel type and capacity the program calculates the vessels specifications such as dimensions and fuel consumption compiled from data on the world merchant fleet.*

[11] *The remaining service years of the vessels are assumed to be constant for all the investment strategies unless the ship-owner decides to withdraw the vessel from service within the ECA zone.*

Vessel Name	Ship A	Ship B	Ship C
Type	Feeder 1000 TEU	Aframax Tanker	Handy-size bulk carrier
Dead weight ton	13.650	100.000	20.000
Vessel main engine yield (kW)	10.166	14.313	5.130
Auxiliary engine yield (kW)	504	608	256
Route	Gothenburg – Rotterdam	Sidi Kerir – Rotterdam	Murmansk – Rotterdam
Yearly round trips	102	14	27
Yearly sailing distance (nm)	102.204	88.452	87.858
Yearly port visits in ECA zone	204	14	27
Average Speed (knots)	15	11.5	11.5
Fuel consumption HFO (Mt/nm)	0.062	0.092	0.040
Fuel consumption HFO + Scrubber (Mt/nm)	0.064	0.095	0.042
Fuel consumption MGO (Mt/nm)	0.059	0.088	0.038
Fuel consumption LNG (Mt/nm)	0.055	0.079	0.035
Time spent in ECA zone (%)	100 %	15 %	45 %

Table 3.4: Specifications of the examined vessels of this study
Source: Own calculations and sea-distances.org

3.2.5 Fuel Prices and Spreads

Given that the aim of this study is to determine the optimal strategy of the ship-owner, estimating the total fuel-related costs during the remaining operational years of the vessel is of critical importance.

This study will adopt the projected prices of residual fuel oil in the transportation sector until 2040 from the Energy Information Administration (EIA). The projections made by the EIA are divided into several scenarios dependent on various macroeconomic growth cases and given the major uncertainty attached to the future level of the price of oil. Of these alternatives, the reference case oil price was 2.4 percent until year 2040, causing moderate price increases of bunker fuel to approximately 850 constant 2013 USD per barrel by 2040 (EIA, 2014).

The EIA expects a real price increase for HFO in the long run, despite a drop in the price of HFO in the short term, resulting in a real increase in the bunker cost of the ship-owner. This is depicted in figure 3.7 (page 37). It is important to note that the price projections are those of HFO with a 3.5 percent Sulphur content, which will only be used by vessels equipped with a scrubber or ship-owners following the strategy of non-compliance inside the ECA zone. Additionally, the introduction of the global

Sulphur regulations in 2020 is incorporated into this analysis. This global Sulphur cap will force ship-owners who are following the MGO strategy to burn 0.5 % Sulphur fuel oil (LSHFO) when operating outside of the ECA zone.

It may be of consequence that the price projections are the prices in the U.S., and therefore subject to alterations for vessel refuelling in European ports. However, it is assumed that these differences are insignificant, given that HFO is a worldwide commodity.

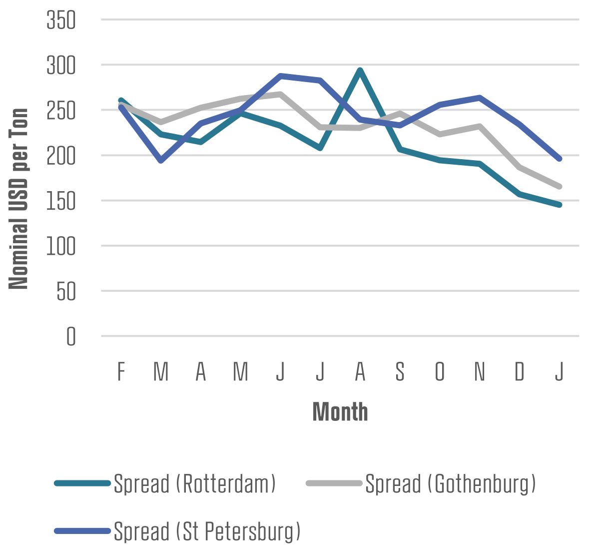

Figure 3.5: Monthly 0.1 % MGO – HFO (IFO360) fuel spreads from February 2015 to January 2016
Source: (Ship & Bunker, 2016)

Because accurate data and projections of the price alternate fuel types are currently unavailable to the authors of this study, static price spreads are used as proxy-variables to project the prices of the alternative fuels of LSHFO and MGO. Although subject to large fluctuations, the prices of these alternative fuels are strongly correlated with the price developments of ordinary HFO as they are all a product of crude oil (DMA, 2012).

MGO: Throughout the last year, the price for MGO has remained significantly above that of HFO. As of august 2014 the HFO – MGO price spread was situated at 350 USD, but several factors can influence the price of MGO in either direction. On July 9th 2014 the Rotterdam spot price for a ton of MGO exceeded that of HFO by 53 percent increasing to 73 percent by December 9th as the price spread during the same period dropped from 299.5 to 264.5 USD (Ship & Bunker, 2015). This happened as a dramatic fall in the global oil price was observed during this time span.

The recent glut in the global oil price has dramatically lowered both the price of MGO and the MGO – HFO price spread. While the MGO – HFO price spread in the port of Rotterdam, Gothenburg and St. Petersburg were averaging 250 USD in February 2015 falling to less than 200 USD at the start of 2016 (see figure 3.5).

Because of the significant volatility in the MGO – HFO price spread observed during the last few years, two price scenarios are examined with a yearly average price spread of 200 USD and 300 USD in the low and high price scenarios, respectively.

- *The price for a ton of MGO is divided into a high and low price scenario with a MGO – HFO price spread of 300 and 200 USD respectively.*

0.5 % LSHFO: Currently, LSHFO with 0.5 % Sulphur content is not widely distributed as this type of fuel have become obsolete in European waters due to the stricter Sulphur requirements of the ECA zones. It is, however, reasonable to assume that the refining costs of the reduction in the Sulphur content will result in a major price spread between LSFO normal HFO.

For the purpose of this study, the price for a tonne of 0.5 % LSFO is therefore assumed to be 100 USD above that of the HFO projection prices. A price spread of 100 USD per ton is significantly lower than that of MGO but will still increase the operational costs of vessels not equipped with a scrubber or LNG engine capabilities after the introduction of the global Sulphur regulation.

- *The LSHFO – HFO price spread is assumed to be 100 USD for the purpose of this study.*

LNG: Few vessels are currently equipped with LNG engine modifications as few ports provide LNG bunker refuelling capabilities. The prospect of operating on LNG therefore relies on the vessel frequently calling at ports supporting such capabilities. LNG import terminals currently operational in Northern Europe are located in Belgium, the Netherlands, the UK, Norway and Sweden and Denmark, and as of 2011 the total LNG storage facilities across these countries contained 2 million m^3.

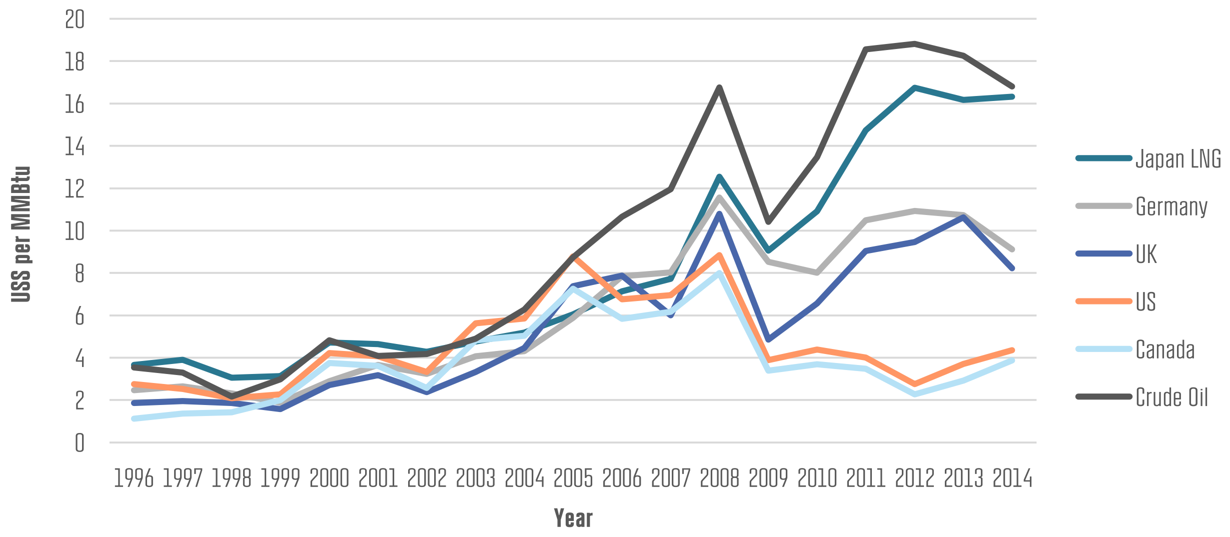

Foto 3.6: Development of gas prices by region
Source: BP (2015)

A future increase in the storage capacity is expected as the demand for LNG rises (DMA, 2012). As of 2012, several LNG production plants are being operated in Northern and North-Eastern Europe, with the majority situated in Norway and Russia. This results in an annual liquidation capacity of 4.8 million metric tons of gas, with future expansions being planned in Western Russia (DMA, 2012). The proximity to large scale gas extraction sites in the North and Barents Sea, results in favourable supply and price conditions for LNG. Utilizing LNG as a maritime fuel does, however, offer great possibilities for the maritime sector as recent advances in technology, such as hydraulic fracking, has made large scale extraction possible in previously unfeasible areas.

Similar to the price projections of HFO, this study adopts price projections from the Energy Information Administration in the reference case oil price scenario. The EIA does not offer projections on the price of LNG and the Henry Hub natural gas price is adopted as a proxy for this variable.

The difficulties associated with the transport of gas outside of pipelines have caused the price of natural gas to vary significantly between the different regions of the World. In 2014, the average import price of LNG in Japan was four times as high as that of the United States while the average German import price of natural gas was 9.11 USD per MMBtu compared with an average import price 16.8 USD per MMBtu for oil[12] (see figure 3.6)(BP, 2015). While the large price difference of LNG in Japan is explained by the costs of LNG transportation from Australia and the Middle East, the differences between the prices of Europe and the US are also explained by the lack of trade in natural gas between the two continents. This separation of the two markets explains the huge differences in the price developments of natural gas between North America and the rest of the World. The recent US ease of the ban of exports of oil and gas has resulted in the creation of numerous gas liquidation plants along the US coast designed for export towards the Asian and European market. This should result in an intertwinement between the American and European markets, thus causing these prices to converge towards a fixed regional price difference.

Even though the price developments between Europe and the US may converge, the abundance of gas extracted in North America will still result in major regional price differences. In order to offset these regional price differences in the cost estimations of this study, the Henry Hub natural gas price projections from the EIA are indexed such that the price measured in MMBtu in 2014 is set to a value of 1.

[12] *Included in both price reports are the costs of insurance and freight.*

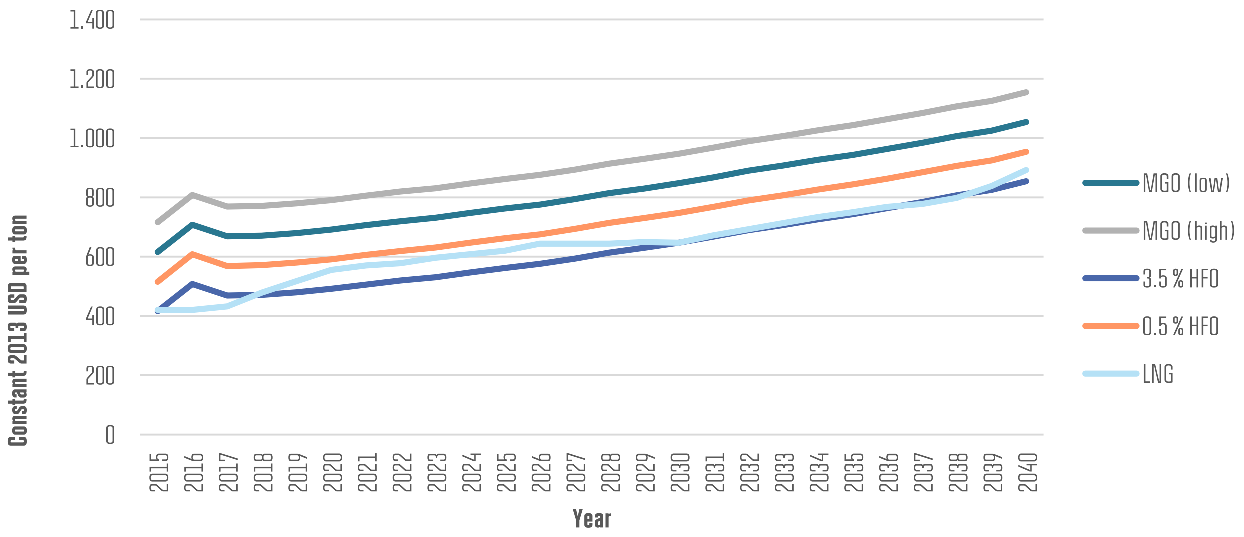

Figure 3.7: Fuel prices adopted for this study
Own calculations based on EIA (2015)

As gas starts being traded across the Atlantic, regional price differences should theoretically be determined by the costs of gas transportation and condensation, as well as regional taxing schemes. This is described in equation 3.1 below, where P_{EU} denotes the price per unit of LNG, L denotes the cost of liquefaction per unit of LNG in Europe, F the freight per unit of LNG, P_{US} the price per unit of natural gas in the US, and ΔT the tax difference between the US and EU.

$$P_{EU} = L + F + \Delta T + P_{US} \qquad (3.1)$$

Since the cost of condensation and transport are similar values fixed in terms of volume of gas, they do not influence the degree of change from one market to the other. In other terms, if L and F are fixed values and P_{US} shifts upward, P_{EU} also shifts upward at the same rate, where the absolute difference simply is $L + F + T$. For simplicity, T is assumed to be a flat rate rather than an Ad Valorem-tax[13].

If the rate of change is the same (as above assumptions determine), we can index a given year based on US forecasts and conclude that the rate of change on the European market follows the same rate of change, because L, F, and T do not influence the rate, only the absolute difference. For example, a rise in US LNG price from 1 to 1.1 (a 10 % increase) from year 0 to year 1 would correspond exactly to a 10 % hike on the European markets regardless of the actual price. As LNG moves towards being a world commodity, global demand changes should affect European prices in exactly this way. The resulting price change (in real terms) should be identical across regional markets.

A real price increase in LNG should therefore reflect an increase in the price of natural gas, and not cost increases in the liquefaction or transportation of the final products. This makes it possible to take into account regional price differences while still operating under the framework of the EIA price developments.

Based on this reasoning, we can use the EIA forecasts in Europe - the indexed price projections only needs to be multiplied with the average price for LNG found in North Western Europe in 2014; the first year of indexation. The average price for LNG in North Western Europe was 9.6 USD per MMBtu in 2014[14]; multiplying this value with the indexed natural gas price projections yields the LNG bunker prices adopted for the purpose of this study. This, along with the price projections of the other fuels adopted for the purpose of this study, is presented in figure 3.7.

[13] From equation 3.1 it is clear that an increase in the price of a unit of gas in the US will result in a similar increase in the price of LNG at European ports. A change from a fixed tax scheme to an ad valorem tax scheme would result in a larger price difference as the tax would change to an increasing function of the price increase.

[14] *See The Economist, 28th of February, 2015 (The Economist, 2015)*

From figure 3.7 it is clear that the price per tonne of LNG and 3.5 % HFO initially starts at a level of approximately 400 USD and gradually increases at a slow pace. The current glut in the world price of oil causes HFO to remain slightly below LNG between 2017 and 2027 before converging towards 800 USD in 2040.

As with all economic projections, it is worth taking into account the large degree of uncertainty attached to such forecasts. A multitude of factors influences the price of oil, making it impossible to project the price for bunker fuel and LNG accurately so far into the future. Additionally, the prices projected by the EIA are international projections and may therefore differ for vessels operating solely within the Baltic and North Sea ECA zones. This is especially true when forecasting the prices incurred by ship-owners who retrofit their ships to operate on LNG. Although fuel price spreads between HFO and the alternate fuels are adopted in this study (in line with MAN Diesel (Andersen et al., 2011), Green Ship (Green Ship of the Future, 2009) and Jiang, et al., (2014)) price projections on HFO are still included in order to increase the explanatory power of the conclusions. Thus, the fuel price projections from the EIA, although only indirectly affecting the price of the alternate fuels, are used to calculate the findings of this study, and it is therefore recommended to take the gap between theory and application into critical account when basing decisions on the results of this study. However, in general, this way of assessing the future prices of different fuels relative to each other provides a usable ballpark estimate that should continually be re-assessed as new data becomes available.

Retrofit Costs

Since both the scrubber and LNG ship engine technologies has to be tailored to the specific vessels and has not been widely distributed aboard the World's merchant fleet, the cost and performance of the two technologies are based on a limited number of observations during recent years. For example, Green Ship (2012) reports the costs of retrofitting a 38,500 DWT tanker to be approximately 5.8 million USD and 7.56 million USD for the installation of a scrubber and LNG engine, respectively. On the other hand,

Part Installed	Unit	Costs
Scrubber		
Scrubber (incl. waste storage)	USD/kW main engine	180
Installation Cost Scrubber	USD/kW main engine	270
LNG: 2-stroke LNG engine		
LNG fuel gas conversion and supply system	USD/kW main engine	342
Installation costs	USD/kW main+ auxiliary	180

Table 3.6: Scrubber and LNG base retrofit prices
Source: DMA (2012)

ENTEC (2005) reports scrubber retrofitting costs of 168 EUR per kW installed on vessels with a main engine capacity of more than 15.000 kW. The retrofitting and new-building costs of these engines are highly dependent on the type of ship as well as the size of the engine, and single price reports are subsequently not sufficiently accurate for the purpose of this study. The only variable retrofit prices for both scrubber solutions and LNG solutions are those reported by DMA (2012), where retrofit prices are listed as a function of engine size measured in euros per kilowatt of engine power. The base retrofit costs as a function of engine power and the corresponding retrofitting costs for each of the vessels examined in this study are presented in tables 3.5 and 3.6, respectively.

From the retrofit costs presented, it is clear that the total costs of retrofitting a ship amounts to several million USD, and the cost of retrofitting an engine to operate on LNG is close to 15 percent more expensive than retrofitting a scrubber. This large difference in retrofitting costs demonstrates that the price for a ton of LNG needs to be significantly below that of HFO for the LNG solution to become economically feasible compared to the scrubber solution, notwithstanding the current infrastructure gaps. Because the retrofit cost estimations are directly proportional to the engine size of the vessel for both scrubber and LNG, further modifications may result in the

	Ship A	Ship B	Ship C
Total scrubber retrofit cost (USD)	4,574,700	6,440,850	2,310,500
Total LNG retrofit cost (USD)	5,397,500	7,581,000	2,726,500

Table 3.5 Approximated retrofitting costs for the vessels examined
Source: Own calculations based on reporting's from DMA (2012)

total retrofitting costs to become unrealistically high for larger vessels. For example, the total retrofitting costs for a 4000 TEU container ship with an engine yield of 43 mega Watt (mW) will amount to almost 20 and 23 million USD for the scrubber and LNG retrofit, respectively. Retrofitting costs of such a magnitude would make the retrofitting of vessels of even moderate sizes extremely unprofitable, thus limiting the feasibility of the retrofitting strategies to smaller vessels. It is, however, worth noting that the listed retrofitting costs estimations are based on reports from a limited number of smaller sized vessels and therefore provides an insufficient basis for calculating the retrofitting costs for a wide segment of the fleet operating within the ECA zone. This report deems it highly unlikely that the relationship between the retrofitting costs and the engine size is characterized by strict linearity, and the cost estimations used in this report may therefore be subject to alterations when more reliable cost estimates become available.

3.2.5.1 Fine Sizes and Frequency of Inspection

By refusing to comply with the Sulphur regulations when operating inside the ECA zone and continuing to burn standard HFO with high Sulphur content, the ship-owner will face sanctioning if discovered by the authorities in the ports or waters of the coastal states. For the purpose of calculation, the sanctioning costs (the fine) imposed upon a non-compliant ship-owner will consist of a lump sum transfer. Although the fine size for non-compliance may amount to thousands of euro, the ship-owner's incentives to comply with the Sulphur regulation critically depend on the frequency of inspections when calling within the ECA zone. A frequency variable is therefore included, which measures the risk of being inspected on each ECA zone port visit.

As previously mentioned, enforcement of the environmental regulations is rare, and the associated fines consist of lump sum transfers that are of negligible magnitude in most of the ECA zone coastal states. Further, the fines vary depending on the coastal state in question, since neither enforcement nor fine sizes are uniform across borders. The Helsinki Commission surveyed Baltic counties and their sanction and penalty methods, and concluded that the current range of administrative fines ranges from EUR 350 to EUR 57.000 (HELCOM, 2014). Data from the Baltic Port Organization indicates that some countries are considering an increase in the impact of fines to as much as EUR 200.000 as a result of the new Sulphur regulations. Additionally, some countries will have punishment defined under their criminal system, where fines are defined case-by-case (Rozmarynowska, 2015).

The frequency of inspection also varies between port states, and several factors have to be taken into consideration when trying to assess an inspection rate. Further, political focus on ensuring compliance may not always translate into actual inspection rate increases. For example, in 2012, Maersk line had 9.690 port calls the ECA zone, but only 57 port inspections were performed, and none of these examined the Sulphur content of the fuel oil carried (Press-Kristensen, 2014). This effectively results in an average rate of port inspection of 0.6% within the ECA zone, and zero inspection of Sulphur compliance specifically. European ports work together in the Paris Memorandum of Understanding (Paris MoU) where a targeting mechanism is used to check vessels. The goal for the Paris MOU is to inspect every vessel active within the EU at least once a year, targeting of high-risk vessels with historic non-compliance (Paris MoU, 2013). Consequentially, non-compliant vessels will have a higher inspection ratio on long-term operations as compared to compliant operators.

For the analysis of fine sizes impact on vessels, a 40,000 USD fine is adopted as a fine size – regardless of the port of sanctioning. In using a proxy for frequency, this model will assume a 10 % chance of inspection, given that the difficulties in defining this parameter. While an average inspection rate of 10 % is significantly higher than the 0.6 percent previously experienced by Maersk Line, it is reasonable to assume that the inspection rate may gradually increase as a consequence of the Paris MOU. In chapter 4 the short term and long term inspection frequencies will be analysed in conjunction with the effect of fines and other punishment mechanisms.

Other forms of sanctioning mentioned as possibilities by policymakers but not included in this analysis, are those of the detention of the vessel by the port state authorities as well as the blacklisting the vessel at the Paris MOU (see chapter 4.4). These alternative sanctioning measures have the potential to incur significant costs on a non-complying ship-owner but are difficult to predict due to the various factors influencing the financial details of the vessel. If the port state authorities have the option to detain a vessel, the loss of the cargo insurance in combination with the lost opportunity costs, due to the vessel not being operable, may reach intolerable levels. This effectively forces the ship-owner to comply with the Sulphur regulations, even though the frequency of being controlled and sanctioned is negligible. Similarly, being blacklisted by the Paris MOU may cause the insurance premium of the vessel to drastically increase.

3.2.6 Analytical Assumptions

The results of the analysis rest upon a number of critical assumptions included in order to simplify a complex relationship between the multiple variables a ship-operator must take into account. These assumptions may simplify the results of the analysis, but are necessary in order to establish a calculable framework. In the following section, the assumptions and the rationale behind them are presented.

Assumption I: Fuel consumption when calling at a port is assumed to be zero

To reduce unnecessary complexity, it is assumed that no fuel is consumed when entering, berthing, or exiting a port. Although this statement clearly does not reflect the real world, the vessel operates at very slow speeds and generally consumes a negligible portion of fuel when calling and berthing.

Assumption II: No regional fuel supply and price imbalances

It is assumed that the type of fuel consumed by the vessel is readily available when calling a port and that the fuel price remains the same for all the ports that are included in this study. The price projections from the EIA are based on an average of prices in the US, and regional price imbalances are therefore not captured in the projections adopted by this study. Since HFO is a global commodity, these price imbalances should not differ significantly although different levels of taxation may affect these regional prices. It is therefore worth noting that the fuel prices in reality may differ, depending on the ports where the examined vessels are calling.

Assumption III: MGO engine modifications have previously been installed

For a standard engine burning HFO, a small retrofit averaging around 130.000 EUR is needed for the engine to also be able to burn MGO (DMA, 2012). Due to previously implemented environmental regulations, vessels operating within the ECA zone are forced to burn MGO when berthing in the ports of the zone, and it is reasonable to assume that the engine modifications needed for it to operate on MGO has already been completed. As such, this cost component is left out of the analysis.

Assumption IV: Fuel consumption is measured from average speed

The fuel consumption is measured from an average sailing speed of the vessel. Maintaining a constant speed along the vessels voyage is, however, highly unlikely due to the current, wind and wave conditions. Because fuel consumption is exponentially correlated with the voyage speed, the fuel consumption of the average speed is negatively biased and may therefore be higher in a real scenario. These volatilities, however, should be relatively minor in comparison to the total fuel related costs and are left out of this analysis for simplicity.

Assumption V: No dual fuel for LNG vessels

Once the engine has been retrofitted to operate on LNG, it is assumed that the vessel will operate solely on LNG. Although engines that are able to run on both LNG and conventional fuel is a technological possibility, the significantly higher retrofit cost compared to that of a scrubber will cause the LNG option to be unfeasible unless the mile costs of burning LNG is less than that of HFO, consequently making HFO fuel an economic redundancy.

Assumption VI: Retrofit cost are financed without issuing debt

The total costs of retrofitting the ships engine, including both the material investment and the refit, are assumed to be financed without issuing debt, and the CAPEX are therefore not divided over multiple periods or subject to interest rate payments. Such an assumption is of course highly unlikely as the retrofitting costs amount to several million USD, and debt and interest repayments may therefore cause the conclusions achieved to be positively biased towards the strategies of retrofitting. The reader is therefore encouraged to consider these financing issues when using the model to access the favourable strategies.

Assumption VII: Loss of cargo space is assumed to be zero

Retrofitting a ship with a scrubber may reduce the total cargo space of the ship. In order to estimate the total costs incurred by such a retrofit, the potential loss of revenue needs to be taken into account.

Source: Scanpix/Iris

On a given container-carrying vessel, up to 0.3 percent of the cargo capacity is lost when retrofitting the vessel with a scrubber depending on the size of the vessel. The extra space needed to install LNG fuel tanks may result in a loss of up to 3 percent on large vessels when retrofitting the engine to operate on LNG (Andersen et al., 2011).

Assumption VIII: All the vessels examined are not equipped with a scrubber or LNG engine prior to the introduction of the new Sulphur regulations

It is assumed that the vessels examined in this study are previously built, and therefore not subject to any of the modifications relevant to the introduction of the new Sulphur regulations, except those required to operate on MGO. The costs of installing a scrubber or modifying the engine to operate on LNG are drastically reduced if installed while the vessel is being built, and reduces the complexities of the decision process of the ship-owner. Thus, it is not the focal point of this study.

Assumption IX: Reported fine sizes and inspections rates are assumed to be constant regardless of year and ECA zone port

It is assumed that both the inspection rate and fine size remains constant through the span of this analysis and therefore does not differ between the different ports within the ECA zone, nor is subject to a tightening of enforcement. Given the huge discrepancies in both the level of enforcement and means of sanctioning, such an assumption is highly unlikely to hold, and the feasibility of the strategy of non-compliance is therefore highly dependent on the ports at which the vessel is calling.

3.2.7 Analytical Results

The following are the results of the optimal fuel strategy of the ship-owner given the different vessels investigated in this study. This is illustrated in figure 3.8, 3.9 and 3.10 for ship A, B and C respectively.

Looking at Ship A (figure 3.8), it is clear that MGO in the low price scenario remains the most favourable strategy of compliance if less than 5 years of operational time remains. The strategy of non-compliance does, however, yields the lowest expected costs although at a very small margin. If more than 5 years remains, however, the strategy of LNG outperforms non-compliance as the strategy yielding the lowest expected costs. Given that the infrastructure supporting LNG refuelling capabilities are underdeveloped and not likely to provide the fuel needed for the vessel to operate, MGO becomes the most viable strategy of compliance. The installation of a scrubber proves superior compared to MGO after 4 and 3 years in the low and high price scenario, respectively. This corresponds to a payback time of 4 and 7 years of the scrubber compared to that of MGO in the low and high price scenarios. This insignificant cost savings of following a strategy of non-compliance will deter moderately risk-averse ship-operators from breaching the environmental regulations as such a small cost difference may not justify the risk of fines and the subsequent increase in the insurance premium and/or the loss of environmentally concerned clients.

The larger engine size in combined with a reduction in the proportion of nautical miles travelled within the ECA zone and the reduced voyage speed of ship B changes the outcome of the most favourable strategies significantly (figure 3.9). These alterations in route speed and engine specifications result in both retrofitting strategies to become highly disadvantageous, and both the scrubber and LNG strategy are consistently the most expensive solutions in a time frame of more than 10 years.

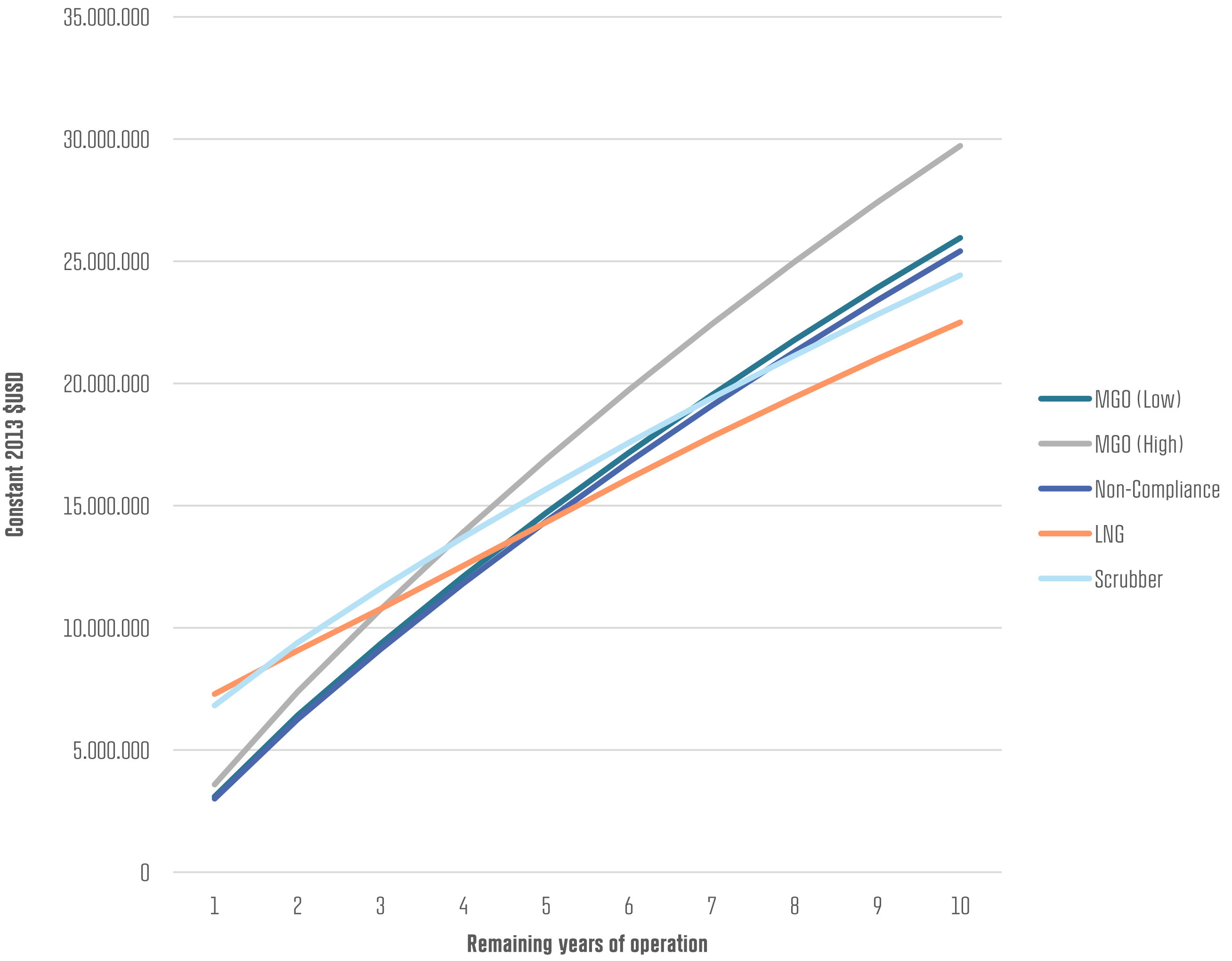

Figure 3.8: Total discounted fuel related costs for Ship A

All costs are measured in constant 2013 USD with an annual discount factor of 7 %. The MGO (low) and (high) lines describe the costs for the vessel operating solely on MGO in the low and high price scenarios respectively while the lines labelled "scrubber", "LNG" and Non-compliance denotes the corresponding strategies. The MGO - HFO fuel spreads are assumed to be 200 and 300 USD in the low and high price scenario, respectively and the price for a ton of low sulphur HFO is 100 USD above that of standard HFO. Additionally, the fine size is assumed to be 40000 USD with a control frequency of 10 percent per ECA zone port visit.
Source: Own calculations

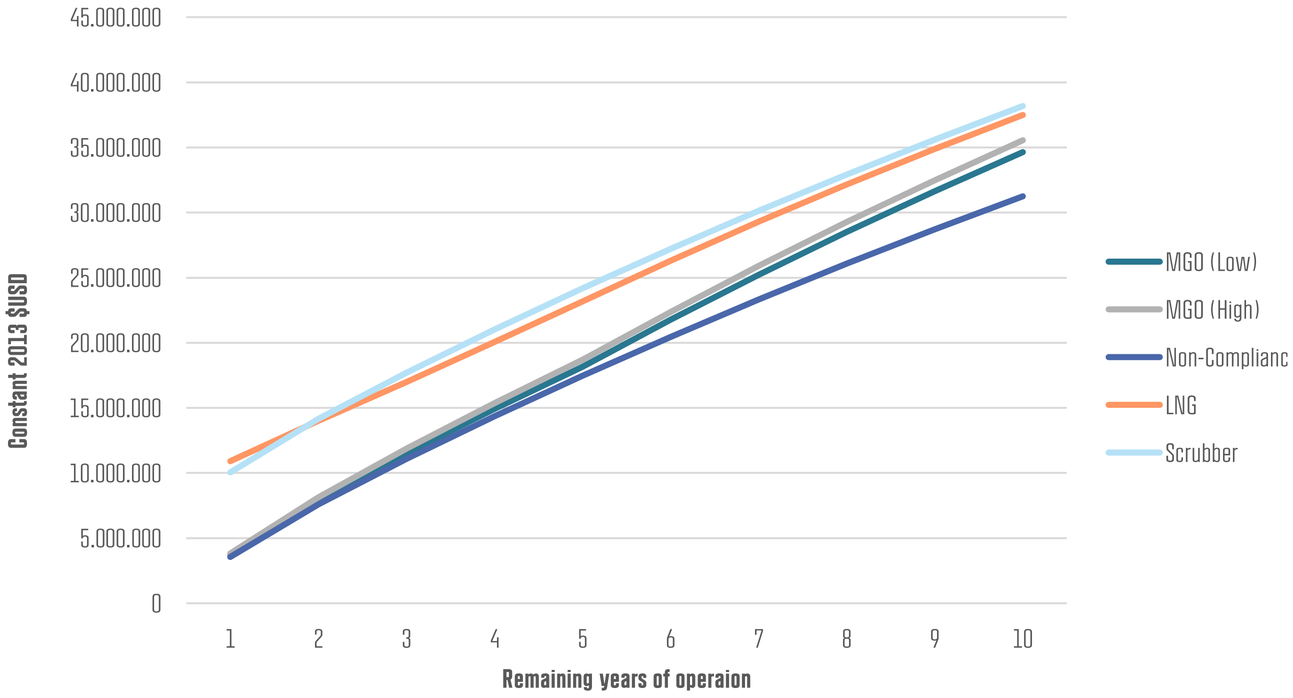

Figure 3.9: Total discounted fuel related costs for Ship B
All costs are measured in constant 2013 USD with an annual discount factor of 7 %. The MGO (low) and (high) lines describe the costs for the vessel operating solely on MGO in the low and high price scenarios respectively while the lines labelled "scrubber", "LNG" and Non-compliance denotes the corresponding strategies. The MGO - HFO fuel spreads are assumed to be 200 and 300 USD in the low and high price scenario, respectively and the price for a ton of low sulphur HFO is 100 USD above that of standard HFO. Additionally, the fine size is assumed to be 40000 USD with a control frequency of 10 percent per ECA zone port visit.
Source: Own calculations

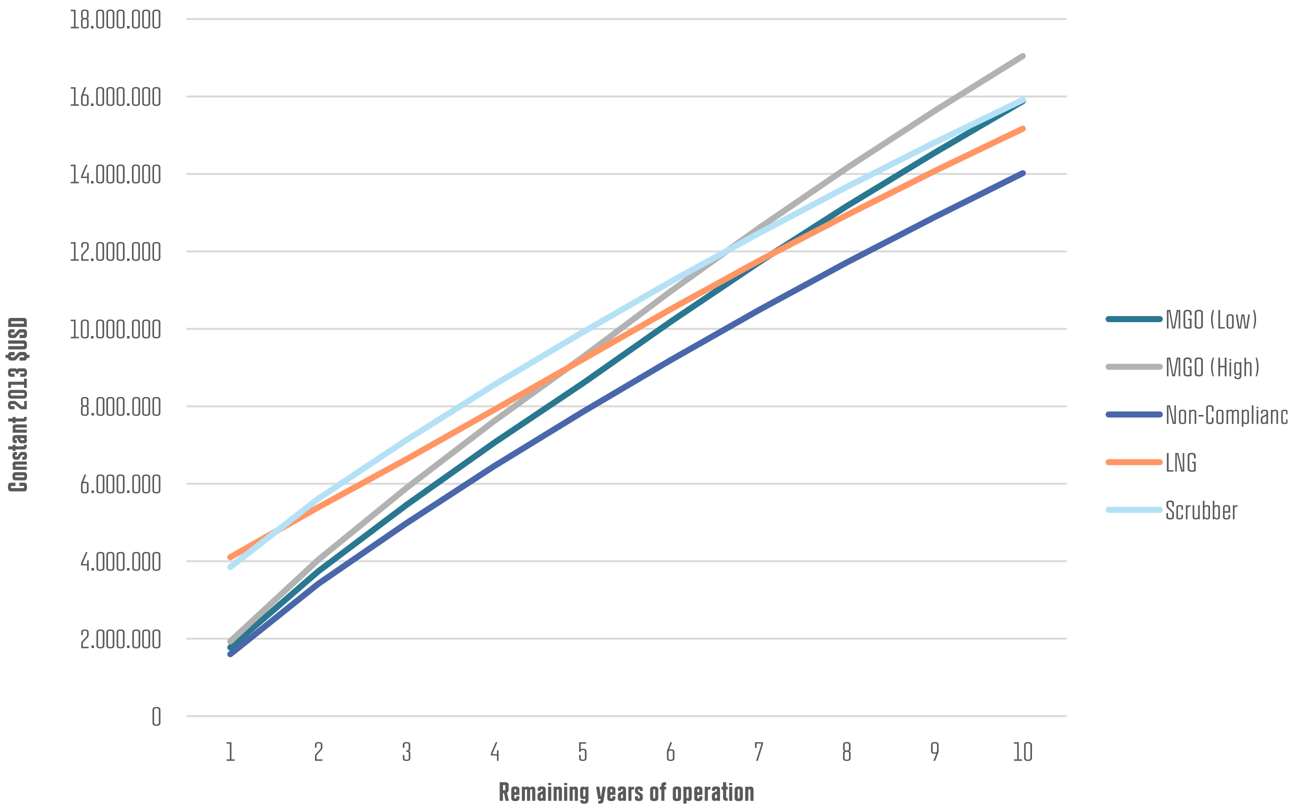

Figure 3.10: Total discounted fuel related costs for Ship C
All costs are measured in constant 2013 USD with an annual discount factor of 7 %. The MGO (low) and (high) lines describe the costs for the vessel operating solely on MGO in the low and high price scenarios respectively while the lines labelled "scrubber", "LNG" and Non-compliance denotes the corresponding strategies. The MGO - HFO fuel spreads are assumed to be 200 and 300 USD in the low and high price scenario, respectively and the price for a ton of low sulphur HFO is 100 USD above that of standard HFO. Additionally, the fine size is assumed to be 40000 USD with a control frequency of 10 percent per ECA zone port visit.
Source: Own calculations

This corresponds to a payback time of more than 10 years for both of the retrofits. The few annual port visits within the ECA zone (14) means that the strategy of non-compliance is the dominant strategy regardless of how many operational years remain. With only a few years of operational time remaining, this cost difference is marginal, but this figure eventually rises to a discounted cost difference of several million USD. Regardless, the MGO-based strategies remain the dominant modes of compliance, with the low price of fuel obviously being favourable.

The relatively lower cost of retrofitting the engine along with the higher proportion of time spent in the ECA zone of ship C creates a strategy ranking much different to that ship B, closer resembling that of ship A (see figure 3.10).

As was the case with ship A, the MGO strategy is the least costly strategy of compliance in the short to medium term in the low fuel price scenario. LNG becomes the favourable strategy if more than 7 operation years remain, thus corresponding to a payback time of 7 years. Aside from LNG, the strategy of retrofitting of the ship with a scrubber is similarly favourable compared to MGO if more than 10 and 7 service years remain in the low and high MGO price scenarios, respectively (yielding scrubber payback times of 10 and 7 years compared to MGO in the respective scenarios). The reduced amount of ECA zone port visits by ship C does, however, result in a larger cost difference between the scrubber and non-compliance strategies compared to ship A. Regardless of how many service years remains, however, non-compliance will be the dominant strategy due to a combination of few ECA zone port visits and the limited enforcement on each port visit.

Although only three different case ships were examined above, the results from the analysis indicate that retrofits are more favourable on smaller vessels due to the diseconomies of scale of the retrofitting costs reported by DMA (2012). Additionally, the choice between the MGO and the scrubber solution is highly dependent on the proportion of operational time spent within the newly established ECA zone. The calculations also indicate that the lax enforcement procedures in the ECA zone implicitly promotes the strategy of non-compliance for risk neutral ship-owners, who potentially gain a cost advantage vis-á-vis compliant ship-operators. The three case vessels examined above are, however, not a sufficient foundation upon which we can draw direct conclusions on the optimal strategies of the ship-owners due to the different engine size, annual days spent at sea, time spent in the ECA zone and different amount of port visits subject to enforcement control. The next sections will further analyse the impacts of the three major variables on the strategic decision. These variables are those of the ECA navigation proportion, the fuel spreads, and the level of enforcement.

3.2.8 The ECA zone proportion

The results above indicate that major differences in the costs and optimal strategies for vessels exist, depending on how much time (as a proportion of total operational time) is spent inside the ECA zone. Given the variables included in this study, it is possible to calculate the total fuel-related costs of a specific vessel as a function of the proportion of time spent in the ECA zone. Figure 3.11 and 3.12 illustrates the lifetime fuel related expenses for ship A, given 5 and 10 remaining operational years of the ship, respectively. Although changes in the proportion of navigation time spent within the ECA zone will inevitably result in changes to the vessel route and destination, it is assumed that the annual nautical miles sailed for each vessel remains constant. Additionally, changes in the annual number of port visits within the ECA zone are subject to change if the proportion of time navigating in the Baltic and North Sea also changes, and the strategy of non-compliance is therefore excluded from this part due to the risk of sanctioning being a function of annual ECA zone port visits. From figure 3.11 and 3.12 it is evident that the proportion of navigation within the ECA zone has a significant impact on the outcome of the feasibility of the different strategies of compliance.

If only five years of service period remains for ship A, the retrofit of a scrubber is advantageous to running on LNG under the following conditions: when a minimum of 60 percent of the navigation time is spent in the ECA and price of MGO is high, or when 80 percent of the navigation time is spent in the ECA zone and the price of MGO is low. The recent drop in the oil price and the MGO-HFO spread cases the retrofit of a scrubber to only be advantageous to low priced MGO if more than 85 % of the time is spent within the ECA zone.

If 10 operational years remain, the larger amount of time that the initial investment is annualized across causes the strategy of MGO to only remain advantageous to the scrubber if less than 40 and 60 percent is spent in the ECA zone in the high and low price, respectively. For LNG, this respectively changes to 20 and 35 with high and low price.

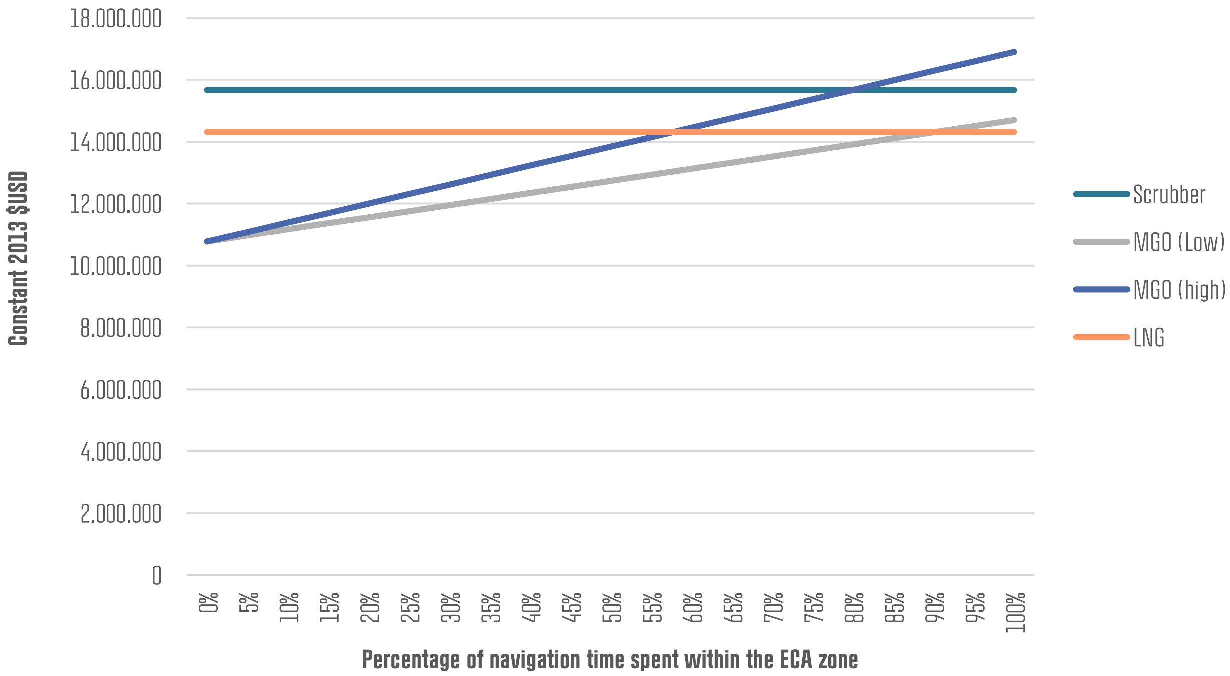

Figure 3.11: Fuel related expenses over 5 years depending on ECA zone navigation for ship A

All costs are measured in constant 2013 USD with an annual discount factor of 7 %. The figure illustrates the total discounted fuel related costs of ship A after 5 years given an annual voyage distance of 102,204 nm and an average speed of 15 knots. The MGO (low) and (high) lines describe the costs for the vessel operating solely on MGO in the low and high price scenarios respectively while the lines labelled "scrubber" and "LNG" denotes the corresponding strategies. The MGO - HFO fuel spreads are assumed to be 200 and 300 USD in the low and high price scenario, respectively and the price for a ton of low Sulphur HFO is 100 USD above that of standard HFO.
Source: Own calculations

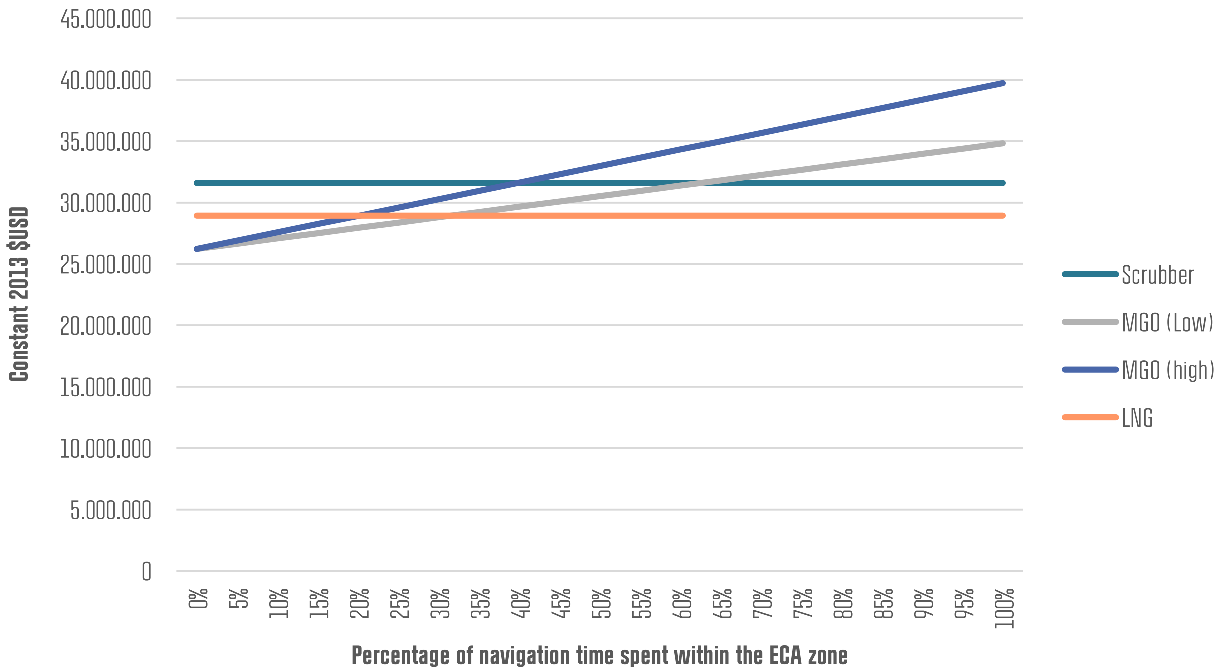

Figure 3.12: Fuel related expenses over 10 years depending on ECA zone navigation for ship A

All costs are measured in constant 2013 USD with an annual discount factor of 7 %. The figure illustrates the total discounted fuel related costs of ship A after 10 years given an annual voyage distance of 102,204 nm and an average speed of 15 knots. The MGO (low) and (high) lines describe the costs for the vessel operating solely on MGO in the low and high price scenarios respectively while the lines labelled "scrubber" and "LNG" denotes the corresponding strategies. The MGO - HFO fuel spreads are assumed to be 200 and 300 USD in the low and high price scenario, respectively and the price for a ton of low Sulphur HFO is 100 USD above that of standard HFO.
Source: Own calculations

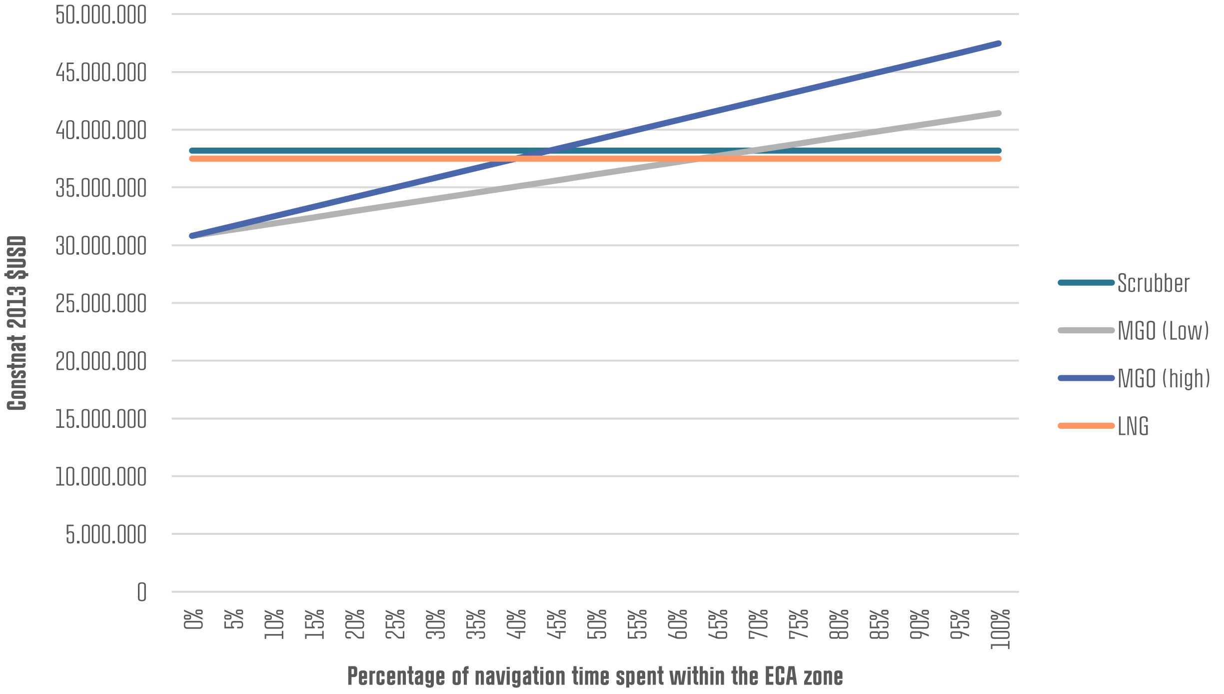

Figure 3.13: Fuel related expenses over 10 years depending on ECA zone navigation for ship B

All costs are measured in constant 2013 USD with an annual discount factor of 7 %. The figure illustrates the total discounted fuel related costs of ship B after 10 years given an annual voyage distance of 88,452 nm, an average speed of 11.5 knots. The MGO (low) and (high) lines describe the costs for the vessel operating solely on MGO in the low and high price scenarios respectively while the lines labelled "scrubber" and "LNG" denotes the corresponding strategies. The MGO - HFO fuel spreads are assumed to be 200 and 300 USD in the low and high price scenario, respectively and the price for a ton of low Sulphur HFO is 100 USD above that of standard HFO.
Source: Own calculations

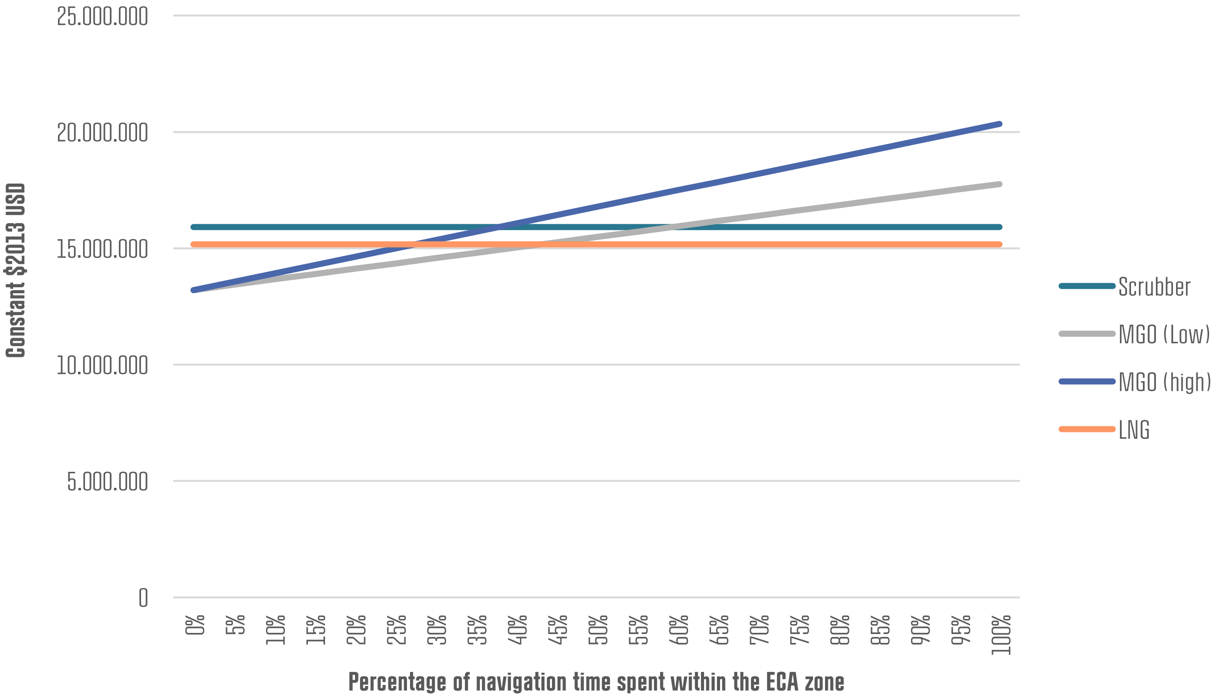

Figure 3.14: Fuel related expenses over 10 years depending on ECA zone navigation for ship C

All costs are measured in constant 2013 USD with an annual discount factor of 7 %. The figure illustrates the total discounted fuel related costs of ship C after 10 years given an annual voyage distance of 87,858 nm and an average speed of 11.5 knots. The MGO (low) and (high) lines describe the costs for the vessel operating solely on MGO in the low and high price scenarios respectively while the lines labelled "scrubber" and "LNG" denotes the corresponding strategies. The MGO - HFO fuel spreads are assumed to be 200 and 300 USD in the low and high price scenario, respectively and the price for a ton of low Sulphur HFO is 100 USD above that of standard HFO.
Source: Own calculations

The price clearly reveals that major cost savings are possible on smaller vessels if the price of LNG remains lower than that of HFO and sufficient infrastructure for refuelling becomes available in the future.

It is, however, worth investigating whether the larger and smaller engine size of ship B and C. respectively, in combination with the reduced voyage speeds and annual mileage will affect these critical ECA zone break-even points[15]. Intuitively, the different engine sizes should cause the retrofits to become less or more favourable, and a different fraction of total voyage distance within the ECA zone should therefore be necessary for the retrofit strategies to become favourable (although the reduced fuel consumption will also lower the direct fuel cost to investment cost ratio favouring MGO). Illustrated in figures 3.14 and 3.15, is the total fuel related expenses after 10 years' operation for ship B and C, respectively.

From figure 3.13 it is evident that the larger size of ship B, relative to that of ship A, and the higher retrofit costs resulting from the increased engine size increases the feasibility of MGO for navigation within the ECA zone. The total costs of both retrofits are almost identical and does not become favourable unless the ship B operates more than 45 and 70 % of the time within the ECA zone in the high and low price scenarios, respectively.
Figure 3.14 reveals that the combination of a reduced engine size and much lower fuel consumption causes the critical points for ship C to be close to identical to those of ship A. This is despite the total costs of the different strategies after 10 years of ship A are almost double those of ship C. For ship C, the scrubber strategy is advantageous to MGO if more than 40 and 60 percent of navigation time is within the ECA zone in the high and low price scenarios, respectively. For the LNG strategy these critical points are reduced to 30 and 45 % in the above mentioned price scenarios.

After comparing the optimal strategies for ship A, B and C over a 10 year period as a function of the fraction of navigation within the ECA zone, it is evident that retrofits becomes increasingly profitable as the percentage of voyage time spent within the ECA zone becomes greater and more operational years remain (note the difference between figures 3.11 and 3.12). Additionally, the retrofitting costs for both the scrubber and LNG engine solutions appear to be considerably more attractive on smaller vessels due to the lower yield of the engine required for propulsion and, consequently, the lower retrofitting costs. The price spreads between the different fuel types also have a large impact on the strategy ranking, as a price increase of MGO relative to that of HFO and LNG would result in the strategies of retrofits to be considerable more attractive for vessels with only partial operations within the ECA zone .

3.2.9 The Role of Fuel Spreads

From the previous chapters it is evident that the costs of retrofitting the vessels constitute an enormous financial burden to the ship-owner. In order to ensure that a retrofit will minimize costs in the long run, the operator must acquire knowledge of the future price level of the different fuel types. This is especially the case with the spread between HFO and MGO, but the spread between HFO and LNG becomes equally important if future development in infrastructure for LNG refuelling and storage facilities becomes reality. From the findings of the previous two sections, it is clear that the price of MGO needs to remain at the current low level in order to continuously be a feasible strategy for ships A and C. It is common to all vessels that the MGO strategy becomes less advantageous the more years of operation the vessel has left. This is because the ship operator has more time to benefit of the lower variable fuel costs incurred by the retrofitting strategies as well as the introduction of the global Sulphur regulation in 2020. Further, the maximum fuel spread needed for MGO to remain advantageous depends critically on the amount of navigation spent within the ECA. For example, the price of MGO compared to HFO needs to be significantly lower for MGO to become the favourable strategy for ship A in the long run, while MGO will remain the dominant strategy for ship B even though an increase in the same price spread may occur.

Figure 3.15, 3.16 and 3.17 illustrate the total fuel related costs as a function of remaining service years for ship A, B and C, respectively, given and MGO price that result in MGO becoming favourable to the retrofit strategies. From figure 3.15, it is evident that a dramatic reduction in the price of MGO relative to that of the alternative fuels are required for MGO to become the dominant strategy after 10 years of operation. For MGO to become advantageous over the scrubber strategy, a price spread of 155 USD is required (illustrated by the line "*MGO (high)*" in figure 3.15) while a MGO – HFO price spread of only 105 USD is required for MGO to be dominant over the LNG strategy (depicted by the line "*MGO (low)*" in figure 3.15).

[15] Recall that ship B and C both operates at an average speed of 11.5 knots compared to 15 knots of ship A

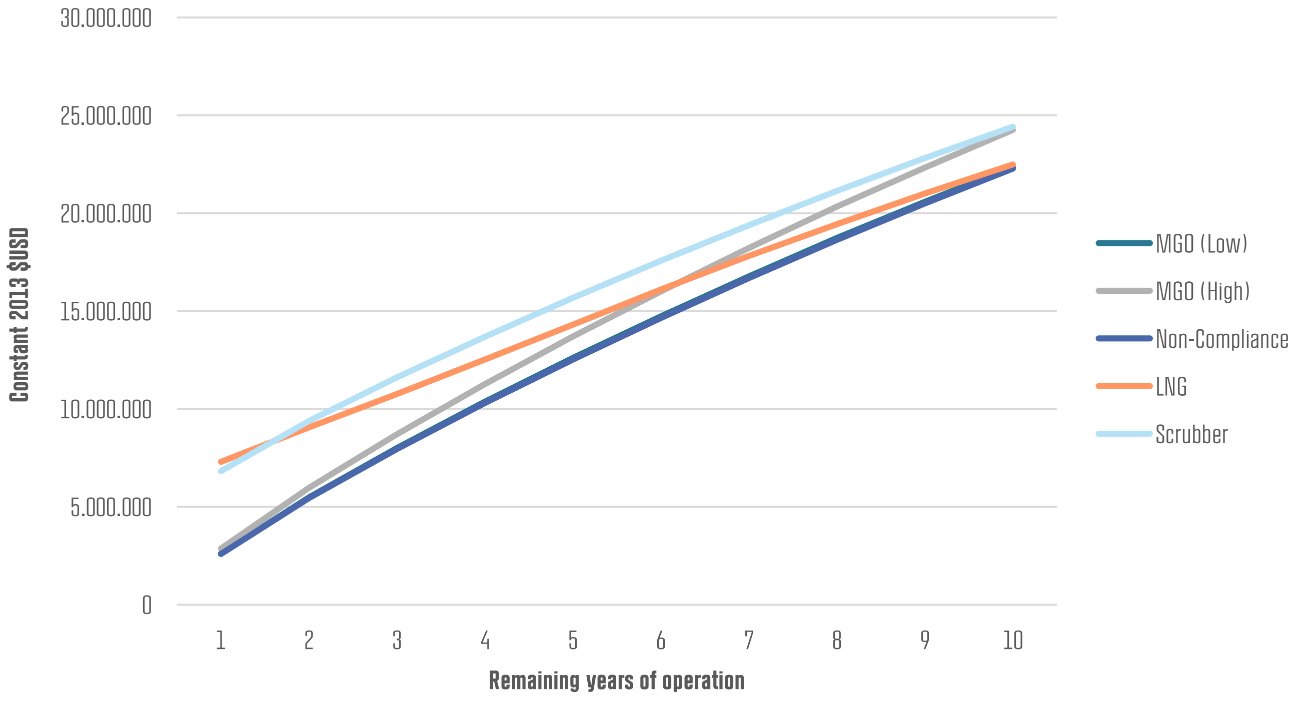

Figure 3.15: Total discounted fuel related costs with alternative MGO prices for Ship A
All costs are measured in constant 2013 USD with an annual discount factor of 7 %. The MGO (low) and (high) lines describe the costs for the vessel operating solely on MGO in the low and high price scenarios respectively while the lines labelled "scrubber", "LNG" and Non-compliance denotes the corresponding strategies. The MGO - HFO fuel spreads are assumed to be 105 and 155 USD in the low and high price scenario, respectively and the price for a ton of low Sulphur HFO is 100 USD above that of standard HFO.
Source: Own calculations

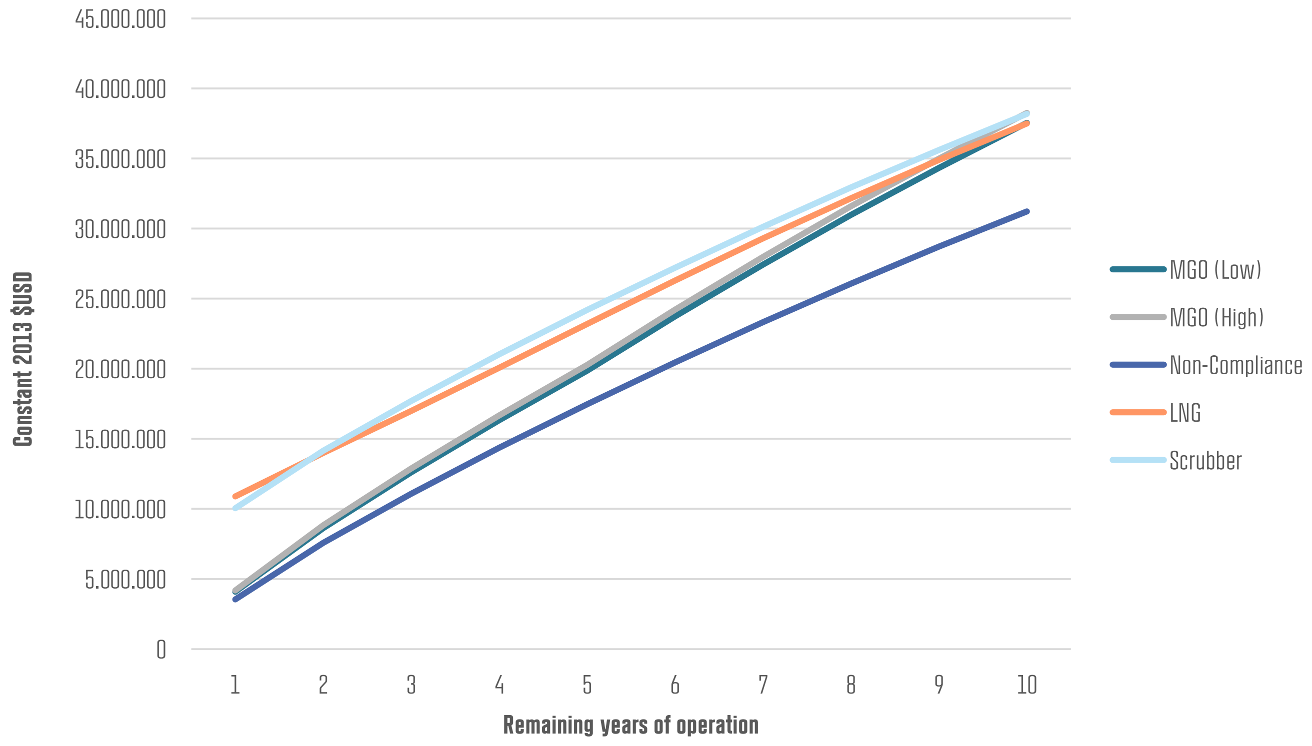

Figure 3.16: Total discounted fuel related costs with alternative MGO prices for Ship B
All costs are measured in constant 2013 USD with an annual discount factor of 7 %. The MGO (low) and (high) lines describe the costs for the vessel operating solely on MGO in the low and high price scenarios respectively while the lines labelled "scrubber", "LNG" and Non-compliance denotes the corresponding strategies. The MGO - HFO fuel spreads are assumed to be 520 and 600 USD in the low and high price scenario, respectively and the price for a ton of low Sulphur HFO is 100 USD above that of standard HFO.
Source: Own calculations

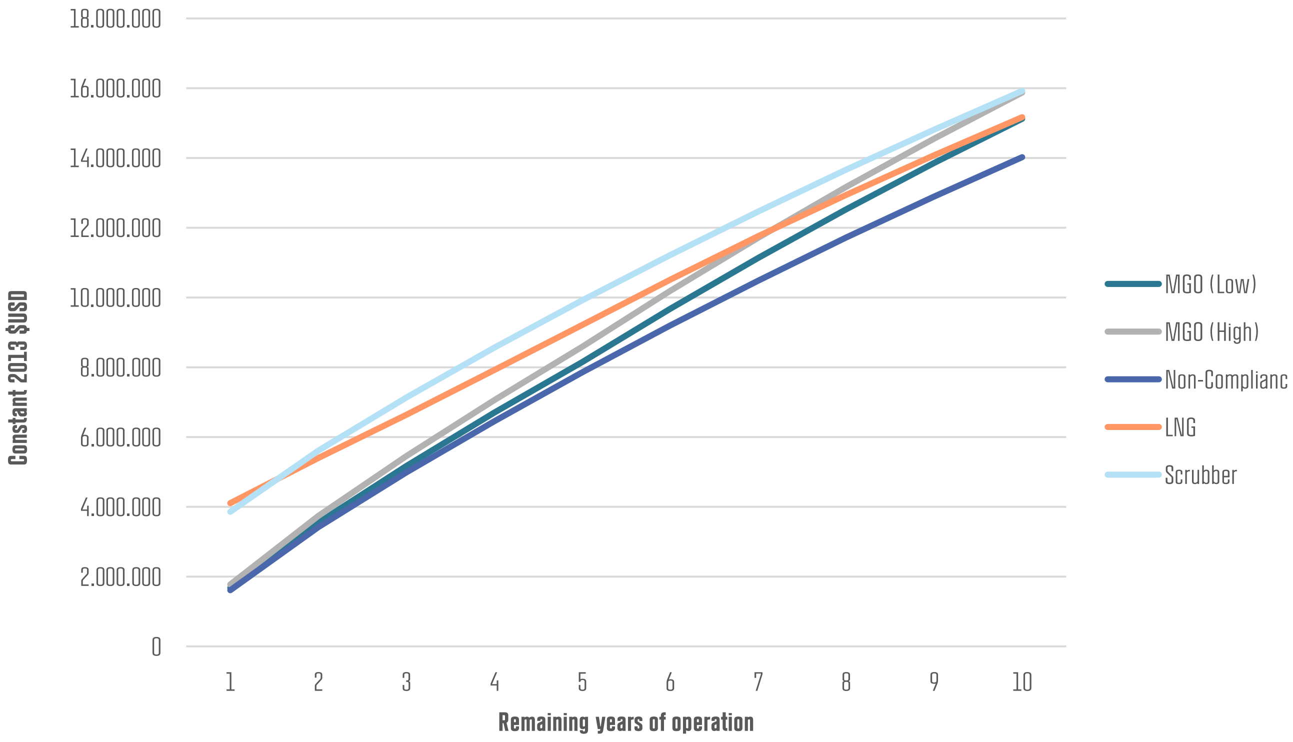

Figure 3.17: Total discounted fuel related costs with alternative MGO prices for Ship C
All costs are measured in constant 2014 USD. The MGO (low) and (high) lines describe the costs for the vessel operating solely on MGO in the low and high price scenarios respectively while the lines labelled "scrubber", "LNG" and Non-compliance denotes the corresponding strategies. The MGO - HFO fuel spreads are assumed to be 135 and 200 USD in the low and high price scenario respectively while the LNG – HFO spread is assumed to be -50 USD and the price for a ton of low Sulphur is 25 USD above that of standard HFO.
Source: Own calculations

For ship B, the critical fuel spreads changes significantly as MGO is by far the most favourable strategy of compliance regardless of the amount of remaining service years. MGO remains advantageous after 10 years compared to the scrubber even with a MGO - HFO price spread of 600 USD (depicted by the line "*MGO (high)*" in figure 3.16) while the maximum price spread allowed for MGO to continuously remain favourable over LNG takes a slightly lower value at 530 USD (illustrated by the line "*MGO (low)*" in figure 3.16).

The critical fuel spreads for ship C closely resemble those of ship A, with a maximum MGO – HFO spread of 200 USD for MGO to remain advantageous to LNG (illustrated by the line "*MGO (low)*" in figure 3.17) while this critical spread is reduced to 135 USD for the scrubber retrofit (depicted by the line "*MGO (high)*" in figure 3.17).

The higher values of the critical spreads of ship C compared to ship A, reflects the reduced navigation time within the ECA zone and the corresponding reduced need for operating on MGO compared. These differences are even more profound when taking ship B into account. This clearly illustrates how the low proportion of time spent within the ECA zone of ship B affects the optimal strategy for the ship-operator, as MGO will remain advantageous over the scrubber even with a severe increase in the price spread. With even fewer operational years remaining, this maximum critical price spread increases even further.

It is, however, also worth emphasizing the large impact the recent glut in the oil price has on the results of this analysis. A return of the price of oil and consequently the MGO – HFO price spread to previous high levels would cause the strategies of retrofits to become increasingly more feasible for vessels with a large degree of operations within the ECA zones. This is especially true for the LNG retrofit strategy as the LNG price may not increase at the same pace as that of oil. This is further emphasized by the fact that engines operating on LNG offer increased fuel efficiency[16]. Should the price of oil and HFO drop further to a level where it was on par with that of LNG when measured by energy content, the LNG strategy would

[16]For example, ship B only requires approximately 800 kilograms of LNG to cover a distance of 10 nm compared to 950 kilograms of HFO if a scrubber is installed.

become highly unfeasible compared to the scrubber due to the much higher retrofitting costs of the LNG engine conversion compared to installing a scrubber. In these examples, focus was on the optimal strategies of compliance. However, as noted above, it is evident that the strategy of non-compliance in some scenarios remained superior to that of compliance. In the next section, the required level of enforcement needed in order to deter cheating will be determined.

3.2.10 The optimal level of enforcement

From the results earlier in this analysis it was evident that the current low fine size in combination with a low frequency of enforcement results in the strategy of non-compliance offering large cost savings compared to the strategies of compliance. Although it is reasonable to assume that a majority of the ship-owners operating in the Baltic and North Sea ECA zone will comply with the new Sulphur regulations regardless of the enforcement level, the risk arises that a significant number of companies may decide to disregard the rules in order to increase financial profits. Financial constraints due the recent meagre years in the shipping market in combination with the limited enforcement procedures have given ship-owners a large incentive to adopt the strategy of non-compliance. Thus, an increase in the sanctioning of non-complying ship-owners is necessary to ensure that the SOx emission regulations are observed by the vessels, as well as maintaining an environment of fair competition within the ECA zone.

In the framework of this analysis, there are three ways to ensure that non-compliance will not remain the strategy with the lowest expected costs. The first is an increase in the fine size, the second is an increase in the inspection ratio, and the third is a combination of the above two methods.

An optimal level of the size of the fine is always subject to interpretation since some policy makers will argue that an infinitely high fine size will force all ship-owners to comply, while more moderate policymakers may argue that an optimal fine size just needs to ensure that the strategy of non-compliance will be equally as expensive as the cheapest strategy of abatement. Determining such an optimal fine size is, however, made difficult by the fact that ships have different specifications and routes, thus requiring the policy makers to adjust the optimal fine size for each vessel caught non-complying or alternatively determining the optimal fine size from the specifications of the vessel having the lowest incentive to comply. That is, the optimal fine size for a vessel operating solely within the ECA zone will most likely be lower compared to that of a vessel only visiting the ECA zone once a month. Additionally, fluctuations in fuel prices and retrofitting costs will also impact the level of such an optimal fine size. Taken together, this implies that it is impossible to determine an optimal enforcement. The complex situation faced by the policy makers is illustrated by equation 3.2 below[17].

$$TC_{j,n}^{NC}(F,\varphi) \geq min\{TC_{j,n}^{SCR}; TC_{j,n}^{MGO}\} \qquad 3.2$$

$F = Fine\ Size$

$\varphi = Inspection\ ratio$

$TC_{j,n}^{NC}(F,\varphi) = Ship\ type\ j\ total\ cost\ of\ polluting\ after\ n\ years$

$TC_{j,n}^{SCR} = Ship\ j\ total\ costs\ of\ the\ scrubber\ strategy\ after\ n\ years$

$TC_{j,n}^{MGO} = Ship\ J\ total\ costs\ of\ the\ MGO\ strategy\ after\ n\ years$

Simplified, the above equation states that for a vessel with an optimal compliance strategy equalling total costs of 20 million USD while having only total costs of 10 million for non-complying, the level of sanctioning will have to be sufficiently high such that the expected costs for non-compliance will equal the 20 million USD during a similar time period (Stigler, 1971).

The complexities of determining an optimal fine size is exemplified by the different fine sizes needed to deter the operators of each of the three examined vessels from non-complying, illustrated in table 3.7.

From the calculated fine sizes, it becomes clear that the large discrepancy in the annual amount of port visits by ship A and the other two vessels results in major fine size differences. For ship A, the optimal fine size is approximately 40 and 25 thousand USD after 5 and 10 years of operation, respectively, given at 204 annual port visits. This is increased to 200 and 380 thousand USD for ship B having only 14 annual ECA zone port callings.

Additionally, it is clear that the optimal fine size is reduced for vessels A and B when a larger amount of operational years remains. This is caused by the larger cost savings achieved when operating with a scrubber due to having a larger amount of years to negate the significant retrofitting costs. For ship B the compliance strategy with the lowest

[17] *Since the LNG strategy is not readily feasible the strategy is excluded to compare non-compliance with the currently feasible strategies of compliance.*

	Dominant strategy of compliance after 5 years	Approximate optimal Fine Size after 5 years	Dominant strategy of compliance after 10 years	Approximate optimal Fine Size after 10 years
Ship A	LNG	40.000	LNG	25.000
Ship B	MGO (low)	200.000	MGO (low)	380.000
Ship C	MGO (low)	110.000	LNG	100.000

Table 3.7: Optimal Fine sizes for the ships examined
Fine sizes are measured in 2014 constant USD. An inspection ratio of 10 percent per ECA zone port visit is assumed while the LNG strategy is excluded.
Source: Own calculations

costs remain that of MGO and the increase in the optimal fine size is therefore caused by the projected increase in the oil price and consequently the HFO-MGO fuel price spread.

It is important to note that the calculations of the optimal fine sizes rests on the assumption that port state authorities will not be able to differentiate between previously non-complying vessels. Further, the policy makers face asymmetric information, as it is questionable whether public authorities have information regarding the remaining operational period of the vessel.

Since it is evident that there is no level of enforcement which would be optimal for all vessels, it is clear that determining the enforcement level is as much a political choice as it is an economic one.

3.2.11 Examining the strategy of termination: Stena Line

As demonstrated above, the introduction of the new Sulphur regulations will result in a significant increase in the fuel related expenses of the shipping companies operating in the Baltic and North Sea. As formulated earlier, ship-operators have the possibility to avoid these extra costs by adopting the strategy of ceasing operations within the ECA zone and either relocating their assets to other markets or terminate operations all together by selling their ships. At present, a majority of the shipping companies operating within the Baltic and North Sea has opted to comply and continue operations within the ECA zone by installing a scrubber or fuel switching to MGO and relatively few changes to route networks has been announced. One of the shipping companies that has announced a reduction in their route network is Stena Line, who recently announced the layoff of 800 employees as well as the withdrawal of one of the ferries operating the route between Trelleborg and the Polish port of Sassnitz (Louise Vogdrup-Schmidt, 2014).

The ferry being retired is the 10,882 gross ton RoPax "Trelleborg" commissioned in 1982 (Stena Line, 2015a). With a vessel age of 32 years, the "Trelleborg" is nearing the end of her service period and retrofitting the vessel because of the Sulphur regulations would therefore prove to be unfeasible.

In addition to the two vessels serving the Trelleborg-Sassnitz route, Stena Line operates two RoPax vessels between Trelleborg and the port of Rostock, situated less than 150 kilometres from the port of Sassnitz. Including the "Trelleborg" three vessels services the route between the port of Trelleborg and the northern coast of Pomerania. The two RoPax vessels servicing the Trelleborg – Rostock route are the "Mecklenburg-Vorpommern" and the "Skåne" at 37,987 and 28,960 gross tonnes, respectively. Both are built in the late 90s while the "Sassnitz" servicing the route to Sassnitz is both larger and newer compared to the "Trelleborg".

According to Jesper Walterson, head of corporate communications in Stena Line, the downsizing is the result of a planned cost reduction of 450 million SEK previously initiated. Walterson also mentions that the introduction of the Sulphur regulations played a major role in the decision process (Louise Vogdrup-Schmidt, 2014). The combination of the "Trelleborg" being an aging ship and the fact that the company operates along both larger and newer RoPax vessels on similar routes makes it clear that retiring the vessel was an obvious choice for Stena Line.

The Stena Line "Trelleborg"
Courtesy of Stena Line Public Photo Libary

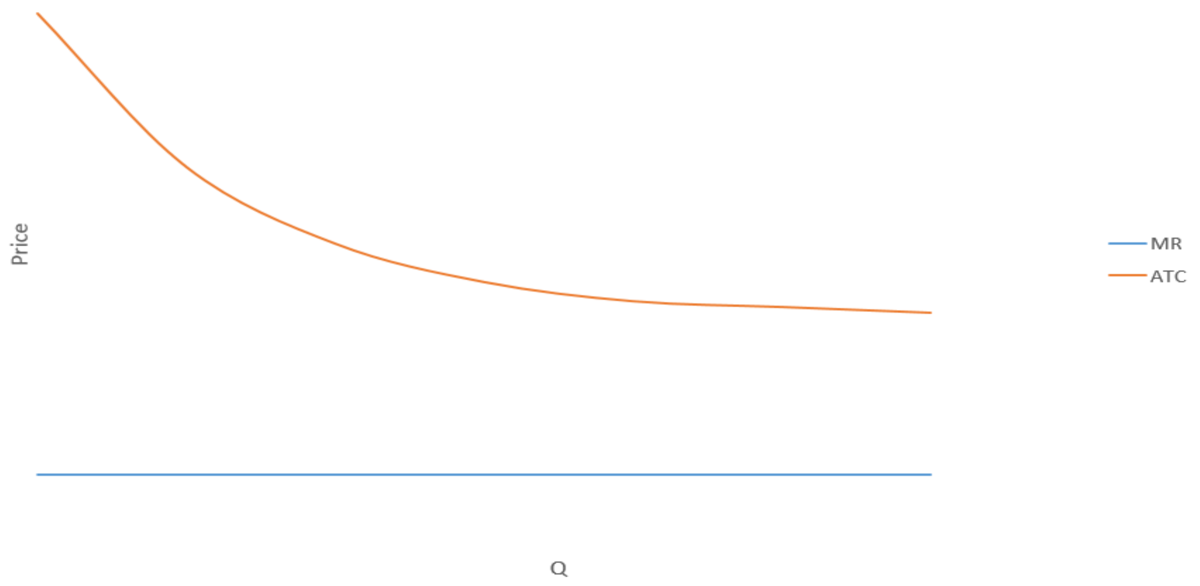

Figure 3.18: Average total costs and marginal revenue functions after the introduction of the Sulphur regulations
After the introduction of the regulations the marginal revenue curve will never exceed the average total cost curve and the vessel will therefore operate with a loss regardless of the amount of cargo transported (Q).
Source: Own illustrations.

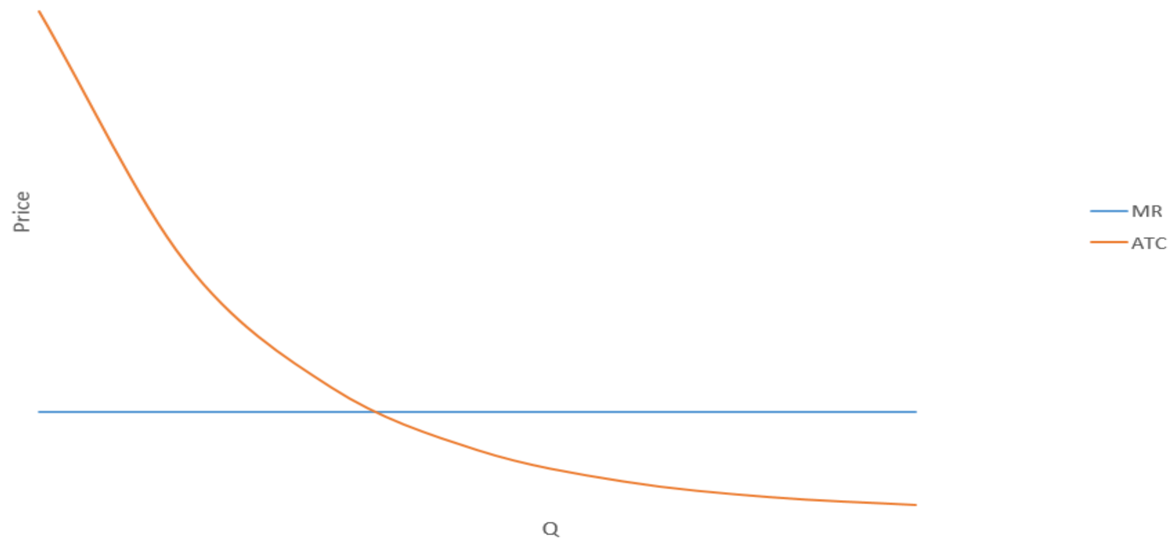

Figure 3.19: Average total cost and marginal revenue curves prior to the introduction of the Sulphur regulation
Prior to the introduction of the regulations the marginal revenue curve exceeds the average total cost curve after the intersection of the curves. Operations are therefore profitable as long as the amount of cargo transported exceeds the intersection of the two curves.
Source: Own illustrations.

This illustrates perfectly how a shipping company can adopt the fifth strategy, namely that of termination of operations.

The rationale behind Stena lines decision to withdraw the “Trelleborg” can be explained by the increase in the average costs of operating the vessel illustrated by the figures 3.18 and 3.19. Figure 3.18 illustrates the average total costs and marginal revenue of an ageing vessel operating within the ECA zone before and after the introduction of the Sulphur regulations, respectively. In figure 3.19 the extra fuel related costs shifts the average total cost curve upwards, while the corresponding increases in the freight rates adopted by the industry equally cause an upwards shift of the marginal revenue line.

Although both lines shift upwards after the introduction of the new regulatory scheme, the average costs of the ageing vessel increases relatively more compared to the revenue. This causes the average total cost curve to exceed that of the marginal revenue, thereby rendering the vessel economically unfeasible. If the increase in the fuel related costs is indeed the reason for the premature retirement of the “Trelleborg”, the introduction of the Sulphur regulation in the Baltic and Nordic Seas does not only reduce the emission of particles into the atmosphere by improvements in fuel types, but also by forcing a modernization of the merchant fleet operating within the ECA zone.

3.2.12 Implications and Conclusion

The introduction of the Sulphur regulations in 2015 will result in significant increases in the annual fuel related costs for ship-owners operating within the Baltic and North Sea. The magnitude of these fuel related costs, however, critically depends on what strategy the ship-owner adopts. These strategies include the retrofitting of a scrubber or LNG engine, substituting HFO with MGO when inside the ECA zone, violating the new regulations by continuously burning HFO, or a mix between two or several of these strategies.

Throughout this analysis, three different ships of different sizes and routes were examined in order to demonstrate how the different specifications of the vessels affected the ship-operators’ optimal strategy in response to the introduction of the sulphur regulations in the Baltic and North Sea. The results revealed that in addition to the price differences between standard HFO and MGO / LNG, the optimal strategy depends on a multitude of factors which includes the costs of retrofitting the engine, vessel size and age, distance sailed within the ECA zone, and finally the severity and frequency of the enforcement of the Sulphur regulation.

The strategy of MGO was found the be the most straightforward of the strategies to adopt – especially for aging ships where a limited number of years were available to compensate for the large investment costs of the scrubber. Because the fuel costs of substituting HFO with the more expensive MGO progressively increases with the distances sailed within the SECA (compared to the fixed investment costs of the retrofits), the strategy of MGO was found to be increasingly advantageous for vessels mainly operating outside of the ECA zone. The recent glut in the price of oil, however, even resulted in MGO being the favourable strategy of compliance for ships solely operating within the ECA zone in the low price spread scenario if more than 5 operational years remain. Additionally, it was found that for vessels operating a majority of the time outside of the ECA zone MGO will remain the dominant strategy even with a drastic increase in the price of MGO relative to the other fuel types. These results fit into the strategies adapted by the major global shipping companies such as Maersk and Hapag-Lloyd who both have chosen to burn MGO/MDO when operating within the established ECA zones in order to comply with the new sulphur regulations.

The alternative strategies of compliance involving the retrofit of a scrubber or LNG engine becomes increasingly favourable compared to using MGO, as the fraction of the voyage days spent within the ECA zone increases. Additionally, the scrubber and LNG solutions are more favourable on vessels of smaller tonnage due to the proportionally larger investment costs associated with the retrofitting of larger vessels. Lastly, retrofits are favourable on younger vessels with at least 5 years of remaining operational time, due to having more service years to take advantage of the reduced operational costs of burning HFO or LNG.

Of the two forms of retrofits examined in this study, LNG was found to outperform the scrubber strategy on all economic aspects unless only a few operational years remain. LNG as the most cost effective strategy critically hinges on the price spread between standard HFO and LNG due to the retrofit cost of the engine to operate on LNG being higher than that of installing a scrubber. In this analysis, the price of LNG per energy content was slightly lower than that of HFO and while such a scenario is plausible in some regions of the world it is by no means a globally applicable conclusion. Thus, the feasibility of operating on LNG therefore depends on the regional pricing of LNG. Additionally, the LNG ship fuel technology has not gained a wide popularity which results in a significant lack of infrastructure supporting LNG refuelling capabilities in virtually all major ports located within the ECA zone. While LNG remains the more cost effective solution of the retrofits (notwithstanding the associated uncertainty), the fuel related costs of operating with a scrubber are only marginally higher, resulting in the retrofit of a scrubber to be the choice for risk averse ship-owners operating vessels with projected fuel related costs of MGO exceeding those of a retrofit.

These results go in line with the strategies adopted by several ship companies operating primarily on short sea routes within the Baltic and North Sea such as DFDS, Brittany and Carnival. However, it is of importance that several major companies operating primarily within the ECA zone, such as Stena Line, has not adopted the scrubber strategy although parts of their fleet remain relatively young with many remaining operational years per ship. This may in part be a product of the recent fall in the MGO price spread combined with a 'wait and see'-approach, but for some companies this may also be caused by the chartering agreements where the ships operator is not the owner. This creates a situation of moral hazard as the ship owner will have no incentive to pay for a retrofit as the ship charterer will obtain all the benefits of reduced fuel costs. Conversely, ship operators chartering the vessels for a limited amount of time will have no incentive to pay the large investment costs and consequently continue operating on HFO (non-compliance) or switch to MGO.

The fourth ship-owner response examined in this study was the strategy of continued operation in the SECA while not complying with the sulphur regulations. Even though the inspection rate adopted for this study exceeded past observations in the ports of the ECA zone (see chapter 4), the strategy of non-compliance was found to incur less costs to the ship-owner compared to both the retrofit of a scrubber and fuel switching to MGO. The feasibility of the strategy of non-compliance is reduced as the average fine size, inspection rate and ports visits increase, but the current lax enforcement results in a significant cost reduction for non-compliers compared to compliers. These results may have a profound impact on the compliant shipping firms operating within the ECA zone, shifting competition in favour of those firms who disregard Sulphur regulation. Such a scenario does not reward compliance and may end up forcing compliant ship-owners out of the shipping market within the ECA zone. If compliant ship-owners are forced out of the SECA, the competition will not only be weakened but the emissions of sulphuric particles in the SECA may also remain at the previous level. This negates the positive effects of regulation that would otherwise have been achieved. It is therefore paramount for the maritime authorities of the SECA to facilitate an effective enforcement scheme such that competition on the SECA remains fair, as it is possible that several ship-operators are currently adopting a 'wait and see'-approach, and refrain from complying with the new regulations until sufficient enforcement is implemented.

The last strategy option of the ship operator is the decision to adopt the strategy of termination. This study only briefly touches on the choice of terminating previous routes and activities in the ECA zone altogether. If the ship-owner deems the additional costs of compliance too high, the ship owner can withdraw from the area by relocating to a non-SECA region or simply sell the vessel. While such strategies are most advantageous for aging vessels with a high level of fuel consumption and where the payback time of the costs retrofit surpasses the remaining operational time of the vessel, the benefits and disadvantages of these decision choices remains outside of the quantitative analysis of this study and is therefore subject to further research.

From the results of this analysis it is clear that no fuel strategy is truly dominant and that a multitude of variables impact the cost structures of ship operators navigating the ECA zone. The oil and gas prices are highly volatile and therefore have the potential to dramatically alter the conclusions of this analysis in a short period of time. The calculations employed here follow the dramatic developments in oil prices which unfolded during the latter part of 2015. It is, however, important to note that if the oil price reverts back to the 2014-levels relative to natural gas prices, it is possible for ship-owners to obtain extreme cost advantages by retrofitting the ship engines to operate on LNG. The reader is advised to review the calculations presented here as oil price projections are updated. Ship operators successfully anticipating the future oil and gas price development are therefore well equipped to secure huge cost savings and ensure a competitive edge in the industry by adopting the favourable fuel type strategies.

4 THE HIERARCHICAL PERSPECTIVE

AS A HIERARCHICAL STRUCTURE, REGULATION IS PERCEIVED AS GIVEN BY THE REGULATOR TO THE MARKET. REGULATORS MUST THEREFORE PROVIDE INCENTIVE FOR COMPLIANCE, BY SELECTING THE CORRECT ENFORCEMENT STATEGIES. THE SHIP OPERATORS MAXIMIZE THEIR UTILITY, AND THEREFORE NEED TO RECOGNIZE THEIR STRATEGIC OPTIONS. THIS SECTION SEEKS TO UNDERSTAND HOW REGULAOTRS ACHIEVE COMPLIANCE AND HOW TO CREATE INCENTIVE FOR A LEVEL PLAYING-FIELD.

Applying a theoretic framework to describe the optimal regulation from a hierarchical perspective to deter non-compliance, Gary Becker's theory of Crime and Punishment can be applied. The theory seeks to understand stakeholders' economical behaviour, given the conditions provided by the state. Stakeholder's behaviour will reflect their economical rational decision process, as they seek to maximize their value (G. S. Becker, 1974; G. Becker, 1968)

Considering vessels as agents, they operate independently of ownership and governance structure. With States as the principals, we assumed them to act in a way that maximizes the chance that agents comply with the market they create. Theory designates that agents will consider the cost and benefits of all possible actions they can take. Non-compliance will happen if the agent gains more benefit from evasion, than the risk of detection and impact of penalization. Thus the optimal decision for a risk neutral agent is that the cost saved by non-compliance (A), being higher than the probability of detection (p) times the penalization (F). To capture the behaviour patterns of agents, a premium value can be introduced to capture if agents behaviour is defined as risk averse or risk seeking (G. Becker, 1968; Eisenhardt, 1989).

Risk neutral: $A > pF$

Risk averse: $A + c > pF$

Risk seeking: $A > pF + c$

Regulators are motivated to limit a negative externality, until the marginal harm is equal to the marginal benefit. To ensure compliance, regulators can employ two strategies: increasing the detection rate (p) or the penalization (F). According to the theory, fines are the suitable solution when agents are risk averse, and if they are risk seeking then high enforcement is the optimal strategy (G. Becker, 1968).

Having understood the basic conflicts of interest in international maritime regulation and achieving compliance, this section seeks to conceptualize the regulatory environment in the European ECA. Firstly, the enforcement provisions of states according to the International Maritime Organization (IMO) will be presented. Understanding these provisions allows the reader to understand how the market is regulated and enforced by the states. Secondly, the EU directive on SO_x emissions will be examined, as the directive has a high impact on the Baltic Sea, given the amount of European states around the coast. Having clarified the provisions of the enforcement actors and the implementation of legislation, the third section will elaborate on uncertainties in relation to the enforcement level and the corresponding industry response to such uncertainties. Returning to Becker, effective enforcement is built around penalization and the probability of getting caught, a tension that will be explored in the last part of this section. This should hopefully provide insights for other ECA's around the world, for both states and ship-operators.

4.1 UNITED NATIONS CONVENTION LAW OF THE SEA ENFORCEMENT PROVISIONS

United Nations Convention Law of the Sea (UNCLOS) defines right and responsibilities of nations in respect to the natural resources, utilization of the ocean and guidelines of environmental preservation. The UN itself does not employ the convention, as it is operationalized by the IMO, the international whaling commission, and the international seabed authority. This report focuses on the IMO, as it is the "competent international organization" within the scope of vessel operations. To define enforcement efforts, Part XII, Section 6 of UNCLOS is concerned with the environmental protection enforcement of vessels. It provides environmental responsibilities and enforcement provisions for Flag-, Coastal- and Port-States. Coastal- and Port-States share some provisions, governed by Section 7 *Safeguards*, which defines states provisions for vessel investigation (United Nations, 1982).

4.1.1 Flag state role

Article 217 in UNCLOS states that flag states must ensure compliance by vessels in their registry, to the international rules and standards established by the competent international organization, to reduce the pollution of the marine environment. Flag states must provide ships with certificates proving compliance with environmental regulation. These certificates are in turn to be accepted as proof of compliance by other states, unless there is a credible suspicion of non-compliance.

If a violation occurs of vessels in their registry, the Flag state is the responsible authority and is required to provide effective enforcement. This is irrespectively of where a violation occurs. If notified of a non-compliant vessel, the flag-state must provide *immediate investigation* in the matter. Penalties imposed on vessels for violations must be *adequate in severity to discourage violations where they occur*, this means that penalties should reflect the severity of the violation – ensuring a certain level of penalties across all flag states for violations. However, the Port- or Costal-state also have capabilities to provide fines (UNCLOS, art. 217).

4.1.2 Port state role

Article 218, *Enforcement by port State*, provides enforcement provisions for port states over vessels voluntarily entering port. If a port state believes that a vessel has violated international environmental regulation, it is allowed to investigate any discharges of polluting elements within the internal waters, territorial sea or exclusive economic zone of that state. Upon request, a port state can also investigate discharge from vessels on the behalf of other states, including investigation requests by the flag state (UNCLOS, art. 218).

Investigation of vessel compliance is primarily done examining bunker logs. However, if these logs are insufficient or show non-compliance, then bunker samples are taken to test the quality of the bunker. The article provides enforcement provisions for Port-states in the Baltic Sea to enforce SECA regulation. It is evident that Port-states have the most direct physical enforcement power on vessels, as they constitute the gateway for vessels cargo (UNCLOS, art 218).

4.1.3 Coastal state role

Article 220, Enforcement by Coastal States, provides coastal states provisions for monitoring compliance. It allows inspection of vessels passing the territorial waters and EEZ of a coastal state, if there are clear grounds for believing that a vessel is non-compliant with international rules and regulation. This is despite the notion of Innocent passage (UNCLOS, Part II, Section 3), as this can be disregarded if evidence supports non-compliance with rules of prevention or reduction of pollution from vessels. If the coastal state is limited in actual enforcement, they may obtain information from the vessel, and pass on enforcement to port states. The impact on vessels in the SECA is that a costal state may, if they have a suspicion, investigate any boat that they believe are non-compliant. Coastal states can therefore act as a catalyst to increase overall enforcement of Sulphur emission rules (UNCLOS, art. 220).

4.1.4 Section 7 Safeguards

For Coastal- and Port-States, certain rules apply as to the proceedings on how to exercise their enforcement provisions. Article 226 refers to *the investigation of foreign vessels*; it states that investigation should *not delay a foreign vessel longer than is essential*. Investigation is seen as being limited to the examination of certificates, records and other documents – required by international rules and standards. Further inspection may be carried out if; there is a clear ground for believing missing correlation between documents and the actual condition of the vessel, documents are not sufficient to confirm violation or valid certificates are not carried (UNCLOS, art. 226).

Release of investigated vessels should be made as promptly as possible, following reasonable procedures such as inspection, bonding or other financial security is provided. Only if the direct seaworthiness of the vessel is questionable, regarding its threat to the marine environment, may the vessel be detained until repairs have been made. This allows states to take administrative measures to prevent vessels form continuing their voyage, if they are deemed a threat to the marine environment (UNCLOS, art. 226).

Article 228, *Suspension and restrictions on institution of proceedings*, provides the flag state with certain powers to counterbalance the proceedings of its registered vessels. Flag states may contact the Port- or Coastal-states stating that they will overtake the proceedings, giving some regulatory power to the Flag-states. The only exceptions are if there is major damage to the violated state in question, or if the flag state has repeatedly disregarded its obligation to enforce effectively. This ensures that Flag-state must oblige by its obligations and cannot just be lenient towards vessels (UNCLOS, art. 228).

4.2 SULPHUR REGULATION

The International Maritime Organization is mandated by the United Nations to regulate maritime affairs, providing a global regulatory framework. Maritime conventions are developed with states, providing the IMO with a high degree of international legitimacy. Their framework provides guidelines and regulation for the maritime industry through conventions regarding: safety, education, navigation (SOLAS) and environmental concerns (MARPOL).

MARPOL is operationalized by the IMO Marine Environment Protection Committee (MEPC), with Section VI of MARPOL focusing on Sulphur emissions. When this section was ratified in 2005, it provided the option to create Sulphur emission control areas, which were introduced in the Baltic Sea and around the North American continent.

The EU Sulphur Directive was used to implement MARPOL Annex VI into national law of EU member states around the Baltic. With a large amount of the states surrounding the Baltic Sea are EU members, this allowed for harmonization of enforcement practices, perhaps ensuring a level playing field. The 2012 amendment directive works with three areas of interest for the industry operating in the SECA zone: Enforcement of by member states, Directive commissions influence on this enforcement and a clause regarding the Supply of bunker fuel (European Parliament & Council of the European Union, 2012).

Power delegation of enforcement frequency adjustments by the commission is defined in article 9 of the directive. It states that the actual power delegation to the EU commission will not be until March 2017, when a report will be published defining this. Yet the directive commits *Member States to establish a system of effective, proportionate and dissuasive penalties for non-compliance.* The former is open for interpretation, which explains why member states have different approaches to implementation of the directive.

The penalties determined must be effective, proportionate and dissuasive and may include fines calculated in such a way as to ensure that the fines at least deprive those responsible of the economic benefits derived from their infringement and that those fines gradually increase for repeated infringements. (Directive 2012/33/EU Art. 11, 2.)

Article 11, Penalties, expands on how Member states should impose penalties for vessels not complying with the emission standards set by the EU. The penalties must reflect the economic gain from cheating, to create a strong incentive for compliance. Currently many different penalization strategies are present in the SECA, which will be elaborated below.

Member States shall take all necessary measures to check by sampling that the Sulphur content of fuels… [Sampling] shall be carried out periodically with sufficient frequency and quantities in such a way that the samples are representative of the fuel examined, and in the case of marine fuel, of the fuel being used by vessels while in relevant sea areas and ports. (Art. 6, 1.)

Article 6, Sampling and analysis, dictates how member states must enforce control of Sulphur content of bunker fuels, as different Sulphur emission limits are enforced in the SECA. Section 1.a. dictates that sampling methods should be: the ships log books, bunker delivery notes or sampling fuel in the tanks. 1.b, provides the Commission with the empowerment to adopt implementing acts concerning the frequency of sampling, the sampling methods and the definition of a sample representative of the fuel examined. In the directives current form, bunker samples are deemed as the strongest proof of violation.

Enforcement should therefore reach equilibrium within the

SECA, when compliance is the only viable option, if regulation reflects how the implementation will be in real life. The Commission can create a unified enforcement, by controlling the frequency of the enforcement and making sure that member states penalize policy deters non-compliance. Critique of the directive is how states interpret penalties as proportionate and able to deter repeated infringements. The EU has the hard legislative power, however soft power organizations like the Helsinki commission (HELCOM) are important in creating the level playing field.

4.3 IMPLEMENTATION OF SECA

A list of uncertain elements affects the implementation of the SECA. Uncertainties arise in the regional geopolitical situation, the new EU commission and the role of states in regional forum HELCOM. The individual national commitments to enforcement the SECA creates uncertainty for the harmonized implementation. Member states pushing for technological innovation can increase enforcement by making it more cost efficient.

4.3.1 EU Commission

The current commission originally listed 10 priorities, where the main focus is on creation of: a stronger internal market, strengthening European competitiveness, creation of an efficient energy union and maintaining the EU as an important global actor. There has been some critique of the commission by Green10, an organization for the ten biggest environmental NGOs. Green10 stated in a common letter in 2014: "… *strong concern over President-Elect Juncker's attempt to downgrade the environment in Europe and asks the European Parliament to reject the Commission"* (Green10, 2014). This critique was coined at the creation of the commission, and adaptations have been made to prioritize sustainability.

Sulphur emissions have become a worry of the commission, and in November 2015 Romania was referred to the Court of Justice of the EU over failure to transpose the EU Sulphur regulations. They were referred due to the importance of adherence to the standard, which aligns the EU with the standards created by the IMO (European Commission, 2015b).

The development and adoption of EU regulation 2015/757, on reduction of carbon dioxide emissions, supports that shipping emissions are indeed in focus. The EU legal framework, active for all European waters by 2018, forces all vessels above 5000 gross tons to monitor, report and verify their CO2 emissions (European Commission, 2015a, 2015b). This scheme provides a regional monitoring, referred to as the MRV, which is comparable to the global scheme under development in the IMO. It was

Source: Scanpix / Iris

implemented because the EU concluded that the IMO was too slow in the process of creating the global system (Maritime Danmark, 2012).

4.3.2 Regional commitment to enforce

The Helsinki Commission (HELCOM) was established as an organization for protection of the marine environment in the Baltic through inter-governmental cooperation between Baltic Sea states. The commission is controlled by the Helsinki convention, which entered into force in 2000. In November 2014 it published a report concerning the enforcement of Sulphur, which is thus able to illustrate states commitment and the uncertainties they identify (HELCOM, 2014). Since IMO rely on member states to enforce rules, HELCOM is an important body when it comes to implementation of IMO rules in the Baltic Sea.

HELCOM findings identifies that there is a need for harmonized enforcement across states for efficient implementation. Deviance in assessment criteria and penalization of non-compliance are seen as a key challenge. Different penalization types include: administrative fines, detention and criminal prosecution. Harmonization is thus hard to achieve, as penalization impact on vessels is not equal in all states.

Targeting vessels for inspections, states agree that existing targeting mechanism by the ports is sufficient. States around the Baltic Sea have signed Paris Memorandum of Understanding (Paris MOU), issuing guidelines and educating control officers to carry out inspections. Their system rewards quality shipping with higher intervals of between investigations, targeting ships based on movement patterns and statistical non-compliance. Some states identified that perhaps the system should be modified slightly to especially target ships operating routes exiting and entering the ECA, to deter non-compliance (HELCOM, 2014).

Due to the strategic position coastal states like Norway, Sweden and Denmark can de-facto increase the enforcement level, through coastal state provisions in UNCLOS. They are located at key waterway junctions, where all traffic for the inner Baltic Sea has to pass. Since all ports are members of the Paris MOU, the penalization can be passed on to the destination ports. This however would require a high investment from costal countries to carry out this type of enforcement, where technology might be the best catalyst for this type of intervention. This alternative should be explored, as the regional Sulphur restrictions implementation might be a beacon for how to implement the global restrictions in 2020/2025.

The only countries that are not affected directly by the EU directive are Norway and Russia. Norway, known as a quality shipper, will most likely provide a high enforcement level. Russia has shown resilience against the implementation of Sulphur emission restrictions within the negotiation process of HELCOM. However implementation is moving forward, as inspections have started from the middle of May 2015 (L. Vogdrup-Schmidt, 2015).

4.3.3 Development of Reporting and Enforcement tech

The development of “The Common Information Sharing Environment for the EU maritime domain” (Maritime CISE) is the first step of the way towards increased enforcement. On top of this THETIS-S is being developed, as an add-on to the existing Paris MOU system. Future developments of the CO2 focused MRV directive could perhaps be used as a catalyst, to increase the overall monitoring of vessels.

New technological developments are emerging, as demand is created for technology used for either proving compliance by the industry or improving enforcement possibilities by states. One technological advance that HELCOM deemed necessary was the need for faster fuel testing, due to the long waiting times with the current testing process (HELCOM, 2014).

For states wanting new enforcement technology a few options have emerged, the first example being the test installation of sniffers under the Great Belt fixed Link Bridge in Denmark, by the Danish technological institute. Due to a direct correlation between the CO2 and SOx, the Sulphur content can be derived from the emission of vessels passing under the bridge (Køcks, 2013). The downside to having fixed sensors is that non-compliant vessels will avoid or use compliant fuels when below the sensor. “Project Sense” is a project currently developing drones, with the same sensors, to automatically investigate ships far from the coastline. This allows the monitoring to be more adaptive, and to capture all vessels deemed risky by authorities (Explicit, 2014).

Both these technologies are in the final development phase and are currently not being used as enforcement techniques. They could however in the future provide better enforcement for states, given their potential to monitor ships automatically and at a lower price than current inspection by fuel testing. The same detector technology has been developed to industry self-monitoring and reporting. This emergence is supporting the development of the European MRV directive, and other Green-shipping rating systems. This provides an option to move away from the traditional bunker notes as proof of compliance, allowing for more data to prove compliance.

4.4 WILL VESSELS COMPLY IN THE BALTIC?

The EU directive is able to influence the frequency, and not the fine level. This critique is important, as the Baltic Port Organization have investigated the administrative fines distributed by Baltic States for non-compliance to range from a few hundred Euros to over 84000 Euros (Rozmarynowska, 2015). Other states utilize their criminal system to determine fines, which makes it difficult to deduct how well their system is able to deal with non-compliance. Penalization in the form of black listing is also a possibility. (HELCOM, 2014) There is a high fluctuation in fines, how they are administered and their impact, which provides some degree of uncertainty for efficient regulation.

The Paris memorandum of Understanding (Paris MOU) provides all European port authorities with a targeting framework for vessel inspections. This system rewards the quality shippers with a higher interval of inspections, while targeting ships based on statistical non-compliance and movement patterns entering and exiting the SECA. Members of the Paris MOU commit themselves to inspecting 25% of the foreign vessels calling their harbours. The targeting mechanism has been enhanced to increase Sulphur inspections of potential non-compliant ships within the ECA, using THESIS-S. A targeting mechanism like this is important when considering enforcement and implementation consist of a vast amount of different types of stakeholders, with different enforcement mandates for each.
(Paris MoU, 2013; Schiferli & Hinchliffe, 2014)

In this study it has not been possible to quantify the economic loss of blacklisting or reputational damage of vessels. Non-compliance might exclude vessels from certain clients, a notion proposed by Desombre as “clubs”. She argues non-compliant operators can be segregated to a secondary market. This is achieved through excludability from the market, forcing all stakeholders in the market to comply. She points out that the demand for higher quality shipping will require customer pressure and policy makers to reward compliant operators/punish non-compliant operators (DeSombre, 2005, 2006).

4.5 LESSONS FOR ECA IMPLEMENTATION

Taking the lessons learned in the Baltic, many things can be transferred to enforcement of other ECAs. Becker define that stakeholders as willing to comply, given that the value of compliance is smaller than the probability of getting caught multiplied by the penalization impact. This impact can either be monetary or market access related.

It is therefore important for regulators to understand what operator’s behaviour and reasoning, as they must use this to provide the correct incentives for compliance. Regulators should increase enforcement until they are able to benefit society more than the cost of enforcement. Understanding the conditions vessels operate under: short-, long-term chartering vs. owning, as this will define the chosen compliance strategy by vessels. It is therefore important to identify the incentive structure of vessels, which is connected to the ownership structure. With leased vessels the question is thus: are ship owners are willing to pay for the asset improvements like scrubbers, compared to a compliance solution where operational costs are increased using MGO (Becker, 1968).

Operators must also understand the actions of regulators to self-maximize their operations to cope with the markets provided by the state. In understanding the long-term developments of the market, vessels can gain long-term competitive advantages by selecting the correct compliance method. Without a level playing-field however, the compliant operators will not have an incentive to adapt to the new market, thus making the market inefficient. Business pressures to create a level playing field in the ECA are apparent with the Trident alliance, being a strong an advocate of harder enforcement. As seen in the next section, operators should consider the possibility to actively engaged with regulators to create a viable working market.

5 THE NETWORK PERSPECTIVE

CONTRARY TO THE HIERARCHICAL AND MARKET PERSPECTIVES, THE NETWORK PERSPECTIVE ASSUMES THAT ACTORS CAN FORM NETWORKS AMONG THEMSELVES TO GIVE MEANING AND VALUES TO CERTAIN ENTITIES. THIS CHAPTER EXAMINES THE PROCESSES BEHIND THE SECA-ZONES, THE PROPOSED BALTIC NOX EMISSION CONTROL AREA, AND THE ALLOWED PH-VALUE OF OPEN-LOOP SCRUBBERS AND SHOWS THAT AN ACTOR NETWORK THEORY APPROACH BRINGS ADDED VALUE TO THE UNDERSTANDING OF POLITICS.

To examine the political processes that lie behind the environmental regulation of international shipping, this chapter takes departure in the Actor-Network Theory (ANT) to analyse how the specific values of specific proposals came to be. First, the report explains the analytical framework; second, the processes for each of the specific issues are outlined; third, the analytical framework is applied to the processes.

The analytical framework is structured around two central concepts: the *semiotic* metaphor and the *strategic* metaphor. The basic assumption here is that the value of a given entity – such as the area covered by a SECA or the allowed level of SOx emissions – is constructed by political actors *in conjunction with non-person actors* rather than being 'given' by some objective measure. Non-person actors can be anything that helps giving the value of the entity, such as a scientific report or a specific calculation (Hansen, 2005b; Law & Mol, 1995a).

The semiotic metaphor describes a situation where the value of an entity is 'stabilized', meaning that certain actors have succeeded in giving the entity a certain value. The strategic metaphor, on the other hand, describes a situation where actors are mobilizing resources to change the value that was otherwise stabilized. Below, the two concepts are explained in more detail.

5.1.1 Semiotic metaphor

The semiotic metaphor illustrates and describes how a network of actors affects a social order. In this metaphor, the network of actors that surround it gives the entity (such as a rule, a norm, or the definition of a particular interpretation) its identity and nature. A common example of an entity is that of Louis Pasteur. Pasteur was a famous scientist, but he was also a politician and a husband to his wife. His identity can be any of these things, depending on the context from which we associate him. Usually, his impressive scientific discoveries come to mind first, and we think of Pasteur as the scientist. It is possible that he could have any of the other identities, but his scientific discoveries are so powerful that we almost exclusively think of him as a scientist (Hansen, 2005a; Latour, 1983, 1993; Law & Mol, 1995b).

The semiotic metaphor is thus an observed entity (which can be a person, a rule, a physical item or anything else) that has an associated network. This network creates one identity, while an opposing network represents another identity for the entity in question. This alternative network is still connected to the entity, but is not strong enough to give identity to the entity. In the example of Pasteur, we could see a network consisting of his scientific discoveries, his laboratory, and his scientific colleagues. The opposing network could consist of his wife, his children, and his responsibilities to provide for his family. While both networks create a context, the scientific network is much stronger when we, the public, think of Pasteur.

Importantly, the individual actors are 'black-boxed'. ANT does not try to explain how networks constitute every actor in turn, but rather takes for granted that some actors have unintelligible aims and goals. The assumption is thus that we can only observe, not explain, these aims and goals.

With Louis Pasteur, for instance, we would simply take the identity of his wife for granted, and not necessarily question what networks give rise to her identity as 'wife'.

5.1.2 Strategic metaphor

The semiotic metaphor describes the identity of the entity by actors in a number of networks. The strategic metaphor on the other hand takes actors as *strategizers*, who seek to mobilize their resources to influence the dominant identity of the entity. Actors deliberately try to give effect to the identity using '*interessement devices'*. These devices are resources (which are also actors, as noted above) mobilized in some specific way to strengthen the link between the strategizing actor and the entity in question, while links between the entity and other actors are weakened. If successful, this mobilization of resources changes the identity of the entity so that the strategizing actor now defines the identity.

A simple example illustrates this. Suppose two actors, an environmental NGO and a shipping firm, are connected to the entity 'emissions from container shipping'. Each actor wants to give an identity to emissions but have completely different conceptions of the value emissions have to society. The NGO wants to give the emissions an identity that implies harmfulness to the environment and large health damages to the public, implying that emissions have a negative impact on society. Conversely, the shipping firm thinks that emissions are a necessary evil because sea transport increases societal value. High emissions from ships allow for cheaper overall transport costs. The lower costs are associated with not having to clean the exhaust gas, implying an overall positive impact on society.

Suppose that the shipping firm and its resources currently provides the identity of the entity such that emissions from ship is generally considered a good thing This is the stable network that we can describe with the semiotic metaphor. The NGO wants to challenge this perception and sending out a scientific report to stakeholders, clearly concluding that the health costs of emissions are far higher than the positive effects of lower transportation costs. This mobilization of resources (in this case information) may result in a change of identity, from emissions being 'positive' to 'harmful'. However, this depends on the strength of the report vis-à-vis the strength of the previously established stable network between the emissions and the shipping firm.

To illustrate the semiotic and the strategic metaphors, we employ a simple illustrative method. Actors are shown as black dots, and black lines between dots represent agreement on a certain identity which constitutes a network. Two networks, as in the case of Pasteur, connect to the entity in question which is placed between the networks of actors. The mobilization of resources and the interessement devices are shown as arrows that cross over the opposing network's link to the entity. This illustrates the effort to disconnect the other network's link to the entity.

5.1.3 The IMO Process: A brief overview

The process to develop new environmental standards in IMO is long, but it can be summarized and understood with relative ease.

Generally, IMO enacts new regulation by creating new conventions or amending existing ones. The members of the UN have voting power at the General Assembly, but in practice, much of the work takes place in the committees of the organization. Delegates supported by advisers from member states have seats in these committees, and each committee have authority over a certain policy area. The relevant committee in this context is the Marine Environment Protection Committee (MEPC).

MEPC meetings, which are annual or semi-annual, cover specific issues, and the major decisions are taken at these gatherings. During MEPC meetings, working groups are often created to treat a specific issue where there is either technical uncertainty or political disagreement. These groups work during the MEPC meeting over the course of several days, and the conclusions inform the MEPC meeting which subsequently decides on the issue. Finally, MEPC has several sub-committees who specialize in technical deliberations in certain areas. In this context, the interesting one is Pollution Prevention and Response (PPR), which was formerly known as Bulk Liquids and Gases (BLG). These sub-committees meet between MEPC meetings and provide input to the general meetings based on technical information provided by members or other stakeholders.

5.2 CASE: THE ROAD TO REVISED SULPHUR RULES IN MEPC

5.2.1 Background

The process leading up to the decision to regulate global Sulphur emission originates in the 1970s when the MARPOL convention was adopted. In the negotiations before adoption, it was discussed whether air pollution should be included in MARPOL, but eventually the proposal was dropped.

During the 1970s, it became clear that air pollutants from vessels were responsible for significant harm to human, animal, and plant life. A ministerial meeting in Geneva in 1979, agreed on the "Convention on Long-range Transboundary Air Pollution". This was the first international legally binding instrument concerning air pollution in shipping. This convention was amended several times to limit emissions of Sulphur, Nitrogen Oxides and volatile organic compounds (VOCs).

It was not until 1988, however, that the IMO Marine Environment Protection Committee (MEPC) decided to include air pollution in its work programme. Eventually, MEPC agreed on a resolution that would allow amendments to MARPOL, including provisions on air pollution. This resulted in the adoption of MARPOL Annex VI in 1997. Annex VI included provisions on limits of Sulphur, Nitrogen Oxides and ozone depleting substances, as well as provisions that allowed for the establishment of so-called Emission Control Areas (ECAs). In these areas, the allowed Sulphur limit was 1.5 % m/m instead of the global limit of 4.5 % m/m.

Core Meetings in Implementation of Sulphur Regulation		
MARPOL VI ratification	May	2005
MEPC 53	July	2005
BLG 10	Apr	2006
MEPC 55	Oct	2006
BLG 11	Apr	2007
MEPC 56	Jul	2007
BLGWGAP2	Nov	2007
BLG12	Feb	2008
MEPC 57	Apr	2008
MEPC 58	Oct	2008

Table 5.1: Core IMO Committee and Sub-Committee meetings regarding SOx Regulation

MEPC 53

In May 2005, the IMO members ratified MARPOL Annex VI, which entered into force the following year. At the MEPC 53 meeting in 2005, it became apparent that there was a need to revise MARPOL Annex VI in light of new scientific studies highlighting the continued harmful effects of emissions (MEPC, 2005). In addition, abatement technologies and engine designs had developed considerably since 1997. Several submissions to MEPC argued that this should be taken into account; as such, developments reduced the cost imposed on ship-owners and shipyards. As a result, MEPC 53 instructed their sub-committee BLG to initiate a revision of Annex VI, taking into account the aforementioned developments. The revision was estimated to take several years.

BLG10 (BLG/10/19)

At the subsequent meeting in BLG (BLG 10), the delegations commenced the revision process by establishing a working group on air pollution (abbreviated BLG WGAP). The working group met during BLG 10, featuring heavy and intense discussions over both scope and ambition of the new revised rules. The working group could not reach agreement on the issue, and only outlined several options for reducing Sulphur emissions (BLG, 2006, para. 14.22 – 14.24).

The plenary accepted the report of the working group, but because of the differences in opinion and the perceived lack of hard evidence or science, the plenary agreed to establish an intersessional correspondence group. This group would meet between BLG 10 and BLG 11 to discuss the technical matters of Sulphur emissions. In this context, it was emphasized that interested parties should submit data, information, or studies that furthered the work of the sub-committee.

BLG 11 (BLG/11/16)

BLG 11 reviewed the results of the correspondence group, concluding that the options for reducing Sulphur emissions could be reduced to three: lowering the global cap, creating Emission Control Areas (ECAs), or emphasizing very low caps around ports and cities along a slightly lower cap.

Following the report, the issue was debated thoroughly. It was questioned whether the petroleum industry could provide low-Sulphur fuel for the maritime sector in the required quantities. The merit of changing to these distillate fuels was also put in question. A large number of delegations stressed the need to assess the availability of distillate in a comprehensive study. They were opposed by other delegations, arguing environmental action should be taken swiftly.

The working group on air pollution was re-established during the session, and the report sparked even more discussion and statements by delegations (BLG, 2007, para. 5.45). Eventually, BLG 11 determined that more time was needed to finalize the MARPOL draft revisions and another intersessional correspondence group was initiated. Parallel to this, the IMO secretary general established an informal expert group of researchers to aid BLG and MEPC in their considerations.

BLGWGAP 2 (BLG/12/6)

At the second intersessional working group meeting, many matters, especially concerning Nitrogen Oxides, were discussed. However, the working group did not consider matters of Sulphur emission levels in detail because the expert group commissioned by the secretary general was still working on it. Thus principal questions remained, which were transferred to BLG 12.

BLG 12 (BLG/12/17)

The outcome of the BLG intersessional working group and the informal expert group was presented at the BLG 12 meeting. The working group presented proposals on a wide range of issues including draft proposals to NOx Tier II and III as well as standards for determination of fuel oil quality. The expert group established by the General Secretary provided additional scientific evidence and background. The groups provided these inputs to allow the BLG to decide on a road forward for Sulphur regulation. The intersessional working group report marked the beginning of elaborate discussions about the best course of action to reduce Sulphur emissions. This culminated in another working group that worked through the BLG session, presenting their results at the end of the session.

This report compressed the options for limiting Sulphur into three distinct solutions. One solution saw emissions lowered through a global cap decrease, but with no stricter caps in ECA's. Another solution saw ECA's as being the main vehicles of emission limit. The final proposal for a solution utilized micro-ECA's that would be geographically limited around harbours. BLG forwarded all of these proposals to MEPC 57.

MEPC 57

All of the considerations that were discussed from BLG 10 to 12 and in various working groups were carried over into MEPC. Due to the high political, economic and environmental importance of the decision, 22 papers were submitted by NGO's, member states and industry associations. Most notably, the European Commission stated that if IMO failed to impose stricter emission standards, the EU would retain its right to impose unilateral requirements in European waters. This was partly in response to some countries (notably Brazil) that argued the industry required more time to implement new requirements. Finland, Germany and Norway submitted a paper that strongly argued that it was imperative that IMO made a clear decision at this meeting. The alternative would be unilateral or regional measures imposed outside of the IMO framework. (MEPC, 2008b).

MEPC decided to establish a three-day working group to finalize the draft for approval on the last day of the MEPC session. The substantive requirements, as well as the timeline for implementation of new regulation were deliberated. The working group evaluated all the relevant submissions and documents carefully, all of which either provided new information or argued for or against one of the three options. Finally, the working group agreed unanimously on a new set of standards which included more stringent global requirements, ECA requirements, and a markedly lower global fuel Sulphur content by 2020 (contingent on a fuel availability study conducted no later than 2018).

Notably, the final report of MEPC 57 emphasized the importance of the result, given that the large working group had agreed on progressive and substantial Sulphur standards (MEPC, 2008b). MEPC 57 approved the draft revisions of the working group, for adoption on MEPC 58.

5.2.2 ANT Analysis of the SOx Process

During the crucial months in early 2008, when the new SOx regulation was finalized, a central discussion was the geographical scope of the regulation. The long process had resulted in a few options that would constitute the basis for negotiation, divided into three core possibilities. Two options emphasizing global and regional SOx requirements, while one emphasized a purely global uniform requirement.

We can identify the two networks that wanted to give effect to the geographical scope of the SOx regulation.

One network, with the main actors being INTERTANKO and ITF, sought to give a global identity to the SOx regulation. The other network centred mainly on North European actors such as Germany and Denmark. They articulated a position emphasizing global regulation *and* regional regulation in ECA-zones. This is shown in figure 5.1.

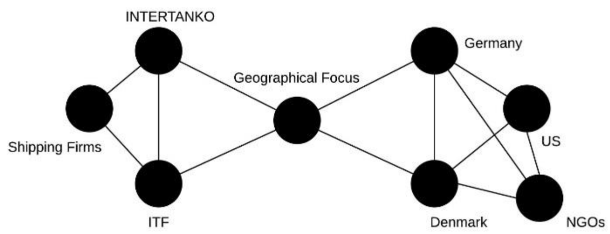

Figure 5.1: Semiotic Metaphor before MEPC 57
SOx-case

INTERTANKO and ITF argued that ECA-zones and regional regulation in general is a worse alternative for several reasons. They suggested that only global regulation should be pursued because of immature abatement technology and the difficulties of enforcing different SOx requirements. They also highlighted the obstacles of differentiated regional requirements, related to fuel-switching problems. This is illustrated as the strategic mobilization conducted by INTERTANKO that seeks to cut off the opposing network in figure 5.2.

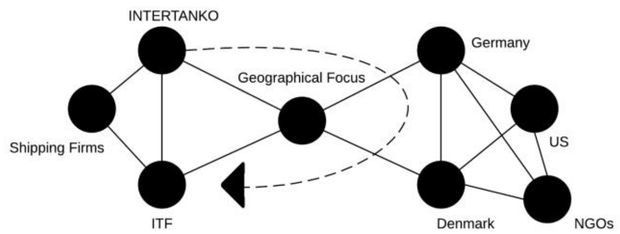

Figure 5.2: Strategic Metaphor at MEPC 57
Interessement device by INTERTANKO

Germany and other Northern European countries opposed ITF and INTERTANKO, arguing that the environmental and health-related benefits from regional regulation outweighed the perceived complications (figure 5.3). This maneuver was materialized by the document submitted by the northern countries (MEPC, 2008h). Evidently, both sets of actors were strategizers who mobilized resources with the aim to change the identity of the geographical focus.

The result of these competing influences on the geographical parameter was that the German/Danish network succeeded in changing the focus towards ECA's and a global scope, which resulted in the model we have today. The suggestion contained in document MEPC 57/4/30 was agreed upon by MEPC57 with only minor modifications, creating SOx ECA zones in Northern Europe and around North America. It is clear that INTERTANKO and ITF did not succeed in determining the geographical scope of SOx regulation.

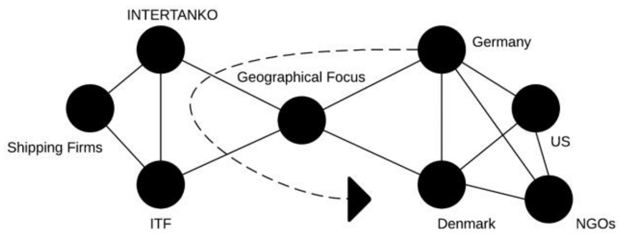

Figure 5.3: Strategic Metaphor at MEPC 57
Interessement device by Germany and Denmark

5.3 CASE: FORMULATION OF WASHWATER DISCHARGE CRITERIA

5.3.1 Background

Parallel with the process of Sulphur-requirements, the question of requirements for exhaust gas cleaning systems (EGCS's) remained an important issue. The core disagreement revolved around the allowable methods for removing Sulphur from exhaust gas. Throughout BLG 10, 11 and 12 and MEPC 56, the delegations and respective working groups had tackled the issue of 'equivalence', which was a term that designated to what extent a given abatement method was as good as using low-Sulphur fuel oil.

MEPC 56 provided the first concrete draft, which was based on a correspondence report with input from many different nations. The MEPC 56 established a working group tasked with discussing these different criteria for the EGCS, most notably the water discharge contents. The working group delegations discussed parameters and criteria extensively with references to the correspondence group report. With respect to pH-values for EGCS's, it was agreed that technological developments and information would warrant further consideration, beyond the draft the group agreed upon.

MEPC 56 approved the report of the working group and instructed an intersessional BLG working group to take into account the outcome of the MEPC working group and provide input to the next MEPC meeting. The concrete draft (including substantive pH values) proposed by the MEPC 56 working group was forwarded to this working group as a secret document.

Core Meetings in Determining pH Value of Scrubber Waste Water		
MEPC 59	Jul	2009
MEPC 60	Mar	2010
MEPC 61	Oct	2010
BLG 15	Feb	2011
BLG 16	Feb	2012
BLG 17	Feb	2013
PPR1	Feb	2014
MEPC 66	Apr	2014
PPR2	Jan	2015
MEPC 67	Sep	2015

Table 5.2: Important meetings in IMO Committees and Sub-Committees

MEPC 57

Following the BLG intersessional working group, and the discussions at BLG 12, it became apparent that the draft guidelines would provide strict pH requirements for open EGCS's (open scrubbers). However, the final guidelines would also contain provisions to revise the criteria in the future, with new inputs and given potential developments. This condition was tied to advice given by GESAMP, a group of experts that permanently provides scientific advice to IMO and its committees. At MEPC 57, the aforementioned working group that also discussed the substantive Sulphur solutions agreed that not enough data and experience with EGCS operations was available to formulate final wash water criteria. There were no submissions explicitly mentioning the pH limit or methods of estimation of open EGCS systems, and the interim guidelines for exhaust gas cleaning were approved.

MEPC 59

GESAMP provided input after reviewing the interim guidelines, which was the basis for the following discussion, with no disagreement on the substantial content of the EGCS guidelines. However, Norway and other states argued that the input of GESAMP warranted careful consideration, as the advice touched items of principal character. The MEPC 59 agreed that there was a need to adopt the interim guidelines straightaway to give them effect, which would otherwise implement them in their current format. As such, the concerns of Norway were given weight and MEPC noted in their adoption of the guidelines (to be known from here as the 2009 EGCS guidelines) that the washwater criteria should be revised in the future.

MEPC 60

In March 2010, MEPC 60 convened, with two submissions regarding to the 2009 Guidelines. The first submission was by Norway and included a lengthy discussion on whether the interim requirements for EGCS' actually conformed to the goal of achieving equivalence with low-Sulphur fuel oil. Essentially, Norway argued that the requirements did not adequately ensure that EGCS systems would be as effective at lowering Sulphur emissions as distillate fuel was.

The second submission by IMarEST, a professional organisation consisting of experts and scientists in marine fields, discussed the implications of the exact wording of the interim guidelines (MEPC, 2010b). IMarEST argued that the time pressure imposed on the various working group and MEPC had resulted in the regulation not specifying how at-sea operations could use another method of measuring. They argued that at-sea operation of EGCS' likely would be required to employ the same measuring techniques as at-harbour operations, which in reality would be impossible since these tests were designed for a vessel that was stationary at berth. In addition to this, IMarEST argued that at-sea operations only would require a minimum pH of 3.0 instead of the much more stringent level of 6.5.

The MEPC acknowledged the two papers, but instead of considering them in a plenary session, the submissions were forwarded to MEPC 61 because of the need for further input.

MEPC 61

At MEPC 61, the US and France both submitted papers that commented the 2009 guidelines. The submission by the US argued that Norway is mistaken in its position from MEPC 60, and subsequently argues that the requirements for equivalence are fine. France suggested a clarification of collection of data on from EGCS' by authorities. Without a plenary discussion, all papers on the issue were forwarded to the BLG sub-committee, which was tasked with considering amendments to the 2009 guidelines, specifically the wash water requirements and measuring methods. The target completion time for the final guidelines for EGCS' was set to be BLG 15, 2011.


Source: Scanpix / Iris

BLG 15

The matter was not on the agenda again until BLG 15, and despite all papers forwarded from MEPC 60 and 61, it was decided to postpone the matter until BLG 17 for two reasons. Firstly, the delegations to BLG 15 did not want multiple revisions of the guidelines, which was a possibility if a decision was prematurely. Secondly, there was a need for more data, scientific evidence and input from interested parties.

BLG 17

The first substantial treatment of the washwater discharge requirements of the 2009 guidelines took place at BLG 17 in February 2013. At this meeting, the previous documents (dating back to 2010 and 2011) were included, as well as two new submissions on the issue.

The first submission was by the Danish delegation and contained a report carried out by the Danish environmental protection agency in cooperation with the private consulting firm COWI. The report focused on the effect of a low wash water pH value on the marine environment during at-sea operations. The conclusion of the report clearly indicated that even very low pH values had a negligible effect on the environment. Subsequently the Danish delegation argued that the pH requirements of the 2009 guidelines should be reconsidered in light of this report. This was in part also that no other submissions, since 2009, had provided arguments in favour of very strict pH requirements.

The second submission was by Interferry, which largely supported the information provided by the Danish administration. Interferry also explicitly supported IMarEST in their three year earlier suggestion that the pH requirement for at-sea operations should be 3.0.

The following debate revealed a deep disagreement between the delegations. A number of delegations supported the Danish suggestion, citing the lower energy requirements and cost efficiency of open-loop EGCS. Other delegations dismissed the proposal because of the lack of studies considering the issue in a wider scope. These discussions were unfruitful, and BLG 17 forwarded the issue to Pollution Prevention and Response (PPR), a sub-committee that was to replace BLG. In addition, BLG 17 invited all interested parties to provide information and studies relating to the issue.

PPR 1

In early 2014, five years after the 2009 guidelines were approved, PPR 1 continued the discussion including all the previous papers that were forwarded. In addition, Norway submitted a paper arguing that the wash water criteria were inconsistent, justifying further deliberation in a technical group. According to Norway, this group should be tasked with clarifying the guidelines before the next revision of the 2009 Guidelines. A number of delegations supported Norway in the plenary discussion, and PPR decided to establish this working group.

The report of the working group and the internal discussions it contained was not publicised. However, the PPR 1 forwarded the discussions and the confidential draft text of the working group to PPR 2 for further deliberation. There was no final decision on neither pH values for wash water nor measuring methods. Yet the draft text included a provision for using flow model calculations, instead of actual measurements (European Commission, 2014).

MEPC 67

Between PPR 1 and PPR 2, MEPC 67 took place in late 2014. While revision of the 2009 EGCS guidelines was not on the agenda, all 28 members of the European Union and the European Commission submitted a joint paper on the matter. The paper argued that there were significant problems with the 2009 guidelines because they hindered the approval of open loop EGCS. The restrictive demands for at-sea operations were impossible to measure with the proposed measuring techniques. The joint paper argued that the 2009 guidelines needed to include the possibility of using flow model calculations to determine the pH value of wash water, which would ultimately better accommodate open loop EGCS as a viable solution. The EU subsequently argued that a decision should be made before PPR 2, and that the suggestions from PPR 1 should be included in the 2009 guidelines.

Despite the number of parties to the submission, MEPC 67 decided not to treat the issue, but rather forwarded the paper and the issue to PPR 2. Eventually, MEPC 68 agreed in May 2015 (based on a draft provided by PPR 2) that both direct measurement as well as computational simulation would suffice as approved methodologies.

5.3.2 ANT Analysis of the pH issue

As described above, the BLG Working Group on Air Pollution 2 (BLGWGAP2) constituted the first agreement on substantive pH-criteria for washwater discharge of scrubbers. This created the tie between the BLGWGAP2-agreement and the scrubber as a technical entity. BLGWGAP2 consisted of a number of countries who all participated in the discussions and subsequently were a part of the agreement. Additionally, GESAMP provided input regarding the substantive criteria, which rubberstamped the pH value of 6.5 that BLGWGAP2 had established. When the 2009 Guidelines were finally approved, the pH value of 6.5 was a function of the relationship between the scrubber as an entity, the BLGWGAP2, and the GESAMP report. This stable relationship is illustrated in figure 5.4.

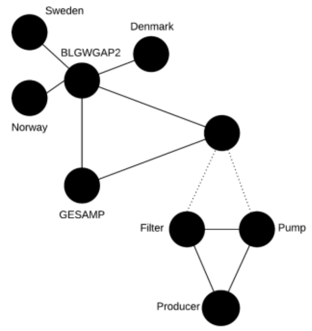

Figure 5.4: Semiotic Metaphor at BLGWGAP2 pH-value case

On the subsequent meeting, the organisation IMarEST submitted their paper to the IMO, arguing for a 3.0 pH value. Essentially, IMarEST sought to weaken or cut the ties between GESAMP, BLGWGAP2 and the scrubber that gave the scrubber the pH-criteria of 6.5. IMarEST used their own submission as a resource to give the scrubber a new pH-criterion of 3.0 instead. This strategic action is illustrated in figure 5.5.

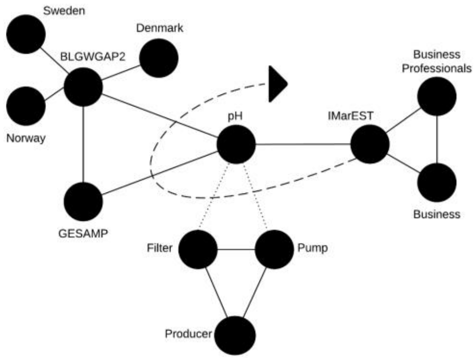

Figure 5.5: Strategic Metaphor after BLGWGAP2
Interessement device by IMarEST

It is evident that IMarEST did not succeed in disrupting the ties between BLGWGAP2, GESAMP, and the scrubber. At MEPC60, it was decided to postpone discussion regarding substantive revision of the 2009 guidelines, forwarding IMarEST and effectively maintaining the pH of 6.5 (MEPC, 2010a, para. 4.3).

IMarEST effectively created an alternative network of actors, that seeking to give the scrubber a new pH criterion of 3.0. This network was not strong enough to change the criterion. However, it did contest the substantive scrubber requirements. This is illustrated in figure 5.6.

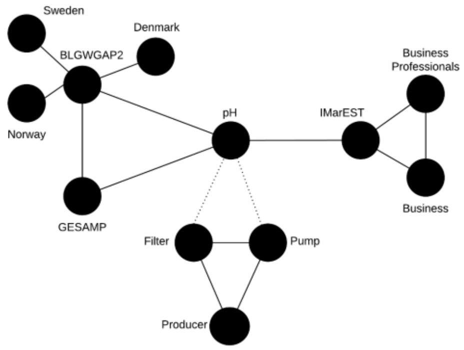

Figure 5.6: Semiotic Metaphor before BLG 17

After a series of delays, the issue is on the agenda at the BLG 17-meeting. In addition to the IMarEST-document, Denmark changes position and stops supporting the pH-value of 6.5, and is now in favour of a lower and less restrictive pH-value. This is illustrated as Denmark changing sides from the BLGWGAP2-network to the IMarEST-network in figure 5.7. Denmark deploys the COWI-report as a resource, using it as an interessement device to weaken the BLGWGAP2-network in favour of the IMarEST-network.

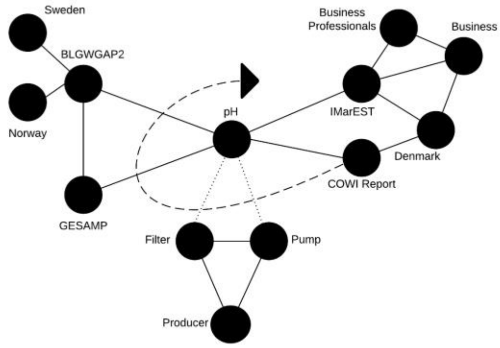

Figure 5.7: Strategic Metaphor at BLG 17
Interessement device by Denmark, using the COWI report

It is evident from the minutes of BLG 17 that this did not have the intended effect. While a substantial discussion took place, there was no consensus to amend the 2009 Guidelines in favour of the 3.0 pH value. In effect, this meant that the 6.5 criterion was still in place and BLGWGAP2 still defined the value of the pH criterion.

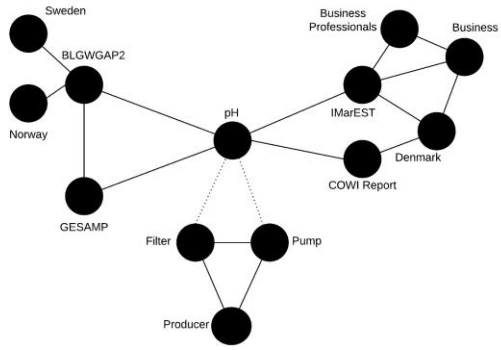

Figure 5.8: Semiotic Metaphor after BLG 17
Many actors in a contentious case

Despite the network forming around Denmark, with the COWI report and the IMarEST, there was a considerate amount of resistance against revising the 2009 guidelines or even agreeing upon a less strict pH criterion. Thus, the BLGWGAP2 network still defined the identity of the pH value as 6.5. The EU submission at MEPC 67 constitutes a strengthening of the network that supported a pH value of 3.0. In addition, the EU submission did not contain any new science, but simply used the gravity of its member states as a resource. This is illustrated in figure 5.9, where the EU is an actor and a resource in itself.

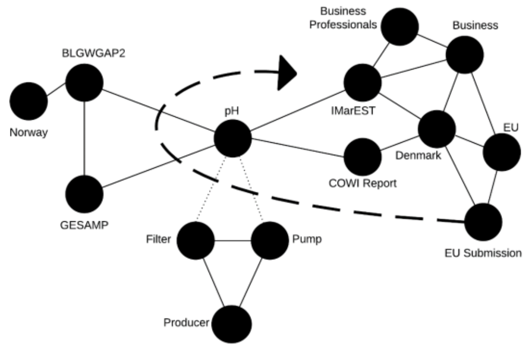

Figure 5.9: Strategic Metaphor before MEPC 67
The EU uses its own power as interessement device

This submission did not manage to bring the discussion into MEPC 67, nor did it manage to change the pH criterion before PPR 2. Eventually, the criterion was changed at MEPC 68 based on the draft agreed upon by PPR 2, indicating that the network built around the EU submission managed to redefine the identity of the pH value.

Source: Scanpix / Iris

5.4 CASE: DETERMINING THE EFFECTIVE DATE OF NOX REGULATION

5.4.1 Background

The revision of MARPOL extended to a revision of the Nitrogen Oxide emission standards (NOx-requirements). Parallel with the work to revise the SOx-standards, IMO discussed whether, and how, to enact NOx-standards that were more stringent.

After a long process, the IMO agreed on a set of new standards with three key components. First, NOx standards should not require retrofitting (unlike SOx-standards) because this is much costlier for NOx reductions. Instead, new regulation should only apply to ships built after the date of effect. Second, the standards would enact a three-tiered set of standards. Tier I standards would be the lowest requirements, soon overridden by Tier II standards, which would apply globally. Tier III, the most stringent set of requirements, would only apply in designated zones known as NOx Emission Control Areas (NECAs). Third, these NECAs and the effective date for Tier 3 requirements in these NECAs would be decided by the IMO.

The BLG and its technical sub-groups agreed upon the specific limits for each tier and a procedure for approving Tier III NECAs was established. In addition, Tier III requirements were scheduled to take effect on January 1 2016, allowing more effective abatement technologies in shipbuilding to be developed. MEPC 58 approved this, and MEPC 59 approved the NECA around North American waters, covering Canada, the US, and parts of the Caribbean.

To assess the feasibility of implementing Tier III requirements, MEPC 62 established a technical correspondence group tasked with reviewing the status of the technology required to implement Tier III standards. This group reported its findings to MEPC 65, which are described below.

Core Meetings in the NOx-case		
MEPC 65	May	2013
⇩		
MEPC 66	April	2014

Table 5.3: Important meetings in IMO Committees and Sub-Committees

MEPC 65

MEPC 65 became an important venue for NOx discussions. The correspondence group reported that Selective Catalytic Reaction (SCR), Exhaust Gas Recirculation (EGR), and dual-fuel LNG technologies all are able to meet Tier III criteria (MEPC, 2013a, para. 4.56). As such, the correspondence group recommended retaining the effective date of January 1, 2016.

However, Russia submitted a paper arguing against the correspondence group (MEPC, 2013b), rejecting the group's position point for point. Concerning SCR, Russia argued that the reduction in NOx-emissions came with an increase in CO2 emissions, rendering SCR unfeasible from a wider point of view. In addition, Russia argued that the costs imposed on ship-owners would be too high and that the correspondence group did not adequately assess the total costs of compliance. On EGR and LNG, Russia simply stated that further work was needed to determine the viability of these abatement strategies. In the case of LNG, the under- developed infrastructure to support operations were seen as a major constraint.

Russia ultimately proposed that the effective date of Tier III requirements in NECAs ought to be moved from 2016 to 2021. In addition, another technology review commissioned by the IMO should be carried out to determine whether 2021 was feasible at all.

In the ensuing discussion, there was great disagreement on the issue. On one hand, the correspondence group and a number of Western countries (Denmark, Germany, U.S., and more) wanted to retain the 2016 date. On the other hand, Russia supported by a number of countries, wanted to postpone the effective date to allow abatement technologies to mature.

The result of the discussion was a majority favouring the Russian proposal, and MEPC 65 subsequently agreed to postpone the effective date of NECAs. A number of countries reserved their position on the issue until further inputs to the process had been received. Effectively, this postponed the final decision to MEPC 66.

Leading up to MEPC 66, there was some debate over how to go ahead in the IMO. Notably, the Danish government delegation and the Danish Shipowners Association (DSA) had divergent views on what to do. The official Danish position (that of the government) was support of the implementation of NOx standards by 2016, regardless of the objections. DSA, on the other hand, argued that appeasing Russia would make sense in order to make future negotiations regarding Baltic regulation easier. While DSA did not support the Russian proposal in itself (which would delay all NECAs), DSA suggested that opposing Russia on this issue would delay NECA rules in the Baltic indefinitely. DSA supported the compromise put forth by Norway and Marshall Islands which would retain date-of-effect for already designated NECAs (Raun, 2014a). In the case of the Baltic, this put DSA on the same side of Russia as the compromise solution would delay the Baltic NECA.

MEPC 66

In the spring of 2014, MEPC 66 met to agree on the effective date of Tier III NECA implementation. A significant number of papers were submitted, with two submissions of particular importance. First, Denmark, U.S., and a number of other countries argued in a paper that the Russian concerns were ungrounded (MEPC, 2013d). The paper contained technical and highly detailed arguments that sought to refute the Russians point by point. The second submission by Norway and the Marshall Islands suggested a middle ground as a compromise. Instead of postponing all effective dates to 2021, the NECA zones already agreed upon would retain the 2016 date and future NECA zones would have effective dates based on when they were proposed.

In addition, a number of papers argued for or against any of the three possibilities. A few submissions suggested that the postponement of the NECA date was unjustified in technical arguments (MEPC, 2014c, 2014e). Other submissions pointed out that the discussion about postponement was undermining the regulatory stability of the IMO. These submissions argued that the compromise or the original 2016 date were better alternatives. Finally, Russia submitted a paper that refuted the arguments laid out in MEPC 66/6/6, effectively defending their original position against the new claims.

In the ensuing discussion, a majority of delegations supported the suggestions put forward in MEPC 66/6/6 by Denmark *et al*. The arguments were centred on the idea of maintaining predictability and integrity in IMO regulation as well as the technical arguments put forth. Delegations supporting the original suggestion cited concerns over economic viability and the effectiveness of abatement methods, very similar to the claims put forward by Russia. Finally, a number of delegations supported the compromise text in MEPC 66/6/10, arguing there was need for a pragmatic solution.

After the long discussion, MEPC 66 agreed on a text that was very close to the suggested compromise suggested in submission MEPC 66/6/10. This agreement retained the date for existing NECAs (i.e. the North American NECA) and set 2021 as date for all future NECAs.

5.4.2 ANT Analysis of the NOx Emission Control Area

Based on the process described above, two distinct networks can be identified. The first network aims to postpone the effective date for the Baltic NECA. While the specific actors differ in their reasoning, they all suggest that the best way to go ahead is to postpone NECA effective date. Most notably Russia, Norway, and the Danish Shipowners Association (DSA) are part of this network that supports a later effective date, even though they do not necessarily coordinate or support this position for the same reasons. For instance, Russia actually wanted all NECAs, both future and current; to be effective later, while DSA argued the Baltic NECA should be delayed to meet Russia halfway in order to facilitate future collaboration. In any case, this network seeks to delay the effective date.

The opposite network support retaining the existing date, although again for a multitude of different reasons. The US, Denmark, BIMCO, as well as the major interest organizations representing business interests all wanted to have the Baltic NECA to take effect in 2016. The US and Denmark argued that the technologies available were adequate for meeting the NOx requirements. BIMCO and business interests emphasized that postponing the effective date would create uncertainty about IMO's commitment and the institution in general. The two networks are shown in figure 5.10 below.

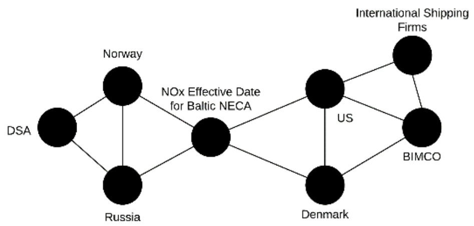

Figure 5.10: Semiotic Metaphor before MEPC 65

The first challenge to this stable network happened when Russia suggested a postponement of the effective date at MEPC 65. Its submission (MEPC, 2013b) both contained the concrete proposal to postpone the effective date, but also a number of technical reasons arguing why this was a sensible proposal.

It is straightforward to see the technical arguments, supported by Russian calculations and observations, to be a mobilization of resources. However, Russia also mobilized a structural resource. Since a future NECA in the Baltic must be approved by all Baltic States, Russia can potentially postpone the Baltic NECA unilaterally for however long Russia wants. The submission and the resources mobilized should be viewed in this light. This may explain why DSA and Norway to some extent sided with the Russians in this matter, but as the assumptions of the analysis, the reasons of the individual actors are black boxed.

This interessement device is seen in figure 5.11, with Russia mobilizing their resources to translate the identity of the NOx effective date.

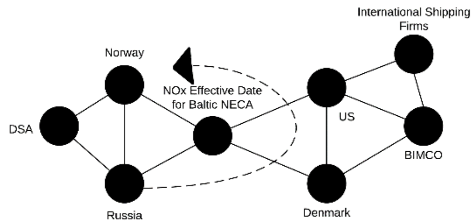

Figure 5.11: Strategic Metaphor at MEPC 65
Russia creates and interessement device

As previously established, the Russian move succeeded in changing the effective date of the Baltic NECA at MEPC 65. Denmark, US, and other actors scrambled before MEPC 66 to undo that decision and change the identity or value of the date back to 2016.

In document MEPC 66/6/6, Denmark, the US, and number of other countries presented very detailed technical arguments refuting the Russian claims. In essence, the countries mobilized different informational resources; that technically and scientifically rejects the Russian position. However, the countries did not mobilize any structural resources the same way Russia did by their unilateral blocking power in the Baltic.

In the end, a compromise was reached that effectively postponed the Baltic NECA despite the efforts of Denmark and the US. This succinctly reveals how technical arguments may be insufficient when an actor decides to mobilize its structural influence. The mobilization of Denmark and the US is shown on figure 5.12.

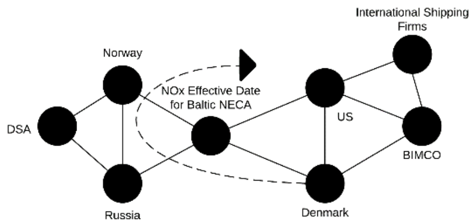

Figure 5.12: Strategic Metaphor at MEPC 66
Denmark and others counter the Russian arguments

5.4.3 Sum-up

It is evident from the three cases that no change in regulation is automatic. In each of the three cases states, firms, or NGO's have sought to influence the key parameters that the MEPC discussed. To do this, the actors mobilized different resources that could help destabilizing the networks that were in place.

In the case of SOx, we saw how alliances between actors were important, and that a network centred on North-European states effectively managed to define the identity of the geographical parameter of the regulation. In the case of pH-limits, it was evident that the mobilization of science was critical, and that the contestation was based on scientific reports. In the case of NOx, it was clear that technical arguments were insufficient to allow for the implementation of a Baltic NOx emission control area. The Russian delegation was never swayed by the reports and findings put forth by virtually everyone else.

The key takeaway here is the recognition that what we take for granted now, such as the level of SOx emissions in the SECA, is the result of a complex political process where many actors try to define the entity in question. Shipowners should be careful to think that regulation in the IMO is automatically formed, and that the industry has little influence on what is decided. In reality, the industry actors have many opportunities to influence the process at various stages. Additionally, the chapter has shown that it is possible to change what is taken for granted by carefully dismantling the reality that is constructed by political entities and employing that knowledge to strategically change the regulation of shipping.

6 IMPLICATIONS FOR BUSINESS STRATEGY AND POLICYMAKING

THE DIFFERENT CHAPTERS IN THIS REPORT HAVE EACH CONTRIBUTED TO THE UNDERSTANDING OF MARITIME REGULATION IN THEIR OWN WAY. WHILE EACH CHAPTER CONTAINS VALUABLE INSIGHT, THE OVERALL CONTRIBUTION OF THE REPORT IS OUTLINED BELOW. CRITICALLY, THE REPORT PROVIDES IMPLICATIONS FOR HOW TO VIEW SHIPPING FROM DIFFERENT THEORETICAL PERSPECTIVES FOR RESEARCHERS AS WELL AS FIRMS AND REGULATORS.

6.1 IMPLICATIONS FOR CIRCULATED APPROACHES AND ASSUMPTIONS

6.1.1 Market

The most fundamental insight provided by this report is that the strategies employed by rational ship operators are determined primarily by the age of their vessels, the time spent in the ECA-zone, the level of enforcement, and the price spread between different types of fuel. Obviously, these are important to every ship-owner operating inside the ECAs, and serves to underline how profound an impact regulation can have on business operations.

This report has shown that ships that do not operate more than a fraction of the time in ECAs should not install scrubbers, because the scrubber serves no purpose the majority of the operational time. Similarly, ships which only have a few years of operational life left should not have a scrubber installed, since the large investment cost cannot be recovered in such a short period. If the price spread between low-Sulphur fuels and heavy fuel oil is larger, all ship-owners' optimal strategies shift towards installing scrubbers. Additionally, if the expected level of enforcement is very low, shipowners profit the most from completely disregarding the rules or delaying compliance and scrubber installation until enforcement reaches a critical point. The Danish Shipowners Association and the Trident Alliance have continuously voiced this criticism.

Not only shipowners, but also regulators can gain insight from these conclusions. The effectiveness of regulation is determined by the level of compliance in the industry, and it is obvious that a correct prediction of this compliance level only can be attained by carefully examining the cost structures and critical parameters of shipowners. In the present case, the most widely debated and crucial element is the question: What level of enforcement is necessary to force the entire industry to comply? As we have seen, different jurisdictions have applied different rules, with the US most notably with very high fines. But as this report has shown, the calculation of the optimal fine must be carefully balanced by a calculation of the expected cost of compliance that a shipowners faces.

This also means that the regulator must know these calculations before the regulation is designed to identify critical parameters that may render the regulation ineffective. Based on the calculations in this report, we identified the expected price spread of fuel types as a very important factor for shipowners who contemplate whether to comply or not comply.

6.1.2 Hierarchy

The implication of employing the hierarchical view, is that regulation is taken as given, nested in an idea that regulation is an uncertainty that must be addressed by stakeholders. As is evident from the economic analysis, regulation can have a great impact on the specific operational costs of vessels. From a hierarchical perspective, these impacts are unknowns that result from a black-boxed process in the IMO or other regulatory arenas. Thus, the main implication is that firms should strategize around the fact that future regulation can affect their current business model profitability.

The three themes that were explored in the political cases illustrate different aspects of these risks. The case of SOx-regulation discussed geographical limits, illustrating the spatial elements of future regulation that must be taken into account. In the case of pH-values for scrubber washwater, technical specifications created uncertainty about certain abatement methods that affect business models, depending on the limits chosen. And finally, the case of NOx-regulation offered insight into how the temporal elements can drastically affect business models and calculations when dates-of-effect are suddenly changed.

More subtly, an underlying theme has been the stability of the regulatory system, illustrated by the NOx-discussion. Here certain industry associations criticized IMO for changing the effective date, because this casted doubt about the reliance of the IMO in the future. Reneging on established agreements could potentially erode the future value of promises and agreements made in the IMO.

From a business point of view, this means that changes in regulation should be accounted for when formulating strategies. Yet business must simultaneously take into account the possibility that agreements and deals made in bodies such as the IMO may change in the future for various reasons. This is crucial for business actors. For firms relying on a specific kind of regulation, sudden changes in the regulatory framework or shifts in dates-of-entry may prove fatal (or vital) to profitability of a given business model. Because of this, even when we consider regulation as ‘given’ in the hierarchical approach, business interests still need to understand the risks and uncertainties associated with any given regulation.

6.1.3 Network

The most important insight that the three cases offer from a network perspective is the idea that regulation is never automatic. In all three cases, it is evident that a long process took place before an ultimate result was agreed upon by the member states in IMO. In each process a number of different actors, all with different views, sought strategically to influence the process to change the outcome in their favour.

This deliberate nature of regulation means that firms or entire industries should understand and proactively interact with regulative “black boxes”. This is different from the reactive hierarchical view, where the regulative formulation process is black-boxed and response to regulation is only ex-ante of the process. From a network perspective, the proactive behaviour of firms can decisively change policy outcomes, depending on the resources mobilized in a specific network of actors.

This implies two central elements worth exploring further: Resources and networks. Resources that can be mobilized in a specific strategy vary greatly in nature and can take many different forms. These resources are mobilized in order to change the entity in question. In the case of pH-values, important scientific evidence was mobilized as resources by both sides. The Danish submission of the COWI-report is a good example: the COWI report became a political resource, mobilized to change the technical requirements for scrubbers.

In each of the cases, we have observed that a group of actors formed a strategic coalition with a specific regulatory aim. Arguably, these coalitions strengthened the position of the involved actors and their mobilized resources.

6.1.4 Implications for the science of Maritime Regulation

It is evident that different approaches and modes of analysis yield different results. However, what is important, shown by this report, is that these different approaches provide different insights into regulation. They do not only differ in their results, but also in their fundamental ontological assumptions about the world and different epistemological perspectives on how we obtain knowledge about the world.

Employing a market-based approach assumes that we can calculate optimal solutions for economic agents, limited only imperfect information. This approach is not concerned with the social reality of not being able to capture reality in economic calculations or mathematics. Conversely, network approaches assume that a social reality is constructed based on how different entities create meaning together, but rejects the idea that reality can be formalized or calculated using mathematics.

From this report, it is evident that using either approach alone insufficiently captures the challenges and issues that ship-owners and regulators face in reality. Separately, either approach can only provide explanations to a limited set of problems, while simultaneously leaving out key assumptions.

Instead, this report has employed different approaches on the same empirical object at the same time. This has drastically increased the explanatory and predictive value of scientific inquiry because elements that a certain approach would be 'blinded' against are more likely to be covered by another approach. In our report, we have shown that regulators should not only consider 'hard numbers' when determining substantive regulation. The report has revealed that subtler unquantifiable social process exists independently of what can be 'objectively' measured, which should also be considered for the optimal choice. However, without employing calculations like the ones done in the above chapters, a regulator or ship-owner would be unable to estimate the impacts of the regulation.

This is important, because it challenges the notion that ship-owners should simply present better and objective science in order to change regulation. This report has shown that 'objective' scientific resources and studies become merely elements of a larger socio-political process. Those who understand that networks, shared meaning, and the creation of social reality are important as well may pass actors that assume regulation is based on these objective calculations. If a strategy is solely based on the idea that other actors will change their point of view when presented with new information, it is most likely inferior to strategies that incorporate ideas about networks and socially constructed realities. This report shows that a more complete understanding of regulation ideally informs any successful political strategy.

A final point for research in maritime regulation is the uncovering of new modes of cooperation between different types of actors. This was very evident in the SOx case, where different governments allied, more or less explicitly, with firms with whom they shared a common interest. Through these alliances and coalitions, states and private actors could influence international regulation together. It is proved that in other global industries NGOs, firms, and states can create regulation in many different configurations (Lister, Poulsen, & Ponte, 2015b). It is sensible to consider how different forms of regulation can work when it comes to global shipping. Future areas of research could include the prerequisite conditions for successful private regulation, the competences of different types of actors, or the different modes of regulation and their merits.

7 APPENDIX A: MATHEMATICS BEHIND THE MODEL

The following chapter outlines the mathematics used in the case on the calculations of the total fuel related costs in the market perspective (see chapter 3).

7.1 COSTS OF THE SCRUBBER STRATEGY

$$TC_{s,j}^{SCR} = R_{s,j}^{SCR} + \sum_{t=0}^{n-1} \frac{D \cdot \gamma_{s,j}^{SCR}(v) \cdot P_t^{HFO}}{(1+\delta)^t}$$

Where:

$R_{s,j}^{SCR} = Scrubber\ acquisition\ and\ installation\ costs\ for\ a\ vessel\ of\ type\ s\ and\ size\ j$
$n = Remaining\ operational\ years\ of\ the\ vessel$
$D = Annual\ distrance\ traveled\ by\ the\ vessel$
$\gamma_{s,j}^{SCR}(v) = HFO(scrubber)\ fuel\ consumption\ as\ a\ function\ of\ speed\ v, for\ a\ vessel\ of\ type\ s\ and\ size\ j$
$P_t^{HFO} = Price\ for\ a\ tonne\ of\ HFO\ in\ year\ t$
$\delta = Annual\ discount\ factor$

7.2 COSTS OF THE MGO STRATEGY

$$TC_{s,j}^{MGO} = \sum_{t=0}^{n-1} \frac{\alpha \cdot D \cdot \gamma_{s,j}^{MGO}(v) \cdot P_t^{MGO} + (1-\alpha) \cdot D \cdot \gamma_{s,j}^{HFO}(v) \cdot \begin{pmatrix} P_t^{HFO} | t \leq 4 \\ P_t^{LSHFO} | \ t > 4 \end{pmatrix}}{(1+\delta)^t}$$

Where:

$n = Remaining\ operational\ years\ of\ the\ vessel$
$D = Annual\ distrance\ traveled\ by\ the\ vessel$
$\alpha = percentage\ of\ voyage\ time\ spent\ in\ the\ SECA$
$\gamma_{s,j}^{HFO}(v) = HFO\ fuel\ consumptionas\ a\ function\ of\ speed\ v, for\ a\ vessel\ of\ type\ s\ and\ size\ j$
$P_t^{HFO} = Price\ for\ a\ tonne\ of\ HFO\ in\ year\ t$
$P_t^{LSHFO} = Price\ for\ a\ tonne\ of\ LSHFO\ in\ year\ t$
$\gamma_{s,j}^{MGO}(v) = MGO\ Fuel\ consumption\ as\ a\ function\ of\ speed\ v, for\ a\ vessel\ of\ type\ s\ and\ size\ j$
$P_t^{MGO} = Price\ for\ a\ tonne\ of\ MGO\ in\ year\ t$
$\delta = Annual\ discount\ factor$

7.3 COSTS OF THE LNG STRATEGY

$$TC_j^{LNG} = R_{s,j}^{LNG} + \sum_{t=0}^{n-1} \frac{D_j \cdot \gamma_j^{LNG} \cdot P_t^{LNG}}{(1+\delta)^t}$$

Where:

$R_{s,j}^{LNG} = LNG\ modification\ acquisition\ and\ installation\ costs\ for\ a\ vessel\ of\ type\ s\ and\ size\ j$
$n = Remaining\ operational\ years\ of\ the\ vessel$
$D = Annual\ distrance\ traveled\ by\ the\ vessel$
$\gamma_{s,j}^{LNG}(v) = LNG\ Fuel\ consumption\ as\ a\ function\ of\ speed\ v, for\ a\ vessel\ of\ type\ s\ and\ size\ j$
$P_t^{LNG} = Price\ for\ a\ tonne\ of\ LNG\ in\ year\ t$
$\delta = Annual\ discount\ factor$

7.4 COSTS OF THE NON-COMPLIANCE STRATEGY

$$TC_{s,j}^{NC} = \sum_{t=0}^{n-1} \frac{D_j \cdot \gamma_{s,j}^{HFO} \cdot \begin{pmatrix} P_t^{HFO} | t \leq 4 \\ P_t^{LSHFO} | \ t > 4 \end{pmatrix} + \theta \cdot \beta \cdot F}{(1+\delta)^t}$$

Where:

$n = Remaining\ operational\ years\ of\ the\ vessel$
$D = Annual\ distrance\ traveled\ by\ the\ vessel$
$\gamma_{s,j}^{HFO}(v) = HFO\ fuel\ consumptionas\ a\ function\ of\ speed\ v, for\ a\ vessel\ of\ type\ s\ and\ size\ j$
$P_t^{HFO} = Price\ for\ a\ tonne\ of\ HFO\ in\ year\ t$
$P_t^{LSHFO} = Price\ for\ a\ tonne\ of\ LSHFO\ in\ year\ t$
$\theta = Annual\ ECA\ zone\ port\ visits$
$\beta = Change\ of\ inspection\ for\ each\ SECA\ port\ visit$
$F = Sanctioning\ per\ port\ visit$

8 APPENDIX B: USER GUIDE TO THE ONLINE CALCULAION TOOL

The calculations presented in the economic case study of chapter 3 are based on a calculation tool specifically designed to support the conclusions of the case study. This calculation tool allows researchers and industry professionals to insert the specifications of a vessel operation that takes place within the ECA zone in order to estimate the costs of four different fuel/retrofit strategies in response to the enhanced sulphur regulations. The ship and route specifications are determined from a wide range of input variables such as type of ship (container, bulk or tanker), vessel size, speed, fuel spreads, annual sailing distance, and sailing distance within the ECA zone. Integrated into the calculation tool is the ship calculation tool made by Hans Otto Kristensen which allows for the determination of vessel fuel consumption given user determined values of speed, vessel engine size, engine type and capacity utilization. This gives the calculation tool a high degree of prediction power while still maintaining significant customization options. The four fuel strategies examined are the following:

- **HFO with a Scrubber**
- **MGO (two price scenarios examined)**
- **LNG with engine modifications**
- **HFO (Non –Compliance including fines)**

After inserting ship and route specifications, the calculation tool estimates the fuel related costs (fuel, engine modifications and fines) of each of the four strategies, and ranks them according to the planned service period length of the ship. Further, the payback period is calculated for the scrubber and LNG modifications for both retrofits and new builds in order to give a simple overview of the most feasible strategies of compliance. The calculation tool is available for download free of charge at the CBS Maritime homepage (http://www.cbs.dk/viden-samfundet/business-in-society/cbs-maritime/downloads).

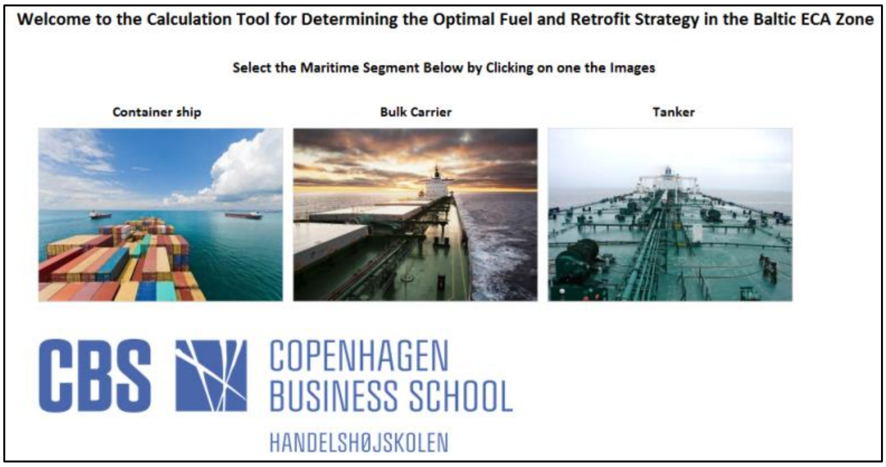

__Figure 8.1__:Calculation Tool Front Page

The following is a guide to successfully utilize the program which includes an explanation of layout and cells in which data can be entered. Understanding this will provide more reliable results. The user interface is divided into three sheets with the first being the front page, the second page containing the major input as well as illustrating the results, and the third allowing for the modification of ship specific variable.

8.1 INTERFACE

The front page allows the user to select the segment of the ship from the categories Container, Bulk and Tanker. By clicking on the picture representing the appropriate ship segment the program automatically redirects the user to the input and result section.

8.2 RESULTS PAGE

The result page allows the user to insert the primary variables and presents the results of the calculations. The left side column labelled "*Input*" contains the input cells where the user can specify the primary inputs of the vessel and route. The "*Results*" section in the middle column lists the total costs of the optimal and second best strategies as a function of remaining service years of the vessel while the section below labelled "*Investment payback period*" lists the payback period of the retrofit strategies. The "*Illustration section*" on the right side columns graphically depicts the results achieved from the middle section by listing the total fuel related costs as a function of the remaining operational years of the ship. Finally, this page features two buttons; the orange button takes the user back to the front-page, allowing for the selection of a ship in another segment. The green button titled "Advanced Parameters" redirects the user to the advanced settings page introduced below.

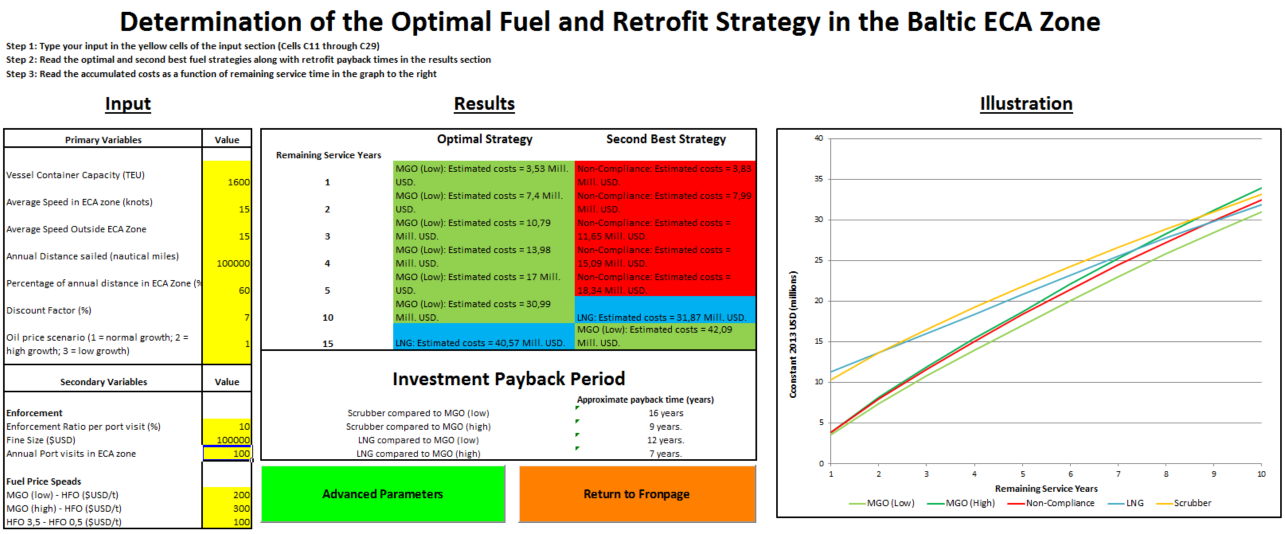

Figure 1: Calculation Tool Results Page
Source: Own illustration

8.2.1 Input

The input section lists the values of the most vital primary and secondary variables required to calculate the optimal fuel strategies. The cells in which the user is encouraged to enter specific values are marked by the colour yellow.

The input cells require the following input:

- **C11:** Enter the maximum DWT or TEU capacity of the vessel depending on the segment selected.
- **C12:** Enter the average sailing speed when operating inside the ECA zone, measured in knots.
- **C13:** Enter the average sailing speed when operating outside of the ECA zone, measured in knots.
- **C14:** Enter the annual distance sailed by the vessel, measured in nautical miles.

- **C15:** Enter the proportion of the annual distance sailed, spent within the waters of the ECA zone measured in percentages (example: for 50 percent insert the value “50”).
- **C16:** Enter the depreciation rate used to discount future cost components, measured in percentages (example: for 7 percent insert the value “7”).
- **C17:** Specify what oil and gas price projection scenario upon which the HFO and LNG fuel prices are calculated. Enter “1” for the reference case scenario, enter “2” for high oil price scenario or enter “3” for the low oil price scenario. For more information about these fuel price scenarios see the U.S Energy Information Administration.
- **C22:** Enter the risk of inspection faced by the ship when calling at a port within the ECA zone, measured in percentages (example: for 10 percent insert the value “10”).
- **C23:** Enter the size of the fine incurred by ship-operators caught non-complying when calling at a port within the ECA zone, measured in USD.
- **C24:** Enter the annual amount of callings at ports located within the ECA zone by the vessel.

8.2.1.1 Fuel price spreads

- **C27:** Enter the average price spread between a metric ton of MGO and standard HFO in the low MGO price scenario measured in USD (a positive value results in the price of MGO being higher than that of HFO, while a negative value results in the opposite).
- **C28:** Enter the average price spread between a metric ton of MGO and standard HFO in the high MGO price scenario measured in USD (a positive value results in the price of MGO being higher than that of HFO, while a negative value results in the opposite).
- **C29:** Enter the average price spread between a metric ton of LSHFO (0.5 %) and HFO (3.5 %), measured in USD (a positive value results in the price of low Sulphur HFO being higher than that of standard HFO, while a negative value results in the opposite).

8.2.2 Results (strategy rankings)

The results section is divided into two columns ranking the optimal and secondary strategies measured by total fuel related costs (fuel, engine modifications and fines). The rankings are calculated depending on a set number of remaining service years (1, 2, 3, 4, 5, 10 and 15) which are listed in column E. This illustrates how the rankings of the different strategies may change depending on the remaining operational years of the ship. A colour code is attached to each strategy in order to easily recognize how different input variables may change the strategy rankings. The colour codes are as follows:

- Scrubber
- MGO (low price)
- MGO (high price)
- LNG
- Non-compliance

8.2.3 Investment Payback Period

The investment payback periods are illustrated in order to give the user an easy measurement of the payback times. Both the scrubber and LNG strategies are compared to the default strategy of operating on MGO, in a high and low MGO – HFO price spread scenario, and therefore illustrate when the investment costs of a retrofit are offset by the higher price of MGO.

8.2.4 Illustration

The graph on the right side columns illustrates the total fuel related costs (vertical axis) as a function of remaining service years of the vessel (horizontal axis). The graph, using the same colour coding as the middle section, therefore serves as an illustration of both the optimal strategy rankings as well as the payback times (found by the intersection between the lines).

8.3 ADVANCED SETTINGS

The Advanced Settings page allows for further customization of the specific vessel and engine modification costs. The left side columns specify the costs of acquisition and installation of the scrubber and LNG modifications and are divided into the two sections of "*Scrubber and LNG price functions*" and "*Predetermined Scrubber and LNG costs*". The columns to the right contain the sections of "*Fuel specifications*" and "*Vessel specifications*" which allow the user to further modify the fuel prices and future regulation as well as the specifications of the vessel such as engine, hull and propeller types. Finally, this page features two buttons; the green button labelled "Return to results" takes the user back to the results page and will include the user defined alterations to the variables. The orange button labelled "*Reset to Defaults*" resets all the variables on the sheet to their default values (this may be useful if the results show inconsistent results).

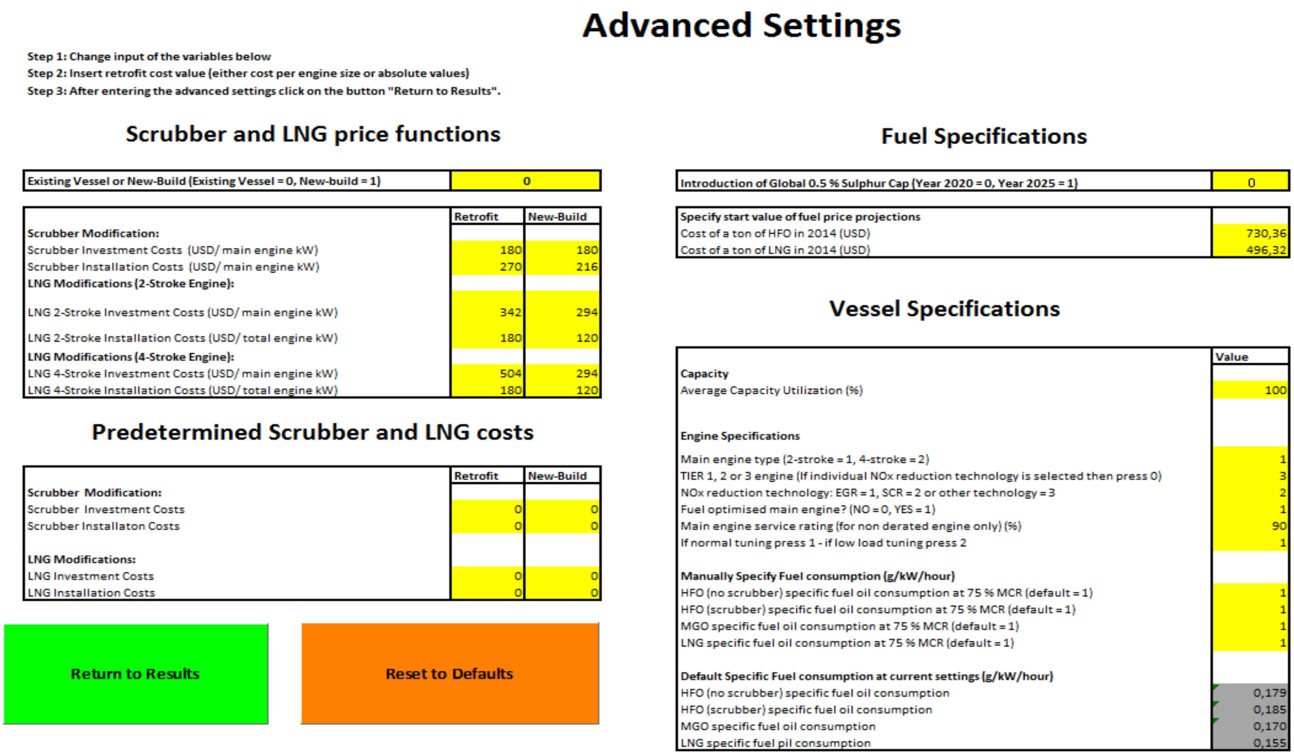

Figure 2: Calculation Tool Advanced Settings Page
Source: Own illustration

8.3.1 Scrubber and LNG price functions:

Most importantly, this section allows the user to determine if the scrubber and LNG modifications are retrofitted on an existing vessel or installed in the process of the acquisition of a new-build vessel. The section additionally contains price functions for the scrubber and LNG modifications, formulated as the total costs of acquisition and installation as a linear function of the ships engine power (adopted from the Danish Maritime Authority (2012)). The cost functions are formulated as costs per engine power (kW) and can be altered by the user.

- **C9:** Select whether the scrubber or LNG extension will be retrofitted or installed on a new build vessel.

- **C13 / D13:** Alter the default setting scrubber investment costs, measured in USD per main engine kW. Use C13 for retrofits and D13 for new build vessels.
- **C14 / D14:** Alter the default setting scrubber installation costs, measured in USD per main engine kW. Use C14 for retrofits and D14 for new build vessels.

- **C16/D16:** Alter the default setting 2-stoke LNG modification investment costs, measured in USD per main engine kW. Use C16 for retrofits and D16 for new build vessels.
- **C17/C17:** Alter the default setting 2-stoke LNG modification installation costs, measured in USD per main engine kW. Use C17 for retrofits and D17 for new build vessels.
- **C19/D19:** Alter the default setting 4-stoke LNG modification investment costs, measured in USD per main engine kW. Use C19 for retrofits and D19 for new build vessels.
- **C20/D20:** Alter the default setting 4-stoke LNG modification installation costs, measured in USD per main engine kW. Use C20 for retrofits and D20 for new build vessels.

8.3.2 Predetermined Scrubber and LNG costs

Alternatively, the calculation tool allows the user to insert predetermined acquisition and installation costs of the scrubber and LNG modifications. For a retrofit or new-build these predetermined costs must be inserted on the left or right hand side respectively. If entering predetermined costs in the new-build column, be sure to enter the value “1” in cell C9 in the above section in order to enable new building features in the calculations.

- **C26/D26:** Enter the scrubber investment costs for the vessel measured in USD, if the results of the predetermined price functions do not yield consistent results. Use C26 for retrofits and D26 for new build vessels.
- **C27/D27:** Enter the scrubber installation costs for the vessel measured in USD, if the results of the predetermined price functions do not yield consistent results. Use C27 for retrofits and D27 for new build vessels.

- **C30 / C30:** Enter the LNG modification investment costs for the vessel measured in USD, if the results of the predetermined price functions do not yield consistent results. Use C30 for retrofits and D30 for new build vessels.

- **C31/D31:** Enter the LNG modification installation costs for the vessel measured in USD, if the results of the predetermined price functions do not yield consistent results. Use C31 for retrofits and D31 for new build vessels.

8.3.3 Fuel Specifications:

The upper right columns contain specifications related to the fuel price forecasts and future introductions of regulation.

- **G9:** Select the year where the global 0.5 % Sulphur cap is introduced. For year 2020 enter the value 0 and for 2025 enter the value 1. Changing this variable will affect when vessels adopting the strategy of MGO and non-compliance will operate on LSHFO outside of the ECA zone.
- **G12:** Alter the value of the average cost of a ton of 3.5 % Sulphur HFO in European ports in 2014 measured in USD per ton. This value serves as the base value for the indexed fuel oil price forecasts of the calculation tool.
- **G13:** Alter the value of the average cost of a ton of LNG in European ports in 2014 measured in USD per ton. This value serves as the base value for the indexed gas price forecasts of the calculation tool.

8.3.4 Vessel Specifications:

The lower right columns contain the advanced vessel specifications which allow the user to customize the average capacity utilization and advanced specifications of the vessels engine type and settings.

8.3.4.1 Vessel and engine specifications

- **G20:** Enter the average capacity utilization of the vessel in % (example: for 100 percent insert the value “100”)
- **G23:** Enter the vessels main engine type. For 2-stroke enter the value “0” and for 4-stroke enter the value “1”.
- **G24:** Select whether the vessel is equipped with a main engine type of tier 1, 2 or 3. Enter “1” for tier 1 engine, enter “2” for tier 2 engine and enter “3” for tier 3 engine.
- **G25:** Select the NOx reduction technology equipped by the vessel. Enter “1” for EGR, enter “2” for SCR and enter “3” for other technologies.
- **G26:** Select whether the engine is fuel optimized. Enter “0” for no fuel optimization and enter “1” for fuel optimization.
- **G27:** Enter the main engine service rating measured in percentages (example: for 90 percent insert the value “90”).
- **G28:** Select the speed tuning of the main engine. Enter “1” for normal tuning or enter “2” for low speed tuning.

8.3.4.2 Fuel Consumption

- **G31/G32/G33/G34:** Specify the fuel oil consumption at 75 % main engine service rating, measured in grams per kilowatt per hour. G31 specifies the fuel oil consumption when operating on HFO without a scrubber, G32 specifies the same for the engine equipped with a scrubber, G32 specifies the same when operating on MGO and G34 specifies the gas consumption when the engine is equipped with LNG modifications and operates on gas. Entering the value of one sets the fuel oil consumption to the level as specified by the marine engineering calculations included in the spreadsheet.

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9.1.1 MEPC Documents Used

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