NORGES HANDELSHØYSKOLE

Bergen, spring 2011

Tightened emission regulations in Northern Europe

Cost analysis of emission reducing alternatives in short sea shipping

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ABSTRACT

Increased focus on local air pollution from shipping traffic in Northern Europe will lead to new challenges for vessels operating in this area. The objective of this paper is to explore how chemical tankers with differing remaining lifetime can adapt to these new emission regulations in the most cost effective manner. There are several ways to respond to the regulations, but in order to minimize costs it is necessary to match the right vessel with the right emission reducing alternative.

This thesis offers an overview of the most relevant alternatives for the shipping industry, which are:

1. Marine gas oil (MGO)
2. Sulphur oxides (SOx) scrubbers
3. Liquid natural gas (LNG)
4. Giving up trade in the regulated areas

In the analysis, Utkilen AS has been used as a case since this is a company operating in the regulated areas. Three of their vessels with differing remaining lifetime have been analyzed in terms of costs over their remaining economical lifetime. Net present value analysis is being used as technical framework for this evaluation.

The analysis comes to the conclusion that in order to minimize costs, the oldest vessel is a candidate for MGO, the medium aged vessel is matched with a SOx scrubber and the newest vessel can be a candidate for LNG. It is emphasized how sensitive the cost analysis is to changes in the different input variables. Fuel price input is identified as the single most important variable and changes in this can lead to other results. Furthermore, it is discussed how shipowners need to think beyond costs and consider other aspects as well. Development in SOx scrubbing technology and LNG infrastructure is necessary if the adoption of these alternatives is to increase.

ACKNOWLEDGEMENTS

This thesis has been written as part of my Master of Science in Business Analysis and Performance Management at the Norwegian School of Economics and Business Administration (NHH), and it marks the end of a five year long education.

The reason for choosing shipping as a topic can be attributed to my work experience from the industry, a strong personal interest for the topic and inspiring input from courses at NHH such as INB 426 – Shipping Economics. In addition, the possibility to write for a company as Det Norske Veritas (DNV) has been of great personal motivation for me. Due to certain regulations in Northern Europe, environmental aspects and shipping economics will now be required to go hand in hand. Most likely, we are just witnessing the beginning of this development and for me it has been very interesting exploring the topic.

Throughout my work with this thesis, many people have provided me with valuable input. I want to thank my supervisor Siri Pettersen Strandenes for professional guidance and feedback along the way. Furthermore, I would like to thank everyone in DNV for providing me with important information and new thoughts, especially Kay Erik Stokke for making this thesis possible. I also want to thank Martin Christian Wold for answering all my questions throughout the process. In addition, my former colleagues in Utkilen deserve thanks for giving me access to their company and providing me with relevant data. I want to thank my friends for help in reading through and quality assuring my thesis. Finally, I would like to thank all the people in the maritime industry that have helped me with important information and inspiring ideas.

Bergen, 15 June 2011

Torstein R. Alvestad

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1 INTRODUCTION

I have chosen to start this paper with a short introduction of the topic. This section is followed by the research question, model and scope/limitations of the dissertation. After this first introductory chapter the necessary background information related to the emission regulations is presented in chapter two. Chapter three describes the most relevant emission reducing alternatives the shipping companies can choose among. From this chapter the reader will gain knowledge about the strengths and weaknesses of the alternatives. In chapter four the theory that is relevant for the analysis is presented. The fifth chapter is on research methods. This chapter describes how I have designed my research and collected my data. It also includes a section regarding the credibility of my findings. The chemical tanker segment and Utkilen AS are briefly presented in chapter six. This shipping company is then used as a case in the analysis which can be found in chapter seven. Chapter seven is the main part of this thesis and contains the analysis which is combined with the material from previous chapters. Following the analysis are the conclusions and recommendations for further research in chapter eight. All of the main findings from the analysis are clearly summarized in that part of the dissertation and together with the analysis-chapter it is closely linked to the main research question.

1.1 New demands in the shipping industry

Shipping is an old industry that has avoided much of the strict emission regulations faced by land based transport, but in the years to come new and stricter regulations will soon become a reality for ships operating in certain geographical regions. Among the drivers for greener shipping we can find the media/public and the shipping companies' business partners, but rules and regulations are in fact the main drivers for more environmental friendly shipping. The International Maritime Organization (IMO[1]) adopted the International Convention for the Prevention of Pollution from Ships in 1973, it is universally known as MARPOL. It has been revised several times, and in the revised MARPOL Annex VI (see IMO 2008) the Baltic- and North Sea was classified as Emission control areas (ECAs). In the time to come these ECAs will face far more stringent emission regulations. The most intricate part of this legislation from the shipowners point of view will come into enforcement 01.01.2015, when the sulphur

[1] IMO is under the United Nations (UN) and its main purpose is to regulate maritime safety and environmental issues. The organization currently has 172 member states.

oxides (SOx) content in marine fuel will have to be less than 0,1% in the ECAs. Nitrogen oxides (NOx) emissions will also be further restricted from 2016. This pose major challenges for the fleet operating in this area today. At the same time IMO will introduce global emission regulations, so it is no overstatement to say that global demand for more environmental friendly fuel and ships only will increase.

A LNG (liquid natural gas) fueled fleet is one way to face the new restrictions put upon the shipping industry. LNG has already proved to be a viable alternative in shipping segments such as platform support vessels (PSVs) and ferries. Other types such as short sea multipurpose roll-on roll-off (RoRo) vessels are under construction and the first retrofit of a chemical tanker is being completed this year, but not all vessels will be suited for LNG. There are other alternatives as well, such as switching to low sulphur distillates, installing scrubbing systems or as a last resort, just give up trading in the ECAs. Characteristics such as age and sailing pattern will favor different alternatives, meaning every company must consider the situation and do their own analysis.

1.2 Research question

The main problem I want to explore is:

Which emission reducing alternatives give the lowest costs for chemical tankers with differing remaining lifetime?

From the research question (RQ) the two follow-up questions listed below have been created:

Is there a tradeoff between investment cost and voyage costs in the long run?

Is there a link between sailing flexibility and second-hand value?

The RQ will be limited to the North- and Baltic-Sea, i.e. the ECA-regions. Focus will be on chemical tanker shipping (Utkilen AS) and remaining lifetime, but sailing pattern is also of great importance when considering the alternatives. Emissions in this setting mean local pollution to air and not green house gases (GHG).

1.3 Model

The below model is an illustration of the RQ and basically what I want to look into when working with this thesis. Following the model's logic there are vessels of various ages operating inside of the ECAs today. These vessels will have to choose different ways of adapting to the new regulations by considering the different alternatives. The four alternatives in the model are the most relevant ones and by combining the right vessel with the right alternative, the result will be a cost effective or a commercial viable choice.

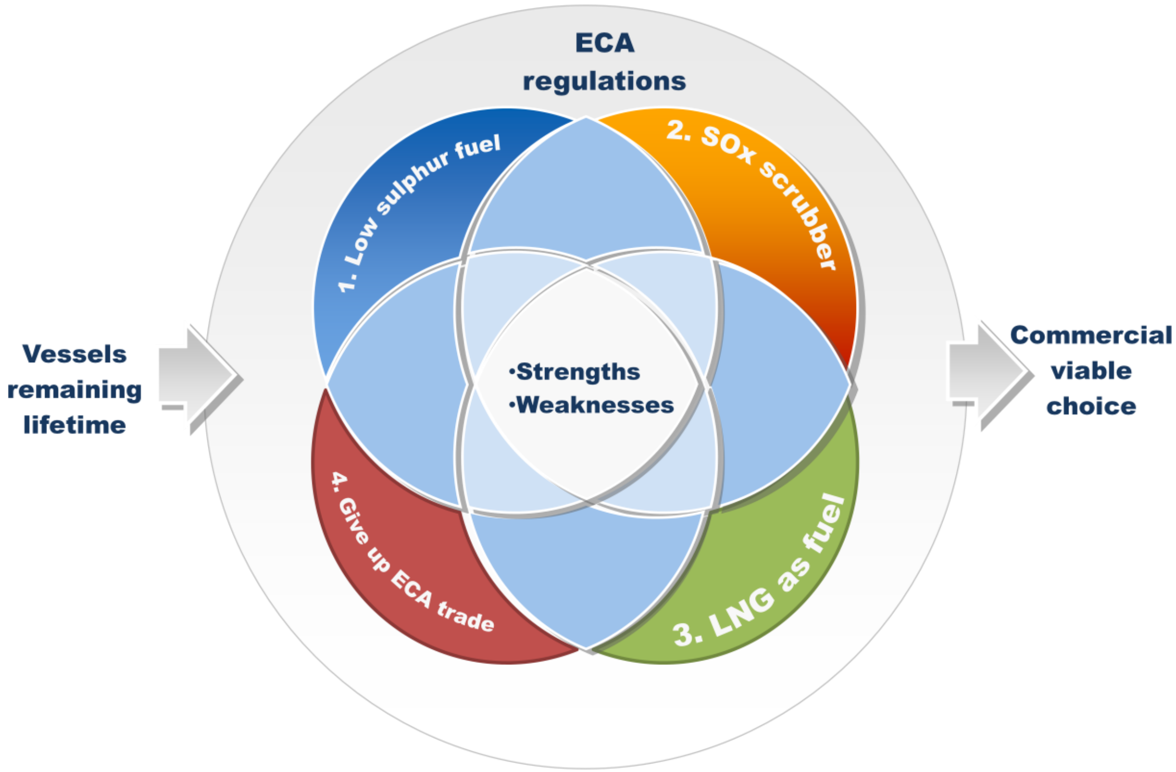

Figure 1: Overview of the RQ.

1.4 Scope and limitations

The focus of this paper is on the ECA regions in Northern Europe. Emissions that are regulated by the ECAs are local pollution to air. Furthermore, short sea shipping (SSS) is the type of shipping operating in the ECAs that will be analyzed. As the name implies, SSS means shipping within a limited geographical area. The existing fleet is the center of attention and not newbuildings. This means the main focus will be on SOx emissions and not NOx, since the upcoming NOx restrictions only are applicable for newbuildings. Utkilen AS is a chemical tanker company that will be used as a case in this thesis, in order to see which alternative can be most economical for some of their vessels. Emission reducing alternatives that will be analyzed are: 1. Low sulphur fuel, i.e. marine gas oil (MGO), 2. SOx scrubbers and 3. LNG. The fourth alternative means giving up ECA trade. After a general description of the alternatives, the transportation of chemicals is the shipping segment I will look into. The cost side of the first three alternatives will be analyzed. An assumption I make is that choice of alternative will not affect the income side in the long run, thus I will not include income in my quantitative analysis.

This is an empirical research thesis and much of chapter two and three is somewhat technical because it is necessary to gain an understanding of the actual conditions. Since the paper has been created for a broad audience and not only economists, chapter four has been written so that also non-economists will be able to appreciate the theoretical framework. I realize the topic is a large one and much cannot be covered within the scope of an individual master thesis due to time and resource limitations. Consequently, my aim is to provide a contribution to this field that can be of assistance for managers considering how to adapt to the new emission regulations.

2 BACKGROUND

2.1 Shipping – The preferred mode of transportation in European waters

One reason shipping historically has avoided much of the environmental focus has been practical difficulties in regulating since it is an international industry. Until now, the center of attention has been on reducing emissions from land based transportation that is easier observable. Today, shipping is the most energy efficient form of transportation there is per ton cargo. While responsible for transporting about 90 % of the world's goods (in weight, not value), approximately 3 % of the global CO_2 emissions comes from shipping activity (NSA 2011). Because of this, shipping is promoted as the preferred form of transportation compared to road, rail and air. Pollution from shipping is of course linked to shipping activity, which is driven by the world economy. According to the second IMO GHG study from 2009, ship transport is most prominent in the northern hemisphere and along coastlines. 70 % of all traffic is within 200 nautical miles (nm) from shore and 44 % is within 50 nm from shore. The representation of world shipping traffic in figure 2 clearly conveys how exposed the European waters are.

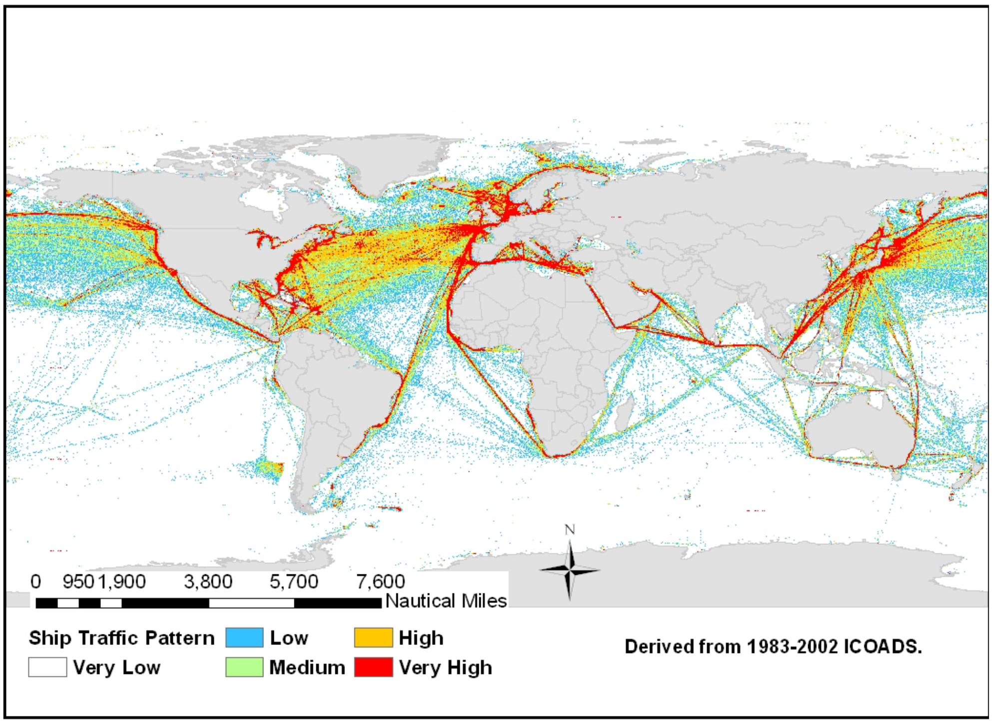

Figure 2: World shipping traffic. Source: IMO 2009.

For the European commission (EC), promotion of SSS instead of road based transportation has been a major priority since 1992 (ITMMA 2010). With this they want to achieve a more sustainable and efficient transport in social, environmental and economic terms. Braekers et. al. (2009, p 2) define external costs of transport as: “costs that result from the use of non-renewable resources, which are not born by individual transporters”.

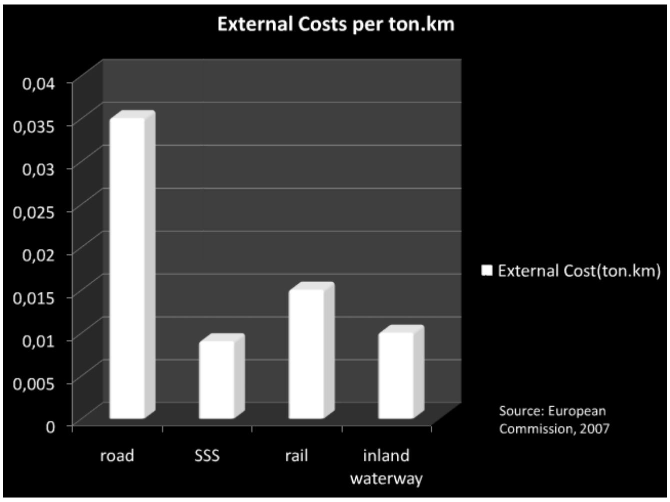

Figure 3: External costs per ton.km. Typical external costs are pollution, congestion and accidents. Source: European Commission 2007, cited by ITMMA 2010.

Figure 3 shows the external costs in euro for different modes of transportation. It clearly demonstrates how SSS gives the lowest external costs per ton km compared to other modes of transportation. Ton.km is a measure that can be defined as “the tonnage of cargo shipped, multiplied by the average distance over which it is transported” (Stopford 2009 p. 146). SSS offers better fuel economy and lower emissions of harmful substances, because of that SSS is considered to be one of the most sustainable and economically competitive modes of transport there is (Francesca and Lourdes 2010). The EC has promoted SSS in several ways. One of them is the creation of motorways of the seas, which are created to bypass land-bottlenecks and introduce new maritime-based logistics chains. Other steps taken have been the Marco Polo program and short-sea promotion centers. SSS is the right way to go in European waters, but even though it is environmentally superior compared to land based transportation, its environmental footprint is not miniscule. The shipping industry has for too long been hiding behind the fact that it is the least polluting form of transport. Reduction of local air-pollution is an issue that is becoming more and more relevant, especially if additional goods are to shift from land to sea.

2.2 Regulations

Owners find that regulations often conflict with their ability to make a profit, but the jungle of rules and regulations is there in order to promote safety, both for life and the environment. Not all maritime areas share the same characteristics, some are more vulnerable to pollution than others due to heavy traffic which has lead to stricter regulations in these areas. As a result, the shipowners are being given an incentive to either adapt to regional rules, or move their fleet elsewhere.

The regulatory system includes six principal participants (Stopford 2009. pp 657-658):

- Classification societies: These societies regulate technical and operational standards for ships.
- The United Nations sets the broad framework for maritime law.
- Flag states: The flag each vessel is registered under. These flag states regulate things such as taxes, compliance with maritime safety conventions, crewing and naval protection.
- Coastal states: The ship must answer to the coastal state's law when trading there.
- The IMO.
- The International Labor Organization (ILO).

All of these participants contribute to maritime regulation and are all important in their own way. In this thesis however, the background for the research comes from IMO's regulations. Their slogan is "Safe, secure and efficient shipping on clean oceans". Since its first conference in 1948 the main objective for IMO has been improvement of safety of life at sea –SOLAS (Dokkum 2007). Concerns for marine pollution have after that become more relevant and following accidents such as the Torrey Canyon[2] in 1967, IMO implemented the MARPOL – Convention. This "International Convention for the Prevention of Pollution from Ships" was implemented in 1973 and modified again in 1978 (Dokkum 2007).

[2] The Torrey Canyon was a supertanker capable of carrying a cargo of 120 000 mt crude oil. Due to a navigational error it was shipwrecked of the western coast of Cornwall, England, causing an environmental disaster.

The Annexes in MARPOL 73/78 include:

- Annex I: Deals with regulations in order to prevent pollution of the seas by oil from ships. This annex requires oil tankers and other ships >400 gross registered tonnage (GRT) to carry a valid International oil pollution prevention certificate.
- Annex II: Regulates noxious liquid substances in bulk, in general called chemicals.
- Annex III: This annex regulates the carriage of packed harmful substances.
- Annex IV: Regulates the prevention of pollution by sewage.
- Annex V: Deals with garbage.
- Annex VI: This annex deals with air pollution caused by ships.

Annex VI came in May 2005, it restricts the emissions of substances which attack the ozone layer, NOx, SOx, volatile organic compounds and exhaust of incinerators (Dokkum 2007). NOx and SOx emissions are directly related to the quality of the vessels fuel, which also is a question of economics. Annex VI sets two emission control standards from ships: Global standards for SOx and NOx in fuel apply everywhere, but in designated ECAs the ships are required to comply with more stringent limits.

SOx emissions are regulated by MARPOL 73/78, Annex VI, Regulation 14. In addition the EC's council directive 2005/33 regulates these emissions while in EU ports and inland waterways (EC 1999, 2005).

NOx emissions are regulated by MARPOL 73/78, Annex VI, Regulation 13. In addition to this Norway has its own NOx tax system, created to work as an incentive for ships in Norwegian waters to reduce emissions.

2.3 NOx and SOx emissions

Since the ECAs restrict NOx and SOx emissions, we are talking about local pollution and not GHG/climate change.

Nitrogenous oxides include NO, NO_2 and other oxides of nitrogen. NO_2 is a reddish brown highly reactive gas that is formed in ambient air temperatures through the oxidation of NO. The main source of man-made NOx emissions comes from high temperature combustion processes, for example a ships engine. Total NOx emissions however, is not just depending on the fuel quality, but also the type of engine. These emissions are harmful both to humans and the environment in several ways. It can form toxic ozone, together with rain it forms nitrous acid that leads to a wide range of environmental effects, it has a fertilizer effect leading to algal growth and depletion of oxygen in the water, NO_2 is also toxic to humans (NMD 2006).

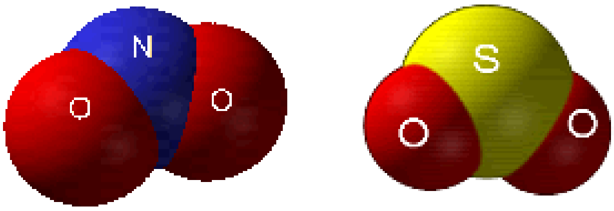

Figure 4: NO_2 and SO_2, the most common forms of NOx and SOx.

The main oxides of sulphur are SO and SO_2, with SO_2 being the main oxide. The sulphur oxide gas SO_2 is a colorless, non-flammable gas with a strong odor that irritates eyes and air-passages. SO_2 mixed with rain can form sulphuric acid (acid rain). This causes major human health problems, it also causes acidification of lakes, fish death, etc. Sulphur oxide gases are formed when fuel containing sulphur is burned, these fuels are mainly coal and oil. Marine fuels normally have a high content of sulphur compared to land-based fuels. Today, the average sulphur content of marine fuel on a global basis (if we disregard the North European ECAs) is 2,7% (IMO 2009). This means the present global sulphur cap of 4,5% and the one coming in 2012 reducing it to 3,5 % will have no practical effects. The European situation is another one. Here shipping is responsible for about 20 % of total SOx emissions and by 2020 it will be the single most important source of SOx emissions (NMD 2006). As a direct result of the cap on sulphur emissions in the ECAs, SOx emissions for 2008 in the North Sea and the Baltic were estimated to have been reduced by 42% (IMO 2009).

2.4 ECAs and emission limits

As mentioned in section 2.1, the EC promotes SSS in European waters since it is considered being one of the most sustainable and economically competitive modes of transport there is (Francesca and Lourdes 2010). At the same time the North- and Baltic Seas are among the most strictly regulated in the world when it comes to air-emissions. Originally there were only restrictions on SOx emissions and the zones were called SECAs (sulphur emission control areas). Later, new limitations on NOx emissions led to the renaming: ECAs. In the Baltic Sea there has been a cap on SOx emissions since May 2006, the North Sea followed in November 2007.

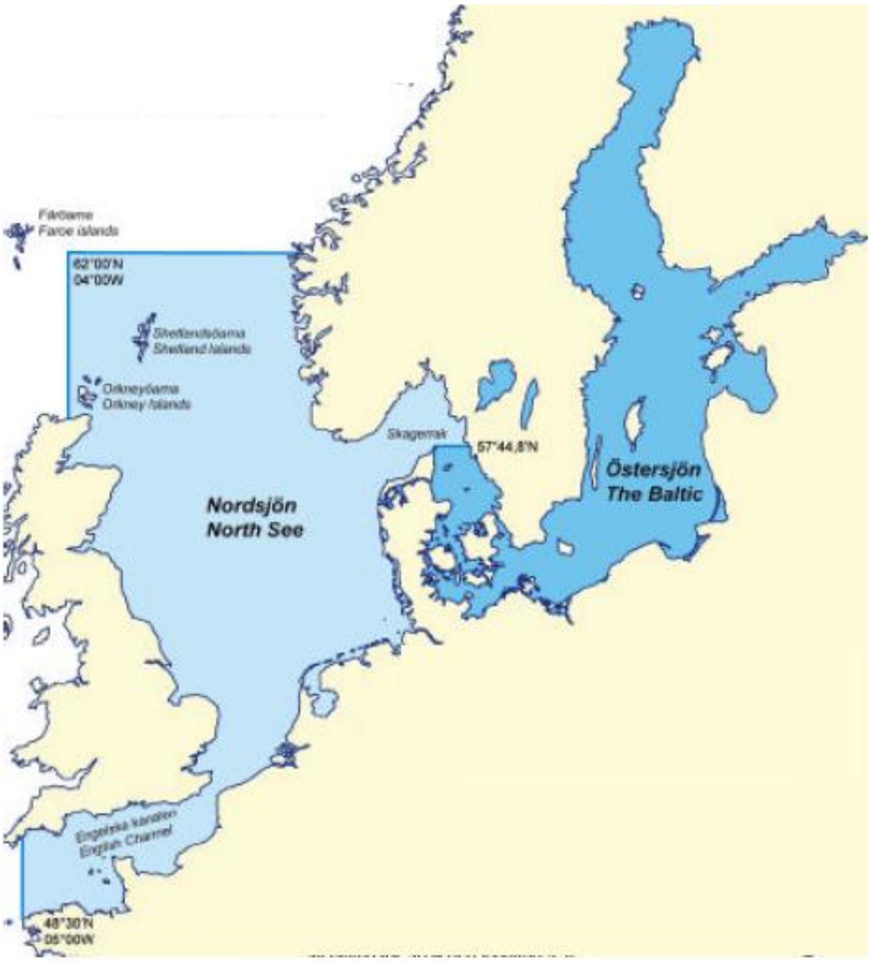

Figure 5: ECAs. Source: MAGALOG 2008.

MARPOL 73/78 Annex VI limits the sulphur content in a ship's fuel. In the ECAs the limit is now < 1%, from 2015 the limit will be < 0,1%. Globally the limit today is < 4,5%. From 2012 it will be < 3,5%, progressively reduced towards 0,5% by 2020 (subject to a feasibility review completed no later than 2018).

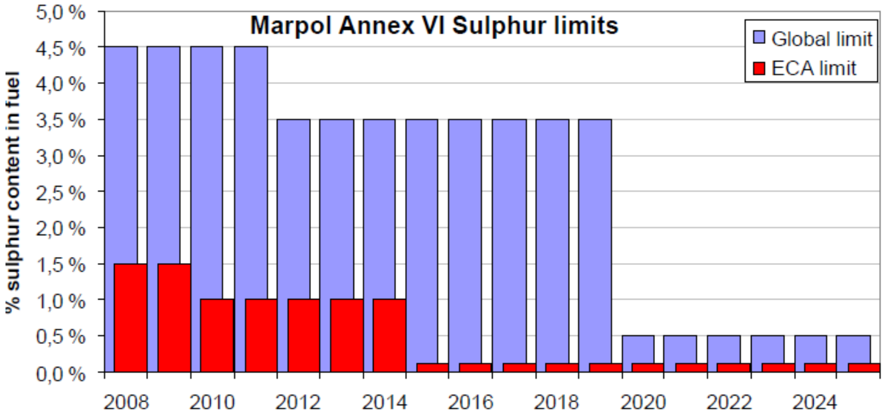

Figure 6: ECA and global sulphur limits. Source: MAGALOG 2008.

It is widely expected that ships will discontinue the use of low sulphur intermediate fuel oil (IFO) in the ECAs from 2015. That is because IFO is not able to meet the < 0,1% SOx demands. Distillate fuels such as MGO provide a much better alternative for meeting the new emission restrictions. As for the global demand of low sulphur fuel, uncertainties in supply can be one reason why the global 0,5% SOx limit in 2020 may be introduced at a later period in time.

For NOx emissions, it is not possible to just change into distillate fuel since the design of the ships engine also plays an important part in total emissions. In 2011 the NOx emission limit was reduced to tier 2 level (globally) and in 2016 it will be reduced to tier 3 level (only in the ECAs). The NOx restrictions will only apply to newbuildings. Therefore, these regulations are not as urgent as the SOx restrictions that will affect all vessels presently sailing in the ECAs.

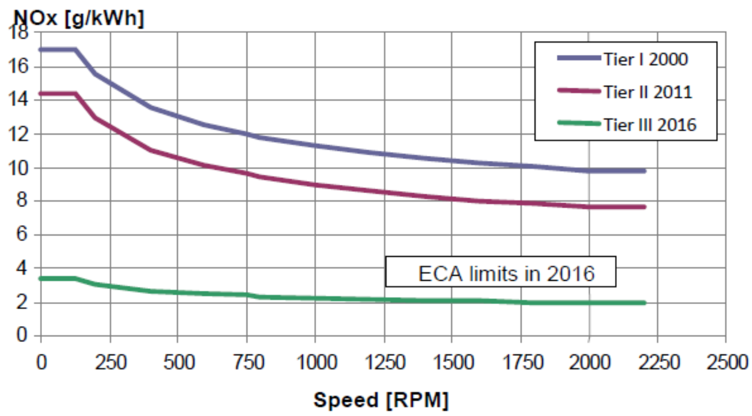

Figure 7: Existing and upcoming NOx emission limitations as a function of engine speed. Source: MAGALOG 2008. g/kWh= gram/kilowatt hour. RPM= Revolutions per minute.

For ships operating in the ECA zones these emission regulations will lead to new challenges. What will the shipowners do in 2015 when they have to comply with the low sulphur limits? Obviously, there are concerns related to increased costs and the big question is: who will pay for this? If it falls upon the shipowners alone we can expect to see a reduction in the supply of ship transport. This may induce a price hike and thereby push some or all of the costs over to the customer. Some studies have tried to quantify this situation where the downside is additional compliance costs, while the upside is greater health benefits. One of these studies is mentioned in Entec[3] (2010), which clearly shows how health benefits outweigh the compliance costs in both a low and high cost scenario for the whole of Europe. Others are

[3] The Entec report was commissioned by a number of North-European shipowner associations and published in July 2010. Its purpose was to draw together the conclusions of six independent reports about the potential impacts of the revised MARPOL Annex VI regulations on sulphur emissions on the maritime sector.

criticizing these new regulations for various reasons. Boholm (2010 p. 1) claims that “the decision to adopt new regulations was taken in secrecy with no prior impact assessment done”. She presents calculations showing how costs of the new regulations for Swedish companies become higher than the value added, which may be true for many countries seen in isolation. Her conclusion is that Europe will experience a modal reversal to road and increased emissions. If this were to happen it would be a great paradox as the purpose of the ECAs has been to reduce emissions. Even if Boholm is correct in her article about the negative sides of the ECAs, the simple fact remains; the shipping industry is a polluter and needs to improve. Generally, companies do not want to do much for the environment unless they can reap some benefits from it. Charterers often have strict requirements when it comes to the vessels that transport their goods, but when these requirements are met, there is little to gain by going above and beyond. Because of that fact, IMO has introduced new regulations and Northern Europe is only the beginning.

In August 2012 the North-American coast will also become an ECA zone with strict emission limitations. Other areas of the world are under consideration, among them the Puerto Rico and US Virgin Islands areas. The Mediterranean Sea is also a relevant candidate for becoming a new ECA zone (Tzannatos 2010). Another regulation in line with IMO’s ECA rules has been introduced by the EC. Directive 2005/33/EC has ensured that since 2010, the sulphur content in fuel must be $< 0,1\%$ when at berth in EU-harbors and inland waterways. This shows how IMO is not the only organization pushing new emission regulations on the industry, others are following and the shipping industry needs to understand the pressure for environmental friendly strategies only will increase. This statement is supported by the SNF (Samfunns og Naeringslivsforskning) report “Fremtidig utvikling i skipsfarten og skipsfartens markeder“. Minsaas et. al. (2000) list environmental concerns as one out of three factors that will dominate the shipping industry the next 20-30 years.

3 HOW TO MEET THE NEW EMISSION REGULATIONS?

According to DNV (2010a/b) and their "ECA survival strategies" there are several ways to manage the SOx demands the ECAs convey. The three main alternatives are:

- Alt 1: Low sulphur fuel, i.e. MGO
- Alt 2: SOx scrubbers for exhaust gas purification
- Alt 3: LNG as fuel

From a practical point of view the low sulphur fuel alternative is the easiest switch. Cleaning systems such as scrubbers and especially LNG fuelled vessels requires a more complex analysis because of higher uncertainty related to various factors such as technology (scrubbers) and availability of fuel (LNG). There is of course also a fourth alternative:

- Alt 4: Give up trading in the ECAs

The last alternative means it is not profitable to comply with the new rules. If margins are already low this may be the only alternative for some owners. For many old ships that cannot bear new investments or extra costs, redeployment, sale or scrapping may be the only feasible option. Since the fuel economy of old vessels normally is worse than new ones, MGO can prove to be a too expensive solution for some of these ships.

This chapter will also include a section about the Norwegian NOx tax/fund and a section about traditional marine fuel and its costs. Both of these sections are important supplements when considering the alternatives mentioned above.

3.1 Alternative 1: Low sulphur fuel

The first alternative shipowners have is to switch over to a type of distillate fuel. The two types to choose among is marine diesel oil (MDO) or MGO. This type of fuel oil is obtained from petroleum distillation and is very clean compared to normal HFO (heavy fuel oil) or IFO. While MDO is a heavier distillate that can contain some residual components, MGO is a pure distillate that contains even less sulphur. In Europe MGO has a maximum content of 0,1 % sulphur, meaning it would comply with the sulphur demands conveyed by the ECAs. Since MGO is a cleaner alternative that always is ECA compliant, it will be used in the continuation of this thesis.

The price of MGO is of course closely linked with the oil price, meaning it fluctuates a lot. This type of fuel is more expensive than IFO, which is being used by ships operating in the ECAs today. It is difficult to make good estimates on how much more expensive since prices vary much, but an average increase of 230 €/metric ton (mt) is one number used in the Entec (2010) report. It is not always the case that shipowners pick up the whole bill for the fuel, but in order to be able to compare different alternatives I will make this assumption.

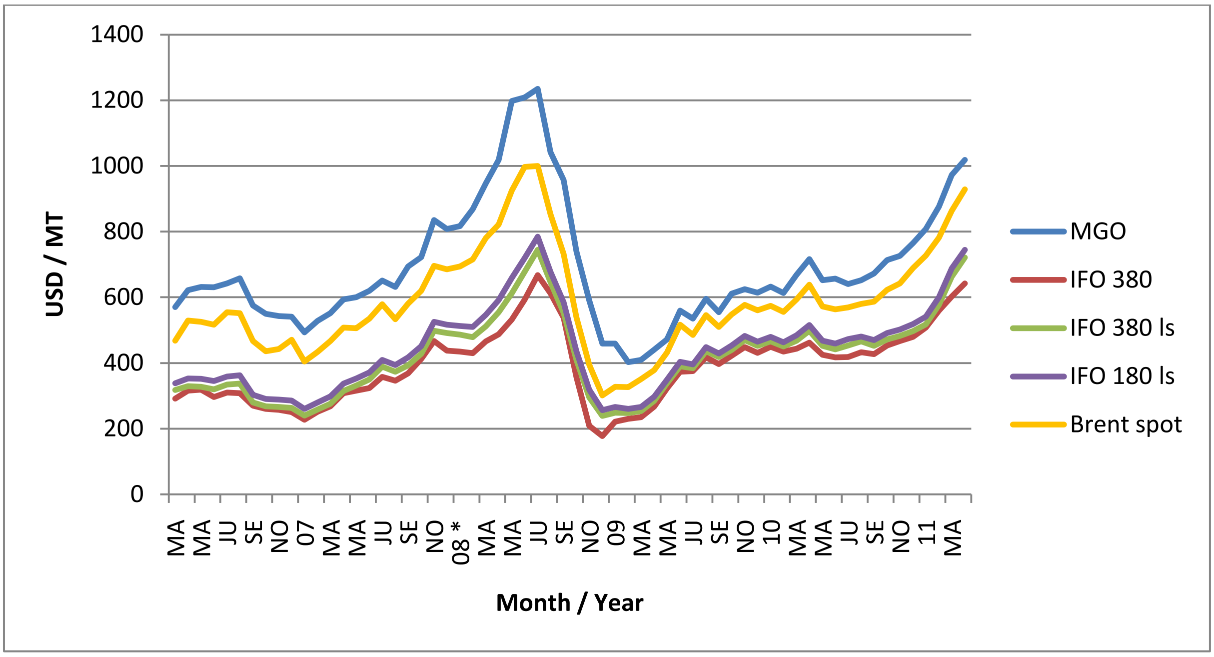

Figure 8: Historical European Brent spot prices and Rotterdam fuel prices.
Source: Platts via Bergen Bunkers AS 2011 and Brent spot from EIA 2011.

The purpose of figure 8 is to illustrate the high correlation between the oil price and the price of MGO and the most common IFO types. Since both MGO and IFO are oil products the correlation does not come as a big surprise. Figure 8 is based on historical fuel prices (Platts[4]) received from Bergen Bunkers AS and Brent oil prices from The U.S Energy Information Administration (EIA 2011). Based on the input data[5] MGO is closely correlated with the oil price since it has a correlation coefficient of 0,973. The coefficient for IFO 380 is 0,930 and for IFO 380 low sulphur (ls) it is 0,949. IFO 180 ls has a correlation coefficient of 0,962. The numbers clearly demonstrate how closely connected these marine fuels are to the oil price.

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[4] Platts is an information service providing daily assessments of market prices for a large variety of products.

[5] Correlation coefficients calculated are based on the time period depicted in figure 8: March 2006 – April 2011. Since the Baltic SOx restrictions came in May 2006, the time period starts from the time low sulphur fuel was sold in large quantities in the region.

MGO also has slightly higher energy content than IFO. Generally, the energy content in bunker and LNG can vary depending on where you receive it. The numbers I will use in the analysis comes from DNV's Natural gas, cleaner energy and solutions department (DNV 2011b). Energy content for each fuel grade is: IFO: 40, MGO: 42,7 and LNG: 49,3 mega joules (MJ) /kg fuel. These numbers can then be used to calculate fuel consumption for the different alternatives. For example, in terms of energy content: 100 mt IFO= 100*(40/42,7)=94 mt MGO. Small variations can occur due to different engine types. For example, based on input from stakeholders, the TNO Report (2011) estimates energy consumption about 2 % higher for LNG engines. I will disregard this in order to simplify the analysis.

Capital expenditures involved when choosing MGO are low compared to other alternatives such as LNG or scrubbers. When assessing the initial investment it will of course depend on the standard of each vessel, and various studies have assessed these costs differently. The IMO estimate that the average cost of converting to low sulphur fuel would be in the region of €100 000 (IMO: BLG12/INF10 cited by SKEMA 2010). While the capital expenditures may be low, the fuel expenditures will be high. As we saw in figure 8, it will depend on the development of the oil price, but when viewed over a longer period, the crude oil price has had a rising trend (Swedish maritime association, 2009, p 25). It is also likely the oil price will continue rising in the near future, as demand from emerging economies such as the BRICS countries[6] increase.

Until now, ships operating in the ECAs have used low sulphur IFO that is a blend between HFO and distillates. The SOx limit has been <1% and supply of low sulphur IFO has not been a problem. Fuel can be supplied virtually anywhere, for high quantities and in central ports delivery by barge is normal. For smaller quantities or in more remote ports, delivery by truck is most often possible. There is a wide consensus that stricter sulphur limits will force ships to use distillates instead of residual oils (Entec 2010). According to the IMO GHG study (2009), total estimated fuel consumption for 2008 in the ECAs amounted to 27 million mt. Of these 27 million mt 78% was IFO. So what will happen if about 21 million mt of IFO were to be replaced by distillates? Obviously, some concerns have been raised regarding the availability of 0,1% sulphur content fuel in sufficient quantities from 2015. Availability is difficult to predict since it depends on a multitude of factors such as supply, demand, political

[6] The BRICS countries include: Brazil, Russia, India, China and South Africa.

developments and development of alternative fuels and solutions. There is general agreement that the demand for distillates will increase in Northern Europe. In addition to this, the introduction of ECAs outside of North America and Canada will increase demand further. Since the European demand will increase substantially and the global demand will follow, refineries will have to explore several options in order to supply distillates. None of the studies reviewed in the Entec report show how the increased demand for distillates will be met.

Using distillates does not pose any major technical challenges (SKEMA 2010). The use of distillate fuel would improve the reliability of engines and reduce maintenance requirements as long as engines are properly adjusted. An effect from improved engine reliability can be reduced insurance cost since the likelihood of accidents as a result of engine failure decreases. A distinction is made between single fuel operations (using only distillates as fuel) and dual fuel operations where the vessel can switch between distillates and HFO (SKEMA 2010). Due to differences between HFO and MGO such as different viscosity and boiling point, switching between fuels can lead to technical challenges and the need for new procedures. An important decision for shipowners building new ships (or retrofitting old ones) would have to be whether to install a single fuel operation-system that is ECA compliant, dependable and cheap, or choose a solution that is able to switch between distillates and HFO (dual fuel operation). By owning a ship designed for single fuel operation, one would in practice exclude it from trading in the non-ECA zones. Highly priced fuel consumed by the ship would leave it at a huge cost-disadvantage compared to other vessels outside of the ECAs, meaning it may trade there but it would not be competitive at low freight rates. For many ships sailing in the regulated areas today, like some of Utkilen's vessels we will analyze in chapter 7, switching between HFO and MGO does not represent a major problem.

3.2 Alternative 2: SOx scrubbers for exhaust gas purification

The second alternative for ships operating in the ECAs is to continue running on low sulphur IFO, but install a cleaning system that reduce SOx emissions. Regulation 4 of Annex VI to MARPOL 73/78 allows, with approval of the administration use of alternative compliance methods, such as exhaust gas cleaning. There are three types of sulphur scrubbers available for ships. These are: Sea water scrubbers (SWS), fresh water scrubbers (FWS) and dry scrubbers. According to Entec (2010) and Tzannatos (2010) the most common type for marine applications is SWS. Thus, SWS is the type of SOx scrubber that will be analyzed in this thesis.

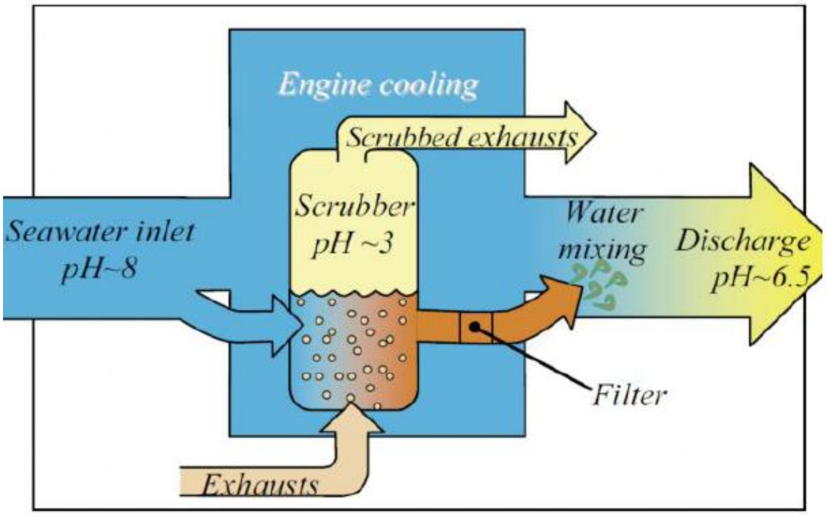

Figure 9: The scrubbing process (SWS). Source: SKEMA 2010.

The SWS principle of operation is to pass the exhaust gas through seawater and the seawater then absorbs the sulphur content. This method takes advantage of the seawaters natural alkalinity and hence its ability to absorb up to 99 % of SO_2 produced by the combustion of HFO (Tzannatos 2010). In this study I will assume the scrubber system can absorb 90% of SO_2 in the fuel. This means that ships equipped with scrubber equipment can continue using low sulphur IFO. It is possible, depending on the specifications of the scrubbers to use higher content sulphur fuel, but due to the limited experience with the technology a conservative absorption rate of 90% is considered more appropriate. This is also supported by experience from some of the vessels that has already tried this technology (SKEMA 2010).

Ocean alkalinity is normally constant and high. For the Baltic Sea however, the situation is special. The Swedish maritime association’s report from 2009 acknowledges the limitations of using SWS in the Baltic Sea. To date, ships sailing the Baltic have not used scrubbers. In the Baltic the waters are more of a brackish type than seawater since the exchange of water through the Danish strait is minimal. Because of this, the alkalinity in the Baltic is lesser than normal and SWS would not work as effectively here as in normal seawater. This is a huge issue since the Baltic Sea is one of the two ECAs in Northern Europe. FWS is a better alternative when sailing in the Baltic, but this technology is more expensive and even less developed than SWS (Entec 2010).

The technology scrubbers utilize dates from the 1930's and scrubbing technology has been well proven on land. Its application to sea is somewhat limited, the prototype on marine engines was first installed on MS Kronprins Harald in 1991 (Trozzi and Vaccaro 1998). One reason for this lacking marine application is limited demand. Limited production capacity may also restrict the adoption of this technology. Due to the limited experience with this technology demand is not expected to increase before 2015, and the Entec report does not expect significant uptake by 2015 when all ships operating in the ECAs must comply with the SOx regulations. According to DNV (2010a) the development is ongoing and today there are about 8 suppliers offering different scrubbing solutions. The main challenge faced by all of these suppliers is that marine scrubbing is a new technology with uncertainties related to costs and operation due to limited experience. In addition, there is concern about the ecological consequences of sending sulphur-containing wastewater back into the sea. This is especially the case in special areas such as the Baltic Sea. A scrubber system will also produce sludge that needs to be disposed of in an appropriate way, typically delivered on-shore for proper disposal. The sludge disposal would not add significant costs, as it is treated in the same way as engine sludge is today (EMSA 2010). Another practical issue with this alternative would be the space required on a vessel that is to be retrofitted. While this would be easy for a newbuilding, an existing vessel not designed for this will not have space readily available. A scenario that also is necessary to take into account is the risk of the scrubber system failing while the ship is at sea. In such a case the vessel would be unable to sail in the ECAs unless it can use an alternative fuel. According to AEA (2009) a 2% fuel consumption penalty is to be expected when using SWS.

As listed above there are many reasons why not to choose the scrubbing alternative and these are all related with much uncertainty. But if we look at the costs associated with this alternative, it seems like a good solution compared to MGO. The capital expenditures can be characterized as medium, while the fuel expenditures will be about the same as today since vessels can continue running on low sulphur IFO. Suppliers of scrubbers claim a repayment period of about one year compared to using MGO[7]. It is important to note how the repayment period for a scrubber system will depend on the oil price, which at the time of writing (April 2011) is rather high. According to SKEMA (2010), initial cost of new built and retrofit scrubbers is 118 and 168 € per installed kW of power, while Tzannatos (2010) use a scrubber

[7] This means that the costs from one year's consumption of MGO can cover the scrubber capital costs plus one year of operation.

cost of 143 €/kW. Extra operating/maintenance costs have been estimated to 0, 8 € per megawatt hour (MWh) for a small ship in one study reviewed by SKEMA (2010)[8]. While scrubber suppliers claim a 20-25 year lifespan this study will use 15 years, which is conservative, but more realistic according to the literature. Based on discussion with the industry the SKEMA study estimates a period of 28 days off hire in order to retrofit a scrubbing system. This is a relatively long period that exceeds the time used for periodical dry-docking of a vessel. If an installment of such a system was undertaken as part of a dry dock the extra days can be expensive as the ships alternative use could have generated significant revenue. According to Tzannatos (2010) the impact of inflation is usually fully counteracted by the lower production costs associated with an expanding market for this type of innovative technology.

In order to reduce NOx emissions, installment of a selective catalytic reduction (SCR) system is one possibility. To comply with the NOx limits that are applicable for newbuildings from 2016, a NOx cleaning system would be necessary both for vessels running on distillates and vessels using a SOx scrubbing system. A challenge that is frequently referred to in many studies is the difficulties with integration between several cleaning systems (Entec 2010.) This is another challenge that needs to be addressed if choosing a SOx scrubber system for newbuildings. A comprehensive analysis of SCRs will not be included in this thesis since the focus is on the immediate transition to 2015 that will affect existing vessels sailing inside of the ECAs.

3.3 Alternative 3: LNG as a marine fuel

3.3.1 Natural gas

Natural gas is the fastest growing energy source in the world and worldwide consumption is forecast to double by 2030 (Chandra 2006). Like oil and coal, natural gas is a fossil fuel that is non-renewable, but its environmental properties are far superior to coal and oil (MAGALOG 2008). Unlike these other two fossil fuels natural gas cannot simply be loaded on ship or train from its source to the final consumer. It is bulky, difficult to handle and expensive to transport, requiring expensive pipelines or complicated conversion systems in order to make the gas more manageable (Hannesson 1998). The low energy-to-volume ratio

[8] See SKEMA (2010) pp 22 for an example of scrubber cost calculations for different vessels sizes.

for gas means storage becomes somewhat more demanding than for oil. As a result of this the transportation of gas has very high capital costs. According to Hannesson (1998) this has two implications for industrial structure. First, gas producers have been reluctant to develop gas fields unless having secured long term commitment from buyers. Second, high capital costs of pipelines and LNG systems make them a classical case of natural monopoly. These challenges has contributed to keeping natural gas behind oil as the main hydrocarbon based fuel, but as coal gave way to oil, the era of oil will most probably give way to natural gas (Chandra 2006). Technological advances and declining costs have allowed it to overcome many of the challenges of the past. Numerous gas reserves around the world remain unexploited due to underdeveloped markets and logistical challenges.

3.3.2 LNG basics

LNG is natural gas that has been cooled to obtain liquid form and requires a temperature near minus 162 °C. It is then 1/600th of its original volume, making efficient storage and transportation possible (Chandra 2006). Natural gas can be transported by pipeline, but this is far less flexible than using LNG carriers. Liquefaction and re-gasification plants are expensive, but the cost of transporting LNG is low and proportionate to distance (Hannesson 1998). Methane (CH_4) is the main component of natural gas, it makes up approximately 90 % while the balance being largely ethane (C_2H_6). Generally speaking, the composition of LNG is the same as natural gas except that LNG has been purified of certain components that would cause problems at very low temperatures. Since it is cleaner than any other fossil fuel, its impact on the environment is small compared to conventional marine fuel. LNG has a potential of up to 90% reduced emissions of NOx and virtually no SOx (MAGALOG 2008). If we relate this to the ECAs and emission regulation LNG is supreme for SOx and NOx removal. This means it will also comply with the NOx limits on newbuildings from 2016 and onwards. It is not given that LNG engines will be approved for tier 3 NOx limits, but it is very likely.

LNG has been used as a marine fuel since 2001, and today there are 22 LNG fuelled vessels in the world, 21 of them operating in Norway. While it took 10 years to get to 22 ships, 17 vessels are under construction/have been contracted for the next three year-period (DNV 2011a). This shows how the adoption rate is increasing and LNG fueled vessels have become a relevant alternative for many shipowners. Ships using the technology today include ferries, PSVs and coast guard vessels, in other words; ships with a rather fixed sailing pattern. But new segments like chemical and RoRo vessels are now slowly following. A distinction is made between dual fuel engines, meaning vessels can run on MGO as an alternative to LNG and single fuel engines only fuelled by LNG. Except for ferries, most LNG fuelled vessels today have dual fuel engines.

In LNG carriers, LNG has been used as a fuel for several decades with few accidents or incidents reported. The physical conditions under which ignition and explosion or fire of LNG can occur are narrower than for other hydrocarbon fuels (MAGALOG 2008). When looking at other segments such as the chemical tanker segment, operational flexibility becomes important since the sailing pattern will be somewhat less fixed than segments which have already adopted LNG as fuel. This challenge has been described by many as a classical "chicken and egg problem", meaning that distributors do not want to develop a bunkering network before there is demand from shipping companies and shipping companies do not want to build LNG fuelled vessels before there is a developed bunkering network. A problem like this does not have an easy fix. Norway is the country leading this development, and here the problem is somewhat mitigated by government involvement. This means publicly owned ships must run on LNG. In addition, the Norwegian NOx fund has been created whereas a NOx tax from vessels sailing between Norwegian ports generates income to the fund. Then, if companies make investments that reduce NOx emissions to air, they can receive financial support up to a certain limit. By creating a NOx tax and a funding system, a financial incentive to reduce NOx emissions has been developed. Government interventions like these are important in order to cope with initial challenges related to availability of LNG.

3.3.3 Units of LNG and price level

Generally, natural gas is sold by its energy content and not per unit of volume. It is common to state the cost of gas to industrial customers in terms of dollars per million British thermal units (MMBTU). In terms of energy 1 MMBTU contains 293 kilowatt hour (kWh). 1 cubic meter (m^3) LNG contains 5,9 MWh of energy and weighs approximately 0,45 mt, meaning volume is the restricting factor.

LNG as a marine fuel is sold by weight, usually per mt. As mentioned in section 3.1, less LNG is required for the same amount of energy output. DNV (2011b) estimate a LNG price of approximately 5000 NOK/mt along the Norwegian coast today (March 2011). This is a price level in between IFO and MGO. Since Norway is home to most of the LNG-marine fuel sale in Northern Europe this price seems representable for the ECAs today. LNG Europe is a supplier in the Antwerp-Rotterdam-Amsterdam (ARA) area that indicates a similar price level. It is important however, to be aware of the fact that prices are negotiated individually with each buyer, depending on factors such as volume and distance.

3.3.4 Challenges

Space requirement is a challenge commonly referred to. Seen from a shipowner's point of view, the challenge related to room for LNG tanks and lines is not insignificant. Not only does the LNG itself require more space than traditional fuels, the cylindrical form of the storage tank requires as much as 3-4 times more space compared to today's fuel systems (Marintek 2009). Loss of cargo space is a big issue for shipowners that are restricted by cargo volume and not weight. This is especially the case for chemicals which vary a great deal with respect to specific gravity (SG). It is not unusual that the restrictive factor is volume and not weight. For example, methanol has a SG of 0,791, meaning 1 mt requires 1/0,791= 1,26 m^3. Chemical tankers carrying this type of cargo frequently would therefore risk reduced space for cargo as a result of a large LNG storage-tank. Other chemical cargoes such as caustic soda and sulphuric acid are the other way around, vessels carrying such cargoes would be better suited for LNG if the storage tanks are integrated into the hull of the vessel since weight is the limiting factor. This means a chemical tanker would be able to carry more mt of cargo and less mt fuel compared to IFO. A simple way around the space problem for many vessels is to place the fuel storage tanks on the forecastle deck. The Swedish product tanker "Bit Viking"[9] that is being retrofitted for LNG propulsion this year has adopted this solution. It virtually eliminates the problem for tanker vessels, but a caveat is the added weight of these LNG-storage tanks that easily can neutralize the advantage of LNG requiring less mt compared to IFO. A solution with smaller hull integrated tanks is under development and can hopefully mitigate this problem.

While LNG is superior from an environmental point of view, current challenges regarding price and availability still limit its application as a marine fuel. Today, there are several models in which the price of LNG is determined. European HUB prices such as TTF, NBP and ZEE use a natural gas index. Other models are based on the oil price development and

[9] Bit Viking is the first vessel of its kind (chemical tanker) to be retrofitted for LNG propulsion. See Tarbit 2010 in the reference chapter.

some use a mixture of both. The natural gas price has traditionally been closely linked to the oil price, but in recent years, gas prices have tended to decouple from oil prices (International Energy agency (IEA) 2010). This change can be attributed to abundant supply of unconventional gas in North America, increased availability of cheaper LNG in Europe and Asia Pacific, and some provisional changes to contractual terms in Europe; all of which have lessened the role of oil prices and increased the role of gas price indexation in long-term contracts (IEA 2010). According to E.ON[10] director Jørgen Kildahl the market for gas is working independently from the oil market. “The natural gas market is not cartel-regulated like the oil market and prices cannot be dictated. Now, the market decides the prices”, says Kildahl (Dagens Naeringsliv 2011 p. 16).

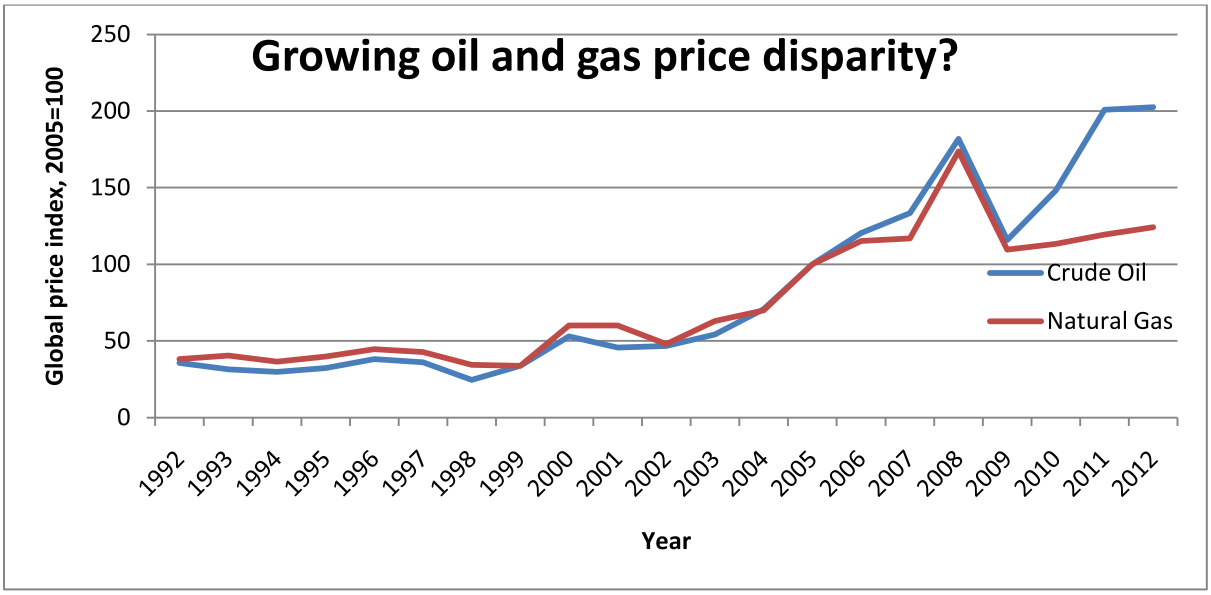

Figure 10: Growing oil and gas price disparity? In 2010 the oil price increased more than the gas price. Over time the prices of the two commodities have been closely correlated. Year 2011 and 2012 in the figure are IMF projections. Source: IMF 2011.

In the same Dagens Naeringsliv article, Professor of petroleum economics, Petter Osmundsen at the University of Stavanger confirms it is possible these two commodities will become independent of each other, but until now, it still remains to be empirically demonstrated. There is considerable uncertainty about whether the move away from oil indexation will be permanent, and even if it is, whether this will lead to lower gas prices relative to oil (IEA 2010). The main reason for the oil and gas disparity today is the low spot prices for natural gas. Shale gas from the US is being produced in sufficient quantities to supply the US, and

[10] E.ON is a German energy company whose main business is energy production and sales of electricity/gas. The company has 80 000 employees in 30 countries and its market value is 46, 3 billion Euros.

they have even started exporting gas to Europe. So even though LNG prices in the ECAs are high today, this development together with an expanding market for LNG can lead to lower prices in the time to come.

In order to explain why price and availability for LNG is fairly unfavorable in the North European ECAs at the moment we can use figure 11:

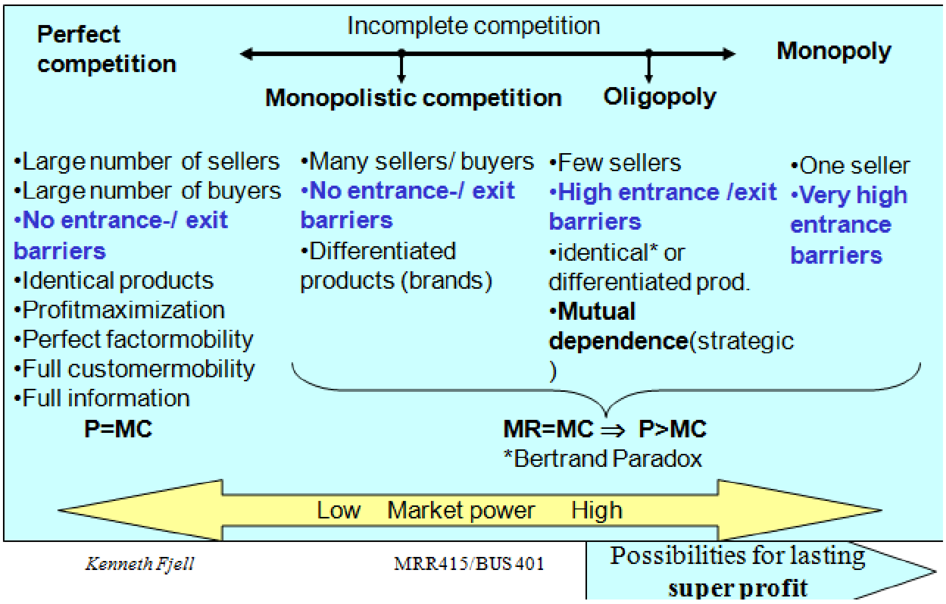

Figure 11: Market structure. Source: Fjell 2009.

Market structure will have a strong impact on the price and availability for a product. The North European LNG market today can be characterized as an oligopoly with few suppliers. Since the suppliers' market power is high, they have a greater impact when it comes to pricing. As small scale LNG plants are being used, the capital costs for entering this market have been substantial. The three Norwegian suppliers to ships today are Gasnor, Nordic LNG and Barents Naturgass. Other suppliers outside of Norway are now slowly emerging. One company is LNG Europe. They are able to supply LNG in the ARA range, and they source LNG from major import terminals. Consequently, there are no limits on capacity, it also eliminates the high barriers to entry. This shows how the availability of LNG is continuously improving throughout Europe. Just like LNG Europe, Gasnor is already sourcing LNG from European terminals and they can today deliver LNG in most of Europe. Gasnor have a new terminal under development in Gothenburg and a Hirtshals terminal is being planned. Several new LNG bunkering facilities in the Baltic are also being developed. For example, Nordic LNG will deliver LNG to Nynashamn, just south of Stockholm.

So while availability and price still pose major challenges, the development in the last few years seems to be showing a very positive trend that eventually can mitigate the availability and pricing challenges related to LNG. Thus, it can be expected that the price of LNG in the ECAs will stay at its current level or even decrease in the time to come.

3.4 Alternative 4: Give up trading in the ECAs

This is the final alternative if none of the first three are feasible. Since ships are mobile, the big question here is: What is the ship's alternative use? Giving up ECA trade can be a possibility in two situations: First, if it is not practically possible to go for any of the other alternatives, i.e. the vessel cannot run on only MGO or be retrofitted due to more practical reasons such as lack of onboard space or old and incompatible engines. Secondly, and more obviously, it is very possible some ships and companies will be unable to bear the extra costs incurred by these new regulations.

It is not expected that choice of alternative will affect income in any significant way in the long run. This is because all vessels sailing in the ECAs will have to comply with the regulations. Basically, no vessel's way of complying will stand out as special or unique over time. It can be argued that certain ways to adapt, such as the use of LNG or scrubbers will lead to certain corporate social responsibility (CSR) effects, which in turn will increase demand for these vessel right before and after 2015. Research on the relationship between CSR and profitability has up until now been unclear, and the conclusion from it all is that we still do not know whether or not it is profitable (see Orlitzky 2008 or Blowfield and Murray 2008). This leads to the assumption that choice of an emission reducing alternative will not affect the income of the vessel in the long run and thus, only costs will be analyzed in this research. Another challenge is to assess if and how much income the ship can generate outside of the ECAs. Due to the complexity of this alternative, giving up trade in the ECAs will only be analyzed from a qualitative point of view. The theoretical framework that will be used can be found in chapter 4: Theory, section 4.4: The four shipping markets.

3.5 The Norwegian NOx tax and the business sector's NOx fund

There has been a tax on NOx emissions from shipping in Norway since 01.01.2007. Tax on NOx emissions came as an effect of the Gothenburg Protocol that has been signed by most countries in Europe. Among other harmful substances, the protocol aims to reduce NOx emissions. The NOx tax affect all vessels that has more than 750 kW of power installed. The two most important reasons why vessels can be exempted from this tax is:

- The ship is in direct traffic between Norwegian and foreign ports.
- The company has signed the environmental agreement with The Business sectors NOx fund.

A direct consequence of the tax is that for vessels sailing between Norwegian ports regularly, this can become a huge cost, while vessels that do not call more than one Norwegian port per voyage are not affected. Emissions are measured by using a NOx factor depending on the ship's engine. The tax is set to 16,14 NOK/kg NOx emitted from 01.01.2011 (Toll 2011). If a company is member of The Business sector's NOx fund it must report emissions to the fund, but instead of paying 16,14 NOK/kg it only pays 4 NOK/kg. In return, the company must implement emission reducing measures. A continuance of the environmental agreement for the period 2011-2017 has been agreed upon by the parties from the previous agreement (2008-2010). An important precondition for the continuance is that the EFTA Surveillance Authority (ESA) approves of the new agreement.

Members of the NOx fund can apply for financial support for investments that will reduce emissions. Given that ESA approves of the new agreement, the rates from 01.01.2011 are as follows (NHO 2011):

- Newbuildings and retrofitting into LNG can receive up to 80% support, limited to 350 NOK per kg NOx reduced.
- Other measures that will reduce NOx emissions for ships can receive up to 80 % support, limited to 225 NOK per kg NOx reduced.

The number of kg NOx reduced is based on actual or estimated taxable NOx emissions from a vessel in one year. Since the focus of this thesis is mainly the transition to 2015 and the cap on SOx emissions, LNG is the only alternative that will be able to receive support from the fund as this is the only alternative that significantly reduces NOx as well as SOx emissions.

3.5.1 The mineral oil tax

Another environmental tax relevant for ships operating along the Norwegian coast is the mineral oil tax. This tax is made up of a basis tax, a sulphur tax and a CO_2 tax. In 2011 it is 1,649 NOK/liter for MGO and for low sulphur IFO it is 1,877 NOK/liter (Bergen Bunkers

2011). The tax is only applicable when discharging a cargo in a Norwegian port after receiving bunker in Norway. Because of that, it is not very relevant for the type of shipping analyzed in this thesis and will not be included in the calculations. Still, it is important to be aware of since it can incur considerable extra costs on voyages along the Norwegian coast. By having good planning routines for bunkering it can be avoided by vessels that frequently travel between Norwegian and foreign ports.

3.6 Traditional marine fuel and its costs

The starting point for any analysis will have to be “the business as usual scenario”. Today most vessels operating in the ECAs are fuelled by low sulphur IFO. This type of fuel is a blend between HFO and distillates, where the most common blends are IFO 180 and IFO 380. Another type of fuel is distillates such as MDO and MGO. Distillates are preferred since they produce the least dirt and less dirty exhaust gases. Unfortunately it is also more expensive as can be seen in the below figure.

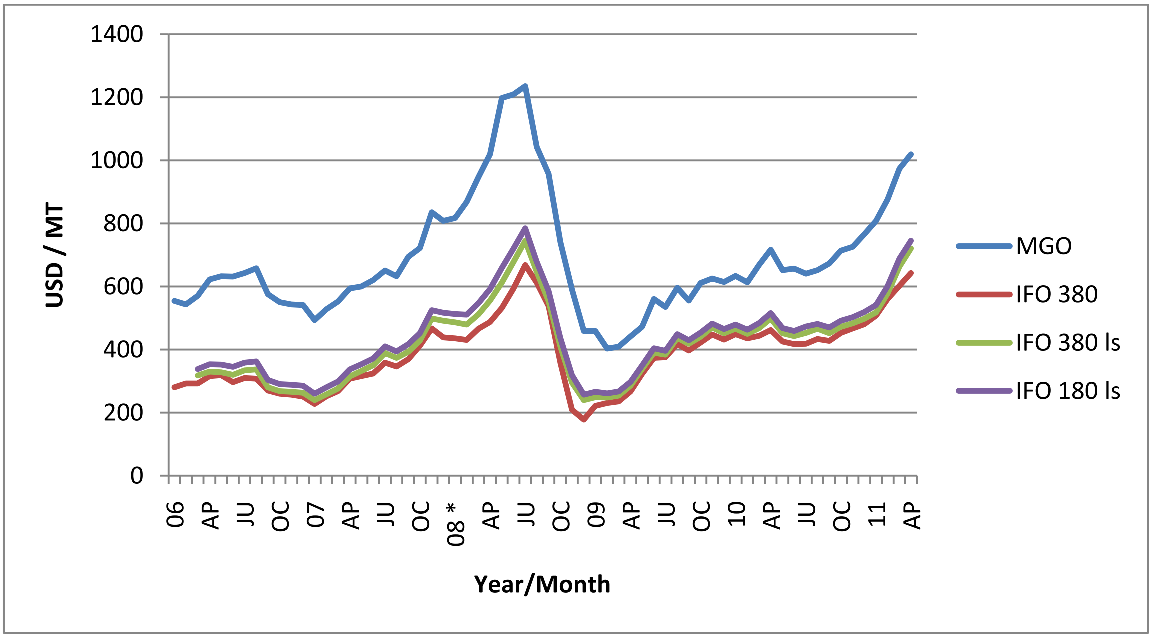

Figure 12: Fuel price development Rotterdam. Source: Platts data received from Bergen Bunkers AS 2011.

Figure 12 is almost identical to figure 8, but here the oil price has been removed, we see in the figure actual prices for delivery of fuel in Rotterdam. Small variations with regards to ordering quantity and delivery dates cannot be ruled out. The X-axis starts well into 2006 since this was when ECA sulphur restriction first became mandatory in the Baltic and low sulphur IFO became available. The purpose of the figure is to depict differences in prices between the fuel grades (regular and low sulphur) and how these have developed over time. A point worth mentioning is that the difference between MGO and IFO is not always constant. This introduces more uncertainty when making comparisons.

When comparing lifetime costs for different alternatives, fuel prices will play a key role in the calculations. It is extremely difficult with expectations in the very long run. For example, what is the oil price in 10 or 15 years? That is perhaps why many shipping companies still have not done much to prepare for the upcoming ECA regulations. Oil prices often fluctuate due to unexpected events around the globe. For instance, at the time of writing (March 2011) rioting and revolutions in North Africa and the Middle East has caused the oil price to rise again. These kinds of unexpected events make forecasting difficult. In the EMSA report (2010) it is acknowledged that a main problem being highlighted in all studies on this particular subject (the 0,1% SOx limits) is the difficulty to predict fuel price trends. Still, forecasts must be added much weight since they are the best sources we have on this type of information.

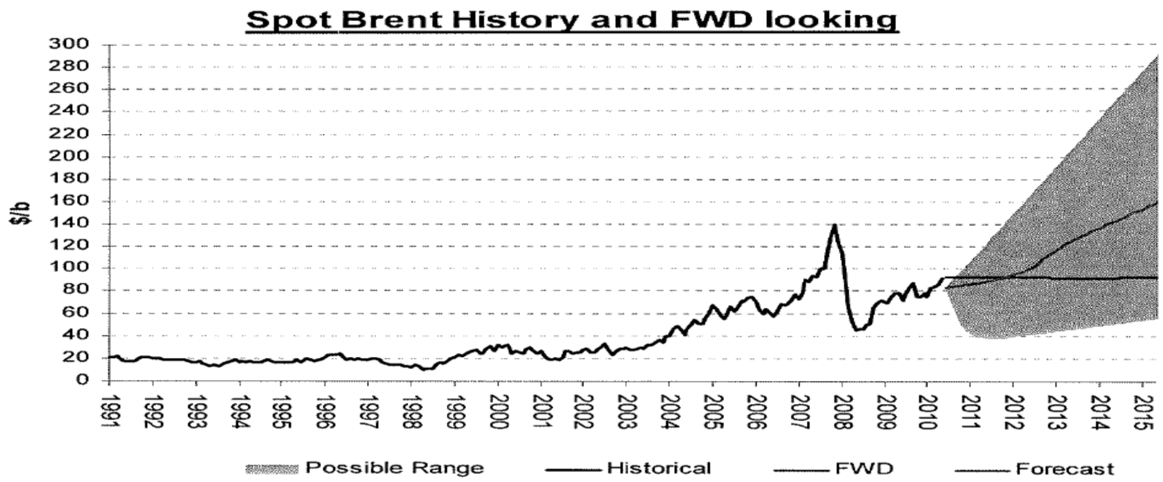

Figure 13: Long term oil price forecast. Source: DnB Nor Markets via Bergen Bunkers AS 2011.

When the ECA SOx restrictions are implemented, the forecast in figure 13 has a possible range between 50-290 USD/barrel. In 2015 the forecasted price is 150 USD/barrel. A period of only 4 years is too short to be used when predicting the development the next 25 years, but it gives a good indication that the oil price is expected to continue upwards. The "World Energy Outlook 2010" –report produced by the IEA has projected average crude oil prices by scenarios as far ahead as 2035. From this report we can read: "Prices are assumed to rise steadily over the entire projection period in all but the 450 Scenario, as rising global demand requires the development of increasingly more expensive sources of oil" (IEA 2010, p 69).

Thus, it is fair to assume an increasing oil price. Previous investment analysis' made by DNV (Mohn 2010) have used a yearly increase of 4,6 %. As already mentioned it is very probable the world demand for oil will increase and this will most likely lead to higher prices, but how high is difficult to say. In the analysis in chapter 7 of this paper, a sensitivity approach with different scenarios regarding initial fuel prices and fuel price development will be presented in order to make the reader aware of the consequences for different scenarios.

4 THEORETICAL FRAMEWORK

The below theory is what will be used as basis for the analysis. It includes four parts: the cost of running ships, capital budgeting, first-mover advantage/disadvantage and the four shipping markets.

4.1 The cost of running ships

According to Stopford (2009) the shipping industry has no internationally accepted standard cost classification. In his book "Maritime Economics" he classifies costs into five categories (Stopford 2009 p. 221):

- Operating costs – Day to day costs of running the ship, such as crew, stores, insurance, administration and maintenance. These costs will incur regardless of the type of voyage the ship is engaged in.
- Periodic maintenance costs like dry docks and special surveys.
- Voyage costs are variable and include fuel costs, port dues, tugs, pilotage and canal dues. Like canal dues, another cost that may or may not occur on a voyage is emission taxes, as this will depend on where the voyage goes.
- Capital costs depend on the way the ship has been financed. It usually includes interest and capital payments on debt finance.
- Cargo-handling costs. Related to the loading/discharging of cargo.

Since the choice of ECA adaptation does not affect all these cost categories the relevant costs for the analysis will be: operating costs (maintenance and repairs), voyage costs (split into: fuel costs and emission taxes) and capital costs (only additional capital costs for choice of alternative).

As can be seen from table 1 below, capital costs are typically the largest, voyage costs are following close behind with fuel costs as the single most important item. In the example below fuel costs make up a combined 76% of total voyage costs. In such a case, focus on fuel expenditures will be crucial for the vessel's profitability.

GENERAL COST CLASSIFICATION		COST ITEMS	
1. Operating costs	14 %	Manning costs	42 %
		Stores and lubricants	14 %
		Repair & maintenance	16 %
		Insurance	12 %
		General costs	16 %
2. Periodic maintenance costs	4 %		n.a.
3. Voyage costs	40 %	Fuel oil	66 %
		Diesel oil	10 %
		Port costs	24 %
		Canal dues	n.a.
4.Cargo-handling costs	n.a.		?
5. Capital costs	42 %	Interest/dividend	?
		Debt repayment	?
SUM	100 %		
Note: This analysis is for a 10-year old Capesize carrier under the Liberian flag at 2005 prices. Relative costs depend on many factors that change over time, so this is just a rough guide.			

Table 1: Cost of running ships. Source: Stopford 2009.

Not all ships will share the exact same profile as the example in table 1. The example serves its purpose however, in illustrating the point that fuel costs is one of the most important expenses. That is also why the way a shipowner decides to comply with the new ECA regulations is so important and will have a direct impact on the ship's expenditures. When ships become older fuel costs also become a larger part of total costs as capital costs will decrease. Since old ships typically are less energy efficient than new ones this makes fuel costs a huge part of their expenses.

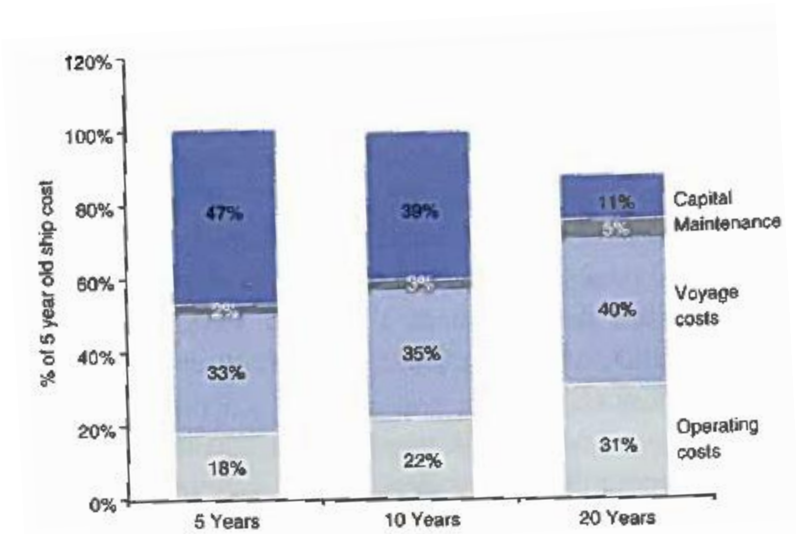

Figure 14: Capesize bulk carrier cost and age. Source: Clarkson research studies 1993 cited by Stopford 2009.

Fuel prices vary a lot and although shipowners cannot control them, they can influence the consumption. The key areas will then be the engine, the hull and the propeller. Another interesting remark is how the interest for new technological solutions often follows high fuel prices and as we could see from figure 12, marine fuel prices has been showing an upward trend since the beginning of 2009.

Since shipping is by definition an international industry, taxation does not figure prominently in most shipping companies (Stopford 2009). By registering a vessel under one of the many open registry flags, exemption from taxation is possible. In order to be competitive with these open registers most major shipping nations have introduced similar tax regimes that make tax expenses small or zero for most shipping companies.

4.2 Capital budgeting

In order to compare the different alternatives faced in a thesis like this it is important to gain an overview of extra costs related to each alternative. There are different methods for such an evaluation, but they all assume a periodical cash flow. Choice of method may lead to various results since each method has its strengths and weaknesses.

4.2.1 Time preference and the cost of capital

For most people and definitely for most companies, income now is more important than income later. Income now can be used to generate even more income. At the same time companies would prefer to delay expenses as long as possible, therefore we experience a time preference meaning we can put the money to use at an earlier point in time so as to enjoy the effects for a longer period. Bredesen (2005) list 3 main reasons for this time preference. First, one looses interests. Instead of investing the money in a project, they could have generated income in a bank. It is therefore an alternative cost in the form of lost interest. Second, inflation reduces the purchasing power of money. This means we can buy more of a commodity for the same amount today than in a year. Third, risk is something that also must be taken into account. After all, anything can happen and it is not always 100% certain an investor will get his money back from a lender. Because of this, risk compensation is also necessary.

In a company, the difference in value between money now and money later is defined as the company cost of capital. This is the interest rate which is to be used when comparing money at different points in time. The rate is determined by considering the financial situation of the company, by finding a weighted average of the cost of capital from different sources (Bergstrand 2009). Typically, there is one source of equity capital from the owners and another source from bank loans. The ratio of debt to equity is referred to as gearing, the higher it is the more risk is involved. By knowing what share of company financing comes from one or the other source we can find the weighted average cost of capital (WACC). If for example 35% is equity and 65% is bank loan we get: 0,35*11 + 0,65*6= 7,75%. (11% is what the owners demand in return on equity and 6% is the cost of borrowing from the bank. These numbers are fictional and only used to illustrate the calculation of the WACC in this example). One can say the cost of capital is used as a means of rationing money for investment. It is of great importance to know the correct cost of capital. If a company applies a cost of capital that is higher than actual cost, there is a risk of making profitable projects look unprofitable and thereby discarded.

4.2.2 Handling inflation

In many real cases, inflation is quite important. It will normally make prices and wages rise over time. Generally, inflation is the average yearly change that should be applied to all regular payments (Bergstrand 2009). But different prices can change in different ways. Some payments can rise faster than general inflation, such as prices for oil products. At the same time some payments may rise more slowly than inflation or actually fall over time. Computer equipment is one example of this. Another example of a commodity that may decrease in price in the near future is natural gas. Inflation affects the investment-analysis in two ways; the cash flow is affected and the WACC must be adjusted for inflation (Bredesen 2005). There are two methods for an analysis with inflation. It can be in nominal or real values. When dealing with growing numbers, one can add the growth to each number (nominal cash flow), or use fixed/real prices. Real prices means the cash flow is expressed in today’s value for the whole projects lifetime. If adding the growth to each number one must also use a nominal WACC (not deduct the growth). On the other hand, if working with a real analysis, inflation must be deducted from the WACC since it is not accounted for in the periodical cash flow. Basically, one just has to be consistent. In reality, nominal and real prices often get mixed up. If the analyst is aware of this, combining the two will lead to identical outcomes. Problems arise when they are unintentionally mixed up. In his book “Accounting for management control”, Bergstrand (2009) recommend a nominal analysis.

4.2.3 Methods of capital budgeting

In this section I will briefly review available methods to evaluate different investment scenarios and decide on a method to use.

Calculating pay-back means one finds out how many years it will take to get the initial investment back. To arrive at this number one simply divides the initial investment with yearly income. Strengths of this method are the ease of calculation and understanding. According to Bergstrand (2009) the two main weaknesses are: 1. Time preference is disregarded and 2. Payments occurring after the pay-back period are completely disregarded. This method is excellent for very simple calculations or initial calculations before more complex methods are being used. Another method in this group is called “the accounting rate of return”, but it also leads to huge simplifications and it is inferior to the pay-back method.

Another group is the discounting methods. Net present value (NPV) eliminates the weaknesses of the pay-back method by including time preference. Calculation of NPV is done by the following formula (Bredesen 2005):

$$-CF_0+\sum_{t=1}^{n}\frac{CF_t}{(1+i)^t}$$

According to the formula, NPV equals the sum of discounted cash flows minus the investment cost. The cash flow is discounted by using a company’s WACC. If NPV is positive the capital invested in the project gives a higher return than the cost of the capital, or put in another way, invested capital gives a higher return than what we would have gotten elsewhere. The working procedure for calculating NPV is (adapted from Bergstrand 2009, p.248):

1. Find the initial investment and the yearly cash consequences over time
2. Estimate the project lifetime and calculate if applicable, the salvage value at the end of the projects lifetime.
3. Subtract taxes from yearly payments.
4. Calculate WACC
5. Calculate NPV

NPV has the advantage of including all future payments. Time preference is also included and the value of future payments is expressed in one clear number. One of the main weaknesses is that we have to specify time preference as a rate of interest, this rate will in many cases decide the outcome of the calculation. It is also difficult to rank projects since the method only separates between positive and negative meaning that all positive projects should be undertaken and negative projects should not. A useful property of this method is that because it includes time preference, it can be used to only compare costs which can be helpful for scenarios where the income side is uncertain or not relevant. By only considering costs there will obviously not be any positive projects.

Another version of the NPV method is calculating annuities. The method is seldom used in real life and does not give much new information compared to the NPV method (Bredesen 2005). When calculating NPV the method can (in some cases) be difficult to understand since the full value of a project is calculated in one number. If we wish to compare yearly payments, this can be done by using annuities. Net annuity can be found by deducting the annuity of outflows from the annuity of inflows. The method has the same advantages and disadvantages as the NPV method. Comparison of investments is also one of the greatest difficulties with this method since the theory says all projects with a positive NPV should be undertaken.

The third group of basic methods includes the internal rate of return (IRR). Bredesen (2005) defines the IRR as the interest rate which gives NPV=0. This means the investment has to be the same as the yearly cash flows discounted with the internal rate of return. The most obvious strength with this method is that there is no need to calculate a WACC. Weaknesses include difficulties with calculating and especially fully understanding the method. Comparison of projects can be difficult. This has to do with economic assumptions of company management not being dealt with in an acceptable way using the IRR analysis. So while this method is widely used in companies everywhere, most researchers in corporate investment tend to prefer the NPV analysis over the IRR analysis.

Real options analysis (ROA) focuses on the value of flexibility. “A real option is the right, but not the obligation, to take an action at a predetermined cost called the exercise price, for a predetermined period of time” (Copeland and Antikarov 2003, p. 5). In their book “Real Options: A practioner’s guide” Copeland and Antikarov criticize the NPV method for not considering options and flexibility. ROA capture the value of managerial flexibility by being able to adapt decisions in response to sudden market developments. This gives the managers the right to defer, expand, contract or abandon the project as more information becomes available. Bendall (2010) describes real options as NPV including flexibility. Thus, value of project with flexibility= value of project without flexibility + value of flexibility. It means the ROA is not a replacement for discounted cash flow analysis, but it extends NPV by being able to incorporate and value a firm's ability to adapt to changing information (Bendall 2010). Thus, real options are most useful when NPV is close to zero since this is where changing circumstances really can alter the results. According to Bendall (2010) the strongest factor limiting wide application of ROA in practice is the wide variety of methodologies that has been proposed under ROA. This causes concern that if a wrong method is applied, one risks making the wrong investment decision. The method draws both on finance, operations and research management techniques and in most cases the appropriate methodology will depend on the data available and the situation at hand.

4.2.4 Choice of capital budgeting method

In the quantitative analysis I will compare costs and not include income since I do not expect choice of alternative to affect income in the long run. As mentioned earlier, there may be some positive effects related to choice of alternative, if not in direct income effects, perhaps in reputation. Short term income effects for an individual company can also be relevant. I will not try to quantify these in order to simplify and keep the thesis manageable. Not including the income side will exclude some of the methods, the pay back method is one of them. But calculating pay-back is to simplify things too much and it does not include time preference, which is important when having a vessel lifetime-perspective. Still, calculating pay-back for a scrubber or LNG investment can be interesting, but it does not give the full picture. Annuities will be ruled out since I want to look at total costs. Another method I will rule out is the internal rate of return due to difficulties in comparing projects and results communicated by the method.

A discounting method must be used in this analysis since time preference is of huge importance. The method that becomes most relevant is NPV. By using this method in comparing lifetime costs of different alternatives it is possible to interpret the results. Of course, NPV has its weaknesses (such as defining time preference in one number over a long period of time), but I think it is the best fit in this situation. Since Utkilen tend to operate their vessels throughout their commercial lifetime the NPV analysis over the vessels' remaining lifetime seems to be appropriate. Another method that could be relevant is ROA. Since the value of flexibility is important in decisions like this, it could perhaps be applied to the situation. Still, based on the data material available the NPV method stands out as the most relevant method for the analysis.

4.3 First-mover advantages and disadvantages

Companies often strive to be the first to offer new products or services, that is, to be a first-mover. If this new service or product satisfies unmet customer demand, the first-mover can capture significant revenues and profits. Such positive effects signal to competitors there is money to be made by imitating the first-mover, but despite imitation, first-movers can have the ability to reap substantial benefits. They can also face a number of disadvantages, so being a first-mover does not by itself guarantee success. According to Hill and Jones (2004) there are several main sources of first-mover advantages. First and foremost, the first-mover may be able to ramp up sales volume ahead of rivals. Second, the first-mover company may be able to create switching costs for its customers. This is something that makes it difficult/costly to go back or buy the service from someone else. Third, accumulation of valuable knowledge is an effect from being first. This can lead to reduced costs and better services. Balanced against the advantages are three disadvantages (Hill and Jones 2004). The first-mover must bear significant pioneering costs that later entrants do not, such as testing of technology and educating customers. Later entrants may be able to free-ride on the first-mover's investment in pioneering the market and learn from the first-mover's mistakes. Second, the company that first offers a unique service can risk building the wrong resources and capabilities. This means one is running a risk of falling into the chasm that separates the early market from the mass market. Finally, the first-mover runs the risk of investing in inferior or obsolete technology. This happens when technology is developing rapidly. By basing the product/service on an early version, a company may invest in something that rapidly becomes less competitive compared to other versions.

Three factors determine for how long the company will be able to exploit the first-mover advantage:

- Complementary assets are the assets required to exploit the new product/service and gain a competitive advantage. Examples of this are marketing and know-how.
- Height of barriers to imitation. These are factors that prevent rivals from imitating the company's distinctive competencies.
- Capable competitors, means companies that can quickly imitate the first-mover.

Being a first-mover can thus result in significant lasting advantages, temporary advantages or in worst case huge disadvantages, depending on the factors mentioned above.

4.4 The four shipping markets

A theoretical framework that will be applied to describe "Alternative 4: Give up ECA trade" is the four shipping markets model:

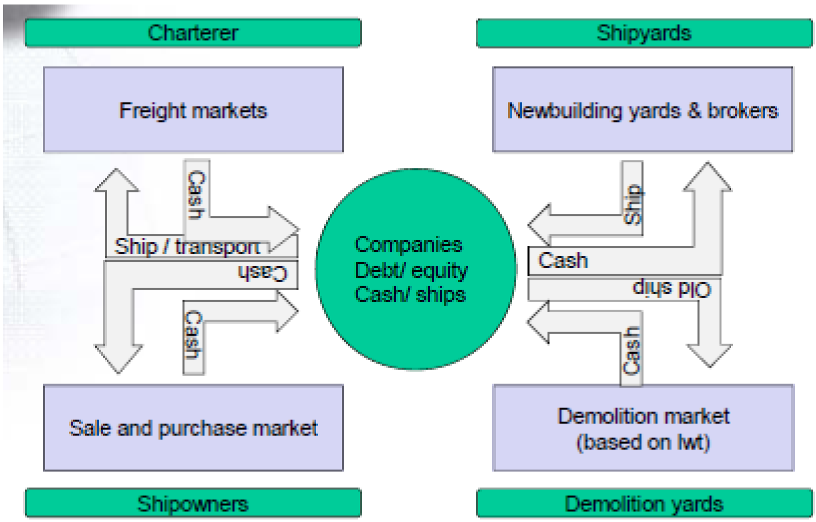

Figure 15: The four shipping markets. Source: Stopford 2009.

Shipowners trade in all these four markets that are linked by cash flow (Stopford 2009). The markets trade different commodities:

The freight market trades in sea transport. It is made up of shipowners, charterers, and brokers who work together to make up contractual agreements. The types of contractual agreements they negotiate are the voyage charter (VC), the contract of affreightment (COA), the time charter (TC) and the bare boat charter. Owners operating in the voyage market contract to carry cargo based on an agreed price per mt while those in the charter market operate based on ships being hired out with a corresponding daily hire. The freight derivatives market is also important because it allows shipowners and charters to hedge their freight risk.

The sale and purchase market trades with second-hand ships. The buyers and sellers in this market are shipowners. Ship prices are very volatile, this makes the market an important source of (potential) revenue for shipowners. The cash flow of the industry is not affected by these transactions since money is changing hands from one shipowner to another without income from an outside source. As this market does not alter the transport capacity supplied, it is called an auxiliary market. By opening up for sale of existing vessels for further trade, this market helps to reduce some of the risk associated with lock in for an investor (Strandenes 2002). Second-hand value of the ships depends on several factors. According to Stopford (2009) these are freight rates, age, inflation, and expectations. For some vessel types the second-hand market can be difficult. The market can be illiquid or even non-existent for specialized vessels. An opportunity to let a vessel into a time charter market will be limited by the fact that the vessel is best suited to operate in a few trades only. Similarly, a sales price may not fully reflect the cost of specialized equipment onboard (Strandenes 2002).

The demolition market trades in ships for scrapping and the prices are quoted in light weight tons[11] (lwt). This market is made up of speculators acting as intermediaries between shipowners and demolition merchants. Prices are determined through negotiations based on the availability of ships for scrapping and the demand for scrap metal. Ship prices are very volatile when it comes to scrapping and prices also vary based on the ship's suitability for scrapping. This market does also adjust supply of transport capacity by removing parts of the old fleet.

The newbuilding market trades with new ships and is made up of shipowners and ship yards. The building of ships goes through an extensive process dealing with contract negotiations in areas such as specifications, delivery date, stage payments, and finance. Price and value of ships can change drastically in short periods of time similar to that of the second-hand market. This market adjusts the supply of transportation capacity and hence the rates in the market. When market conditions are good owners order (a lot of) new ships, this can lead to overcapacity and is basically a recipe of how to kill a market.

When assessing the economic life of a vessel the linkage between the markets plays a key role. In high markets the existence of limited shipbuilding capacity can induce owners to postpone the demolition of old vessels, similarly a good freight market with high demand can also induce owners to keep old vessels for continued trading. Assessing both the chance of technological obsoleteness and political decisions that will affect ship values is another aspect of great importance when assessing the economic life of a vessel (Strandenes 2002). If considering giving up ECA trade all of the above markets are relevant, except for the newbuilding market. This means the shipowner's alternatives for using a vessel for further

[11] Lwt is the weight of a ship's hull, equipment and machinery; the basis on which ships usually is sold for scrap.

trading are to let the vessel on a time charter, operate in another area, sell it on the second-hand market or scrap it.

4.4.1 Opportunity cost

Opportunity cost is considered to be a central concept in decision making. It is crucial that the benefit obtained from the chosen course of action outweighs the opportunity cost, but there is much controversy surrounding this important concept (see discussion between McRae 1970, Burch & Henry 1974, McRae 1974). In the jungle of definitions, one definition I think reflects the type of decisions shipowners must make is: “Opportunity cost is the potential benefit that is given up when one alternative is selected over another.” (Garrison, Noreen and Seal, 2003, p. 39).

5 METHODS

The term “methods” is used as a systematic procedure to reach a goal. Choice of methods says something about how one is going to arrive at a result and how to ensure that the result is trustworthy (Grønmo 2004). Knowledge and use of methods is not a goal in itself, but it is important in order to make an informed choice about the research that is being undertaken.

5.1 The research process

The research process can be described as an ongoing process since one does not complete each part in a stepwise manner, but go back and forth to improve each part until satisfied, or as long as time permits. Important parts included in the research process are formulation and clarification of research topic, critical literature review, understanding research philosophy and approach, formulate the research design, negotiate access and ethical issues, collect data and analyze data. While all of these are important, the part where one formulates and clarifies the research topic is perhaps the most difficult one. Besides from deciding on the research topic that forms the foundation for this thesis, collecting data has been my greatest challenge. Even with good contacts and backup from professionals in DNV it is not easy to get hold of the exact data one is looking for. Because of that, several adaptations have been made throughout the writing process, meaning the research has been subject to some revision.

5.2 Research approach and design

When choosing research approach there is two main approaches: The deductive approach (general to specific) and the inductive approach (specific to general). Both of these can be used in combination, in fact it is often advantageous to combine them. My research is of a more deductive type since the form is more structured and the information moves from general to specific as theory is used to gain an understanding of the situation. When looking at the purpose of this research I would call it both descriptive and explanatory. Descriptive since I need to examine the different alternative ways shipping companies can adapt to the new regulations. It is crucial to have a good understanding of this before moving on to the analysis. The descriptive part is then a forerunner to more explanatory research since the goal is to examine how these alternatives can fit to different vessel characteristics – if there is some sort of relationship between them. While there has been quite some research on this topic, it is still associated with much uncertainty and limited practical application, and the assumptions used when assessing the problem will be decisive for the outcome.

This thesis is an empirical one, meaning it is based on information about actual conditions in society (Grønmo 2004). The research is to a large extent based on a qualitative approach, but a substantial amount of quantitative data has also been collected and analyzed. A reason for this is the nature of the topic and RQ. By combining the two approaches, one is able to use both of their advantages which make the thesis more complete. Sometimes it is just not enough to express real world conditions in words. Numbers are more specific and can give good examples of actual conditions, but numbers seen in isolation can also give a very narrow image of the situation at hand and a combination is sometimes the best strategy. Some researchers warn students about collecting both qualitative and quantitative data in too large amounts since the workload can become beyond the scope of a master thesis. I have tried to keep this in mind and to keep the amount of information and data manageable.

5.3 Research strategy and data collection

Several research strategies have been used in order to collect the relevant information and data. The distinction between information and data is that data can be defined as information that has been processed (Grønmo 2004). In many ways, this is what I have done when collecting information. Information has been collected and processed in order to make it ready for use in the analysis. Two of the research strategies used in this thesis is a literature review and a case study. Secondary data can be defined as "data used for a research project that were originally collected for another purpose" (Saunders et al. 2009 p 600). The literature review covers a lot of secondary data from textbooks, articles and web pages (see chapter 9: References). By searching in several of the databases available from the NHH library, I have been able to find a great deal of relevant material. Another important source in the literature search has been DNV. Since they have had some degree of influence on the topic chosen, they have also been able to help out with relevant research reports and other secondary data. Primary data can be defined as "data collected specifically for the research project being undertaken" (Saunders et al. 2009 p 598). I have used the shipping company Utkilen AS as a case study. From this case I have collected some primary data to be used in the analysis. A case study is a strategy of doing research which involves an empirical investigation of a particular contemporary phenomenon within its real life context, using multiple sources of evidence (Saunders et al. 2009). In my case I have used semi- and unstructured interviews in person, and via e-mail to collect primary data. Collection of secondary data from Utkilen's voyage-records has also been an important source.

Data has also been collected from a variety of companies. E-mail correspondence has been the main method used to collect this from individuals within DNV, Utkilen, Bergen Bunkers, LNG Europe, Nordic LNG, Gasnor and Wärtsilä. Since I am writing for DNV the challenge of gaining access to data has been somewhat mitigated. This is also true in the case of Utkilen. By having some contacts, collection of data has become easier in a number of companies, on the other hand, lack of contacts has led to no or very limited access in other companies. One particular data difficulty has been gathering LNG prices. Since suppliers are few they do not want to make the prices public. This is probably also based on the fact that price is negotiated individually with each buyer based on quantity and place of delivery. Both qualitative and quantitative data collected in this paper is mainly presented in chapter 3 and 7.

Throughout the work with my research I have tried to uphold good research ethics by being aware of choices regarding my interaction with respondents and presentation of the data. Transparency is a key word here, which means it should be easy to see what I have done and why I did it.

5.4 Credibility of findings

"Scientific methodology needs to be seen for what it truly is, a way of preventing me from deceiving myself in regard to my creatively formed subjective hunches which have developed out of the relationship between me and my material" (Rogers 1961 cited by Saunders et al. 2009 p. 156).

Reducing the possibility of getting the answer wrong means attention has to be paid towards two important elements: Reliability and validity.

"Reliability refers to the extent to which your data collection techniques or analysis procedures will yield consistent findings" (Saunders 2009 p. 156). The question one has to ask is: Will similar, independent studies come to the same conclusions? Threats to reliability include subject or participant error/bias and observer error/bias. "Validity is concerned with whether the findings are really about what they appear to be about" (Saunders 2009 p. 157). Is the data relevant to the research question? Threats to validity include history, testing, instrumentation, mortality and maturation. For validity to be high the results must match the

RQ. Validity can in fact be low even though reliability is high. This means reliability is a necessity, but not a guarantee for validity. Another aspect that is important to review in most studies is external validity or generalisability, meaning whether or not the findings will be applicable in other settings.

Like all studies, also this one has weaknesses. When it comes to reliability, the data (and data quality) available will depend much on accessible contacts since the scope of the thesis is so large and much if the data needed is quite special. There is a risk that important sources of information, such as individuals with much knowledge on the topic are left out. Furthermore, it is important for the researcher to be aware of observer bias. When writing for a company, the researcher will indirectly be affected by the company's point of view on certain aspects. For example, it is of my impression that DNV has a positive view towards LNG as an answer to the ECA regulations. While LNG may be the answer in some cases it is important for me as a researcher not to be biased by this view and automatically favor the LNG alternative.

Regarding validity "history" will probably lead to more and better information the closer one gets to 2015 and introduction of the emission regulations. More and more reports appear as we get closer to 2015. From the reference chapter in this thesis we can see that most reports are from 2010 or 2011. "Maturation" can also lead to changes in opinions and a development that could have led to other results. As for external validity I think the qualitative part of the thesis is more generalisable since this is something many shipowners can gain important knowledge from. The quantitative part is not generalisable since I use a specific case, and all cases will be different. Still, it can confirm some of the expectations many actors in the industry already have towards choice of ECA solution. Fuel price input and assumptions around its development is one of the most important factors in the analysis. This input is subject to criticism as various experts and reports may have different views on what is considered appropriate input. From the work with this thesis, I have reviewed several reports and calculations where fuel price input range from (in my opinion) very unrealistic to quite reasonable. A way to avoid some of this criticism is to use a scenario approach in order to cover several possibilities. This can also make an alternative more robust if we find similar results for different scenarios. Just as fuel price input, other input variables in the analysis can also be subject to criticism as changes in them can have a big impact on the results (for example choice of WACC).

6 CASE: UTKILEN AS

6.1 The chemical tanker segment

Liquid chemicals have been transported in bulk across the seas since about 1950 (Kendall and Buckley 2001). Typical characteristics for chemical tankers are carrying capacity, number of tanks and tank coating. Basically, this is a very sophisticated tanker, designed with specific operating conditions in mind. A typical chemical tanker can for example have 18 tanks with a complex cargo system that allows it to load/discharge different cargoes from each tank. Some typical cargoes are naphtha, alcohols, caustic soda and styrene. Since each cargo has different chemical properties the loading of chemicals can become a complex task, requiring comprehensive knowledge about the ship's and cargo's properties. In addition to this the segment is highly regulated. Different cargoes have different SG and can also react with other substances. Some cargoes requires heating, continuous circulation or other kinds of special treatment. Cargoes are also easily contaminated if not handled properly. This puts the chemical tanker business into the high-end part of the wet-bulk trade.

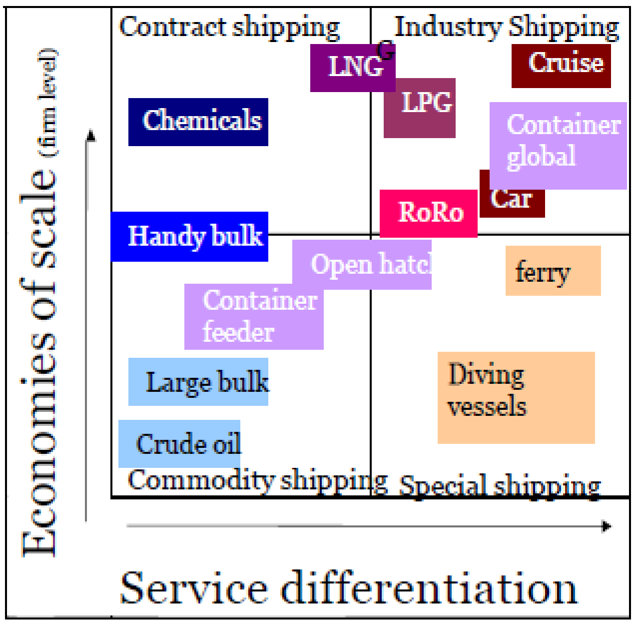

Figure 16: Shipping segments as strategic types.
Source: Wijnolst and Wergeland 2009.

The framework in figure 16 is used as a tool to analyze the shipping industry. It is closely related to Michael Porter's three generic strategies (cost leadership, differentiation strategy and focus strategy) and has been developed by McKinsey & Co. and The Centre for International Economics and Shipping at the Norwegian School of Economics and Business

Administration. The basic idea is that there are two main sources for creating competitive advantage in shipping. These are economies of scale at firm level and service differentiation. With economies of scale it is not so much focus on the cost side, but more on the income side. This means a large organization and several ships will make it is easier to secure good contracts, since the customer then will be offered more flexibility. Economies of scale in this respect then, means a big and professional organization. With service differentiation it is meant how customer-tailored the company's services are. By applying these two dimensions one gets four generic types of shipping.

Commodity shipping is a type where there are neither economies of scale, nor service differentiation. This is the closest we will come to perfect competition since there is nothing separating the companies in this segment. When differentiation is high and economies of scale are low, we are in the specialty shipping box. This is a form that can create monopolies since there are few direct competitors. Contract shipping is a type where the service/differentiation is homogenous, but economies of scale are effectively utilized. To operate in this segment, size matters to secure the right contracts (just look at the world's largest chemical tanker companies: Odfjell and Stolt Nielsen.). Companies that specialize in COAs sometimes describe their business as industrial shipping. This is because their goal is to provide a service in the long run. In this type of shipping the company must tailor its services for the customer while at the same time utilizing economies of scale. Industrial shipping can be characterized by very specialized services that in turn mean a difficult second-hand market. Many companies operating in the contract shipping box may view their type of shipping as industrial shipping since they feel they differentiate their services. The truth may be that they operate between the boxes in figure 16.

From figure 16 we can draw some implications regarding the chemical tanker segment (Wijnolst and Wergeland 2009):

- It is a concentrated industry
- There is a positive scale effect of fleet size
- Fairly homogeneous services
- Close customer relations

6.2 Utkilen AS

"Utkilen shall be a leading, preferred and reliable transporter of bulk liquids". (Utkilen 2011)

Utkilen AS is a fully integrated shipping company with headquarter located in Bergen. It has in-house functions for chartering, crewing, ship management and operations. Anders Utkilens Rederi AS was established as a stockholding company In 1967, but the history of the Utkilen-family and shipping dates more than 100 years back, to when Annanias Utkilen bought his first ship, "Prøven" in 1889 (Bakka 2006). In 2007 the company changed name to Utkilen. Since the stockholding company was established, Utkilen has grown into one of the leading chemical tanker companies operating in Northern Europe. It is family owned, with owners that have a long-term perspective. This is reflected in their contract coverage that is about 60% (Utkilen 2011) and good relations with charterers such as Omya. Since Utkilen is of strategic importance to Omya they are already co-owners of some Utkilen vessels (Bakka 2006). About 370 sailors work onboard the vessels and around 50 employees work on-shore. The fleet totals 20 ships and two newbuildings scheduled for delivery this year (Utkilen 2011). In terms of vessel size, the fleet ranges from about 3000 dead weight tons (dwt) up to about 20 000 dwt. The company transport chemicals and other bulk liquid cargoes. Transportation of "calcium carbonate slurry" from Elnesvågen (located between Molde and Kristiansund, Norway), to the Continent and Baltic is part of Utkilen's core business. Cargoes such as sulphuric acid and methanol are then brought back to the Continent from the Baltic.

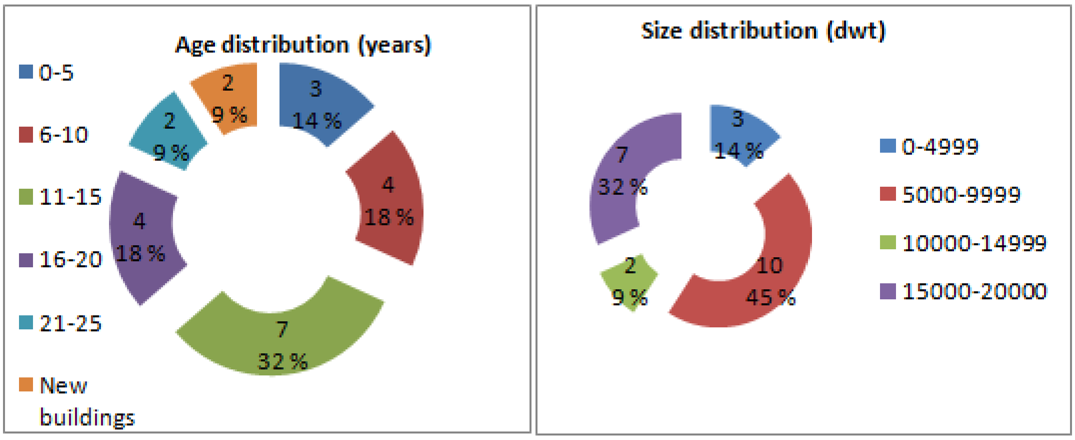

Figure 17 and 18: Age and size distribution of the Utkilen fleet: 20 vessels and 2 newbuildings being delivered in 2011. Source: Utkilen 2011.

Most voyages performed by Utkilen vessels are inside of the ECA zones. Consequently, the company will be hit hard by the new emission regulations and how they choose to comply will have a great impact on their costs and thereby profitability.

Out of Utkilen's fleet I have picked three vessels with differing remaining lifetime. They all spend most of their time operating inside of the North European ECAs. The vessels are:

- Straum, built in 2010
- Xanthia, built in 2003
- Solstraum, built in 1990

By analyzing vessels with differing remaining lifetime, the analysis will give good indications on how to respond to the upcoming regulations for existing chemical tankers operating in this region. Both a quantitative and a qualitative approach will be taken in order to get a clearer picture of how these vessels can adapt to the demands conveyed by the ECAs.

7 ANALYSIS AND DISCUSSION

The basis for the analysis and discussion includes information obtained from the literature review, unstructured interviews and correspondence with experts from several companies. This data will be combined with relevant theory that has been presented in chapter 4, and together it will be applied to the specific case of Utkilen.

This chapter is divided into four main sections. Section 7.1 is a quantitative part where three of Utkilen's vessels have been analyzed in terms of costs. Possible first-mover advantages are explored in section 7.2. In section 7.3 a more general discussion of the MGO, Scrubber and LNG alternatives will be presented. Here we look at the qualitative reasoning behind which alternative to choose. Finally, Section 7.4 will cover alternative four, which means giving up trade in the ECAs. The four shipping markets-model is used in order to cover this last alternative.

7.1 Utkilen and their chemical tankers from a cost perspective

7.1.1 General Assumptions

Time of investment and retrofit-capacity

By delaying the adaptation as long as possible (late 2014/beginning of 2015) the shipowners will save money by continuing running their vessels as today. This means for 2011, 2012, 2013 and 2014 the costs will be identical for all alternatives. If everyone does this it can lead to capacity problems when all ships need to adapt at the same time. In the analysis I will not take this potential problem into account.

Engine load

As the situation is today, vessels operate with different engine load depending on several factors such as weather conditions and time to next voyage (laydays/cancelling). In order to simplify it is possible to set engine load to 100%, but that will overestimate costs severely since the relationship between engine load and fuel consumption is non-linear, meaning higher engine load consumes much more fuel. This would also favor the LNG alternative since increasing LNG consumption leads to increased savings compared to IFO or MGO. As I have access to historical fuel data for the vessels I will use this and convert it into

MGO/Scrubber/LNG consumption. This can be done by multiplying with the MJ/kg factor described in section 3.1. Engine load is therefore disregarded when calculating fuel costs.

Regarding maintenance costs these will be calculated by using a $/kWh factor. Because of this it is necessary to include an engine load figure when determining kWh per vessel. This figure has been set to 75% for all vessels in order not to overestimate maintenance costs. More about maintenance costs follows in section 7.1.2.

Currency

The following exchange rates have been used for all calculations and the model is not adjusted for potential currency movements: 1 EUR = 1,4 USD = 7,8 NOK. 1 USD = 5,6 NOK. These are average exchange rates from March 2011.

Lifetime

While vessels are fully capable of operating up to 30 years, restrictions from charterers does not allow for this. In Utkilen's case I will assume a lifetime of 25 years, but in the case of Solstraum I will also look at a theoretical lifetime of 30 years since the choice of alternative in that case would be of some interest. A number of charterers allow for more than 25 years and a few for less, but the simple fact is that old vessels will be less flexible since they are not eligible for use to many charterers. Costs will be calculated annually for each year of the vessels lifetime and discounted to the NPV in NOK.

WACC

A high discount rate will reduce costs, low will increase costs. This seems strange at first display, but it is important to remember the same goes for income. In this analysis a nominal discount rate of 7 % is being used as basis to reflect the company's WACC. It has been tested increasing and reducing this WACC in the model and although it can have a significant impact on the numbers, only a high rate will have any impact on the final results seen over the vessels' lifetime. A question that is relevant for the analysis however, is when one alternative becomes more economical than another. By using different discount rates we will change this. Therefore the analysis will also examine how changing the WACC can affect the results.

7.1.2 Annual cash flow

All of the expenditures that have been included in the cash flow of the NPV analysis are described below. Detailed Excel sheets of the model used can be found in the appendices.

Capital expenditures (CapEx)

For a permanent change to MGO an additional investment of 400 000 NOK has been assumed in all cases. IMO's average estimation has been reduced (estimate: 100 000 €) in order to avoid over-assessing the costs. This is also based on input from superintendents for the vessels analyzed. A SWS investment cost from the SKEMA (2010) report has been used (168 €/kW). Regarding the LNG investment it is difficult being accurate with these figures as there is little experience yet of marine turnkey projects. For dual fuel engines, Wärtsilä is a company that can take on such a project and one general estimate received from them is 800-900 €/kW (Haggblom 2011). 900 €/kW is thus assumed for Straum and Xanthia. This is a number given without any guarantees as there are a lot of unknown factors in a project like this and foreseeing it all is difficult without some preliminary engineering. LNG investment cost for MT Solstraum (even though a retrofit to LNG is unrealistic due to the vessel's age) has been determined by combining costs for tank[12] and engine[13], since a cost per installed kW could result in a too low figure. Utkilen is a member of the Norwegian NOx fund and subsidies from the fund have therefore been included where applicable. It can be argued these subsidies should have been larger if retrofitting into LNG and thus calling more Norwegian ports for taking fuel. This has not been included in the quantitative analysis since such a figure is uncertain at best.

Voyage expenditures (VoyEx)

These expenditures include fuel costs that are being adjusted annually depending on the relevant scenario. Fuel expenditures are by far the largest costs in these calculations. Hence, the quantitative analysis in this chapter will mainly focus on fuel inputs.

[12] 2*250 m^3 tank and piping= 28 million NOK. Source: DNV (2011b) .

[13] Based on two planned chemical tankers (6300 kW installed) with an estimated price of 35 million NOK each. Source: DNV (2011b).

Emission tax expenditures (TaxEx)

Is made up of historical taxable NOx emissions from a one year period; 4 NOK/kg until the beginning of 2018 and 16,14 NOK/kg from 2018. This means we assume ESA approves a continuance of the NOx fund. An annual growth of 3,5% has been added to the numbers in order to reflect the increased focus on environmental concerns related to shipping in the time to come. Since Utkilen does not call many Norwegian ports in the same voyage they are less exposed to the NOx tax and these expenditures have a very small impact on the analysis.

Maintenance expenditures (OpEx)

Finding maintenance expenditures for the various alternatives has proven to be a difficult task since most shipping companies does not have accessible cost data on such a detailed level. Still, both the literature on the subject and experts suppose there are differences between the alternatives. Because of that I think it is important to illustrate this dissimilarity in the analysis and one way to do that is by using a $/kWh factor. IFO maintenance cost from DNV report no. 2009-2027[14] has been used in this study, and for IFO 0,018 $/kWh has been assumed. It is expected that MGO leads to a longer interval time between overhauls, and to a longer lifetime of components that will lead to reduced maintenance costs (DNV 2009). Based on conversations with superintendents in Utkilen a cost reduction of 30-40 % may be possible. Consequently, MGO maintenance expenditures have been set to 0,012 $/kWh in the analysis. Scrubber maintenance costs are 0,019 $/kWh[15]. Maintenance costs for dual fuel LNG engines have been set to 0,018 $/kWh since operating with double systems may neutralize savings from LNG propulsion.

In the model it has been tested setting maintenance expenditures for all alternatives equal. This does not have a noteworthy impact on the results. Thus, maintenance costs will not be addressed further in the scenarios.

[14] This report focused on the Nordic short sea shipping segment and considered several sets of shipowners' criteria for investing in LNG fuelled vessels in this market. The financial aspects of environmental friendly LNG propulsion compared to traditional fuel oils were the main focus of the study.

[15] SKEMA (2010) assumes 0,8 €/MWh in maintenance costs for SWS. This has been converted to approximately 0,001 $/kWh giving a total scrubber maintenance cost of 0,018 + 0,001=0,019 $/kWh.

7.1.3 Ranking of the variables in the model

Because the quantitative analysis relies tremendously on the assumptions taken, a scenario approach is a useful way of analyzing the situation. When making an investment analysis over such a long period one needs to focus on the major costs that have the most impact on the results. Section 7.1.1-2 discussed how it has been tested changing these variables in the model. The below tornado chart has been created in Excel and is meant to give the reader an indication on how these variables can affect the model.

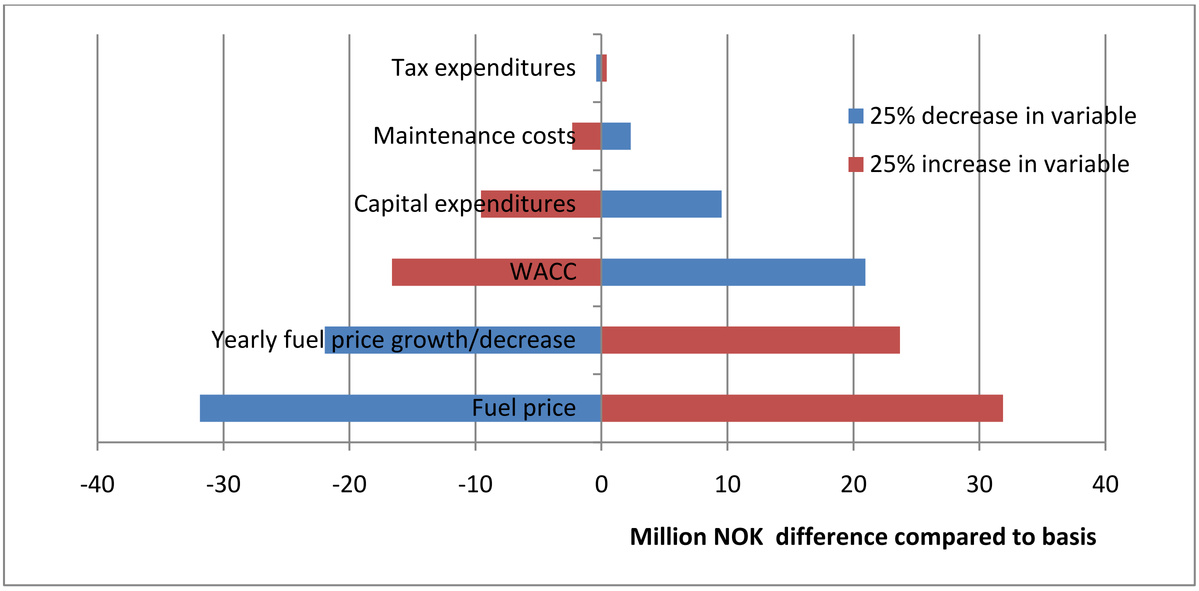

Figure 19: Tornado chart based on scenario 1 input for the vessel Xanthia. Basis is the cost difference between LNG and MGO (LNG-MGO).

Input data in this chart is based on the vessel Xanthia and scenario 1 which is presented in the next section. Along the X-axis, 0 corresponds to approximately 85 MNOK in cost difference between LNG and MGO (MGO is 85 MNOK more expensive over Xanthia's remaining lifetime). By increasing for example maintenance costs with 25% in the model, the cost difference is reduced by 3 MNOK. A 25% decrease in the fuel price would reduce the difference with 32 MNOK so that the cost difference between LNG and MGO now is: 85-32=53 MNOK.

It is important to keep in mind that the main purpose with figure 19 only is to give the reader an impression of how the variables can affect the results. It shows how fuel prices are the most important variables, while tax, maintenance and capital expenditures are of less importance in comparison. The chosen WACC is also of some significance as we can see from the figure. This tornado chart is only for one specific vessel in one specific scenario where LNG - MGO has been used as basis. Tornado charts for Straum and Solstraum has also been created under scenario 1, with LNG-MGO as basis. They can be found in the appendices under “Tornado charts”. Straum has the same ranking of the variables as Xanthia. Solstraum over 30 years gives almost the same ranking, but in this case capital expenditures are given the highest significance. This is quite logical since we compare LNG that has high capital costs, with MGO that has very low capital costs, over a very short period of time. As a result, the capital costs are a much larger part of total costs. Solstraum over 25 years gives a totally different ranking of the variables since its remaining lifetime is so short (Solstraum is 25 year old in 2015.) Capital expenditures will have an enormous impact on the basis value, but that should not come as any surprise. Since LNG is out of the question for Solstraum over 25 years the results communicated from its tornado chart with LNG-MGO as basis is not given much weight.

From this short discussion we can conclude that the ranking of the variables as presented in figure 19 is representable for Straum and Xanthia. This contributes to strengthen the impression from section 7.1.1-2 about the variables' ranking. Thus, changes in initial fuel price per mt, annual fuel price growth/decrease and WACC will be the center of attention in the scenarios below.

7.1.4 Scenario 1: Today’s (high) bunker prices

Input to scenario 1

In scenario 1 we use a LNG price based on input from DNV. IFO and MGO prices are based on the Platts data from figure 12, page 32.

Fuel prices March 2011		
LNG - Norway	893	$/mt
IFO 380 low sulphur (ls) - Rotterdam	663	$/mt
MGO - Rotterdam	973	$/mt

Table 2: Fuel price input for scenario 1.

These are the actual prices the market face today and with expectations of even higher oil prices they are considered relevant for the analysis. Norway and Rotterdam prices have been selected since they are both applicable inside of the ECAs and these are the locations a company like Utkilen could use for taking LNG/IFO/MGO. Regarding annual changes in expenditures, table 3 gives a summary of the assumptions in this scenario:

Annual price changes	IFO380ls	MGO	Scrubber	LNG
Capital expenditures (CapEx)	2,5 %	2,5 %	0,0 %	0,0 %
Voyage expenditures (VoyEx)	3,0 %	3,0 %	3,0 %	0,0 %
Emission tax expenditures. (TaxEx)	3,5 %	3,5 %	3,5 %	3,5 %
Operating expenditures (OpEx)	2,5 %	2,5 %	2,5 %	2,5 %

Table 3: Annual price change inputs for scenario 1.

Scrubber and LNG capital costs are assumed not to be affected by inflation due to lower production costs associated with an expanding market. All operating expenditures (maintenance costs) are set to follow an inflation level of 2,5%, while emission tax expenditures are set to 3,5% in order to reflect increased focus on the environment in the future. The most critical variable here is how the fuel prices will change over time. For the period 2011-2016 IMF in their "World Economic Outlook Database" have projected an average global inflation level of 3,16% per year (IMF 2011). In this analysis the number has been reduced to 3% for the sake of simplicity and in order to avoid overstating bunker costs. LNG prices are set to stay at its current level because an expanding market is assumed as more vessels shift over to LNG, and cheaper sources of LNG will become available, for example through large import terminals.

The WACC in scenario 1 is set to 7% in order to reflect the company's cost of capital. This number is based on conversations with players in the industry.

Results from scenario 1

If we now use these inputs in the model and combine them with data about the relevant vessels the model has produced the following results:

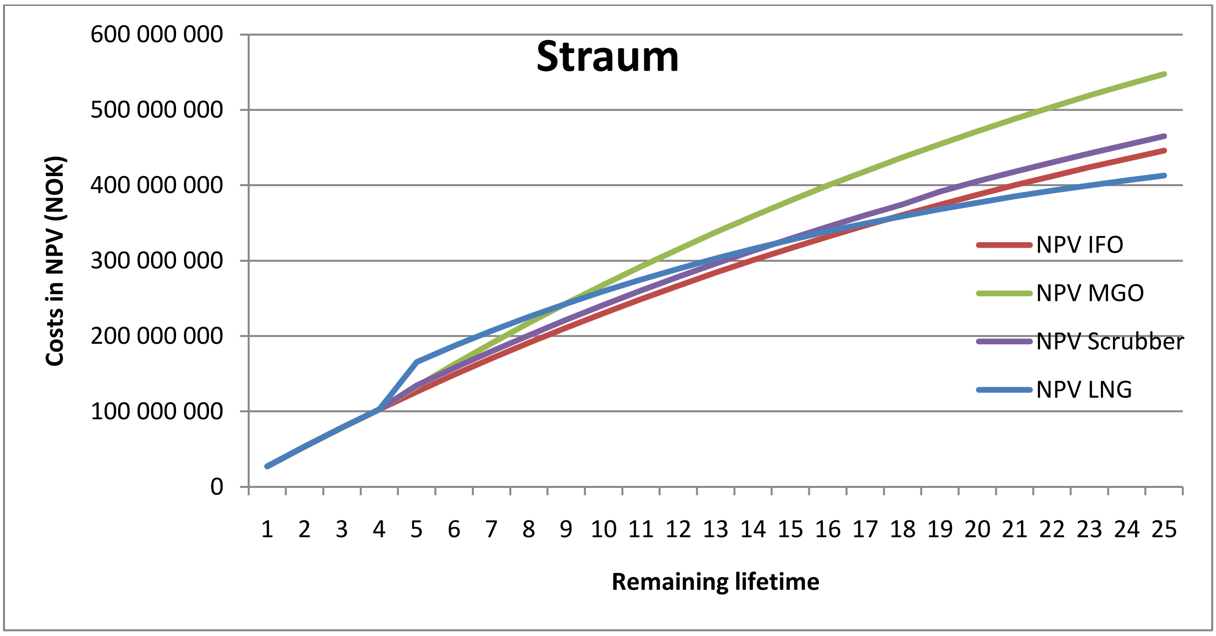

Figure 20: NPV of costs for Straum: Scenario 1.

For the vessel Straum, in its last year of operation, the discounted costs for LNG are well below the scrubbing alternative which is second best and the MGO alternative which gives the highest costs. The red line has been included to illustrate the cost level of today's fuel. Year five in the figure represents 2015 when extra capital costs are required. The small rise in the lines in year five thus represents extra capital costs. Already in year nine the LNG alternative gives lower costs than the MGO alternative and in year 15 LNG is cheaper than the scrubbing alternative. This means the LNG solution requires about ten years of remaining lifetime to overcome the second best alternative in this scenario. If comparing with MGO it takes much less. So seen from a pure cost-point of view, LNG seems to be the best alternative for Straum given the assumptions in this scenario. Compared to today's fuel we can also see how the LNG alternative gives a lower NPV after 25 years. It is 7% lower while scrubber and MGO are 4% and 23% more expensive. An interesting observation regarding the scrubbing alternative is how it only requires one year in order to offer lower costs than the MGO alternative. The results are sensitive to changes in the input variables; a 15% reduction in the IFO 380 ls price or a reduced annual average growth of only 1,5% would make the scrubber and LNG alternative equal. They will also be the same if initial LNG price is increased by 22,6% or annual average growth for LNG is increased to 1,76% instead of 0%. If we use a WACC of 18,2% scrubbing and LNG will come out with equal costs under this scenario.

Figure 21 depicts the situation for Xanthia:

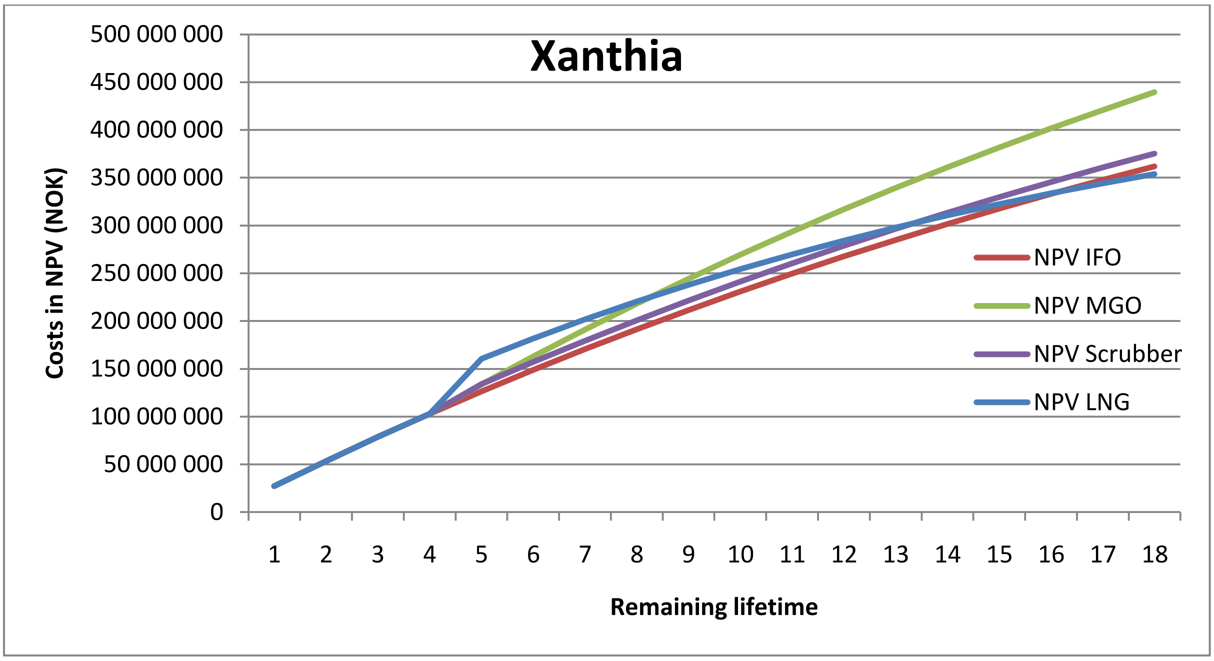

Figure 21: NPV of costs for Xanthia: Scenario 1.

Also here the LNG alternative gives the lowest NPV of costs, but the cost difference between LNG and scrubbing is not as large as it was for Straum. About 22 million NOK separates the two in favour of LNG over Xanthia's remaining lifetime. The results from this figure are not without some ambiguity, even though less costly it is not certain LNG is the right choice for Xanthia. Loss of operational flexibility can in fact favour the scrubbing alternative when the total expenditures for the two are converging. The MGO alternative is also in this scenario very expensive compared to the other solutions. In terms of added costs compared to IFO the LNG alternative is 2% better, scrubber is 2% more expensive and the MGO solution becomes 21% more expensive. For Xanthia, the input variables are even more sensitive than for Straum. A 6,7% reduction in the IFO 380 ls price or annual growth set to 2 % instead of 3% would make the two most cost effective alternatives equivalent. They will also be equal if the initial LNG price is increased with 11,5% or the annual average growth in LNG prices is set to 1,15% instead of 0%. For Xanthia, a WACC of 16,7% would be required for scrubbing and LNG to come out with identical costs.

For our third vessel, Solstraum, the remaining lifetime has been set to both 25 and 30 years to see if that has any impact on choice of most economical alternative.

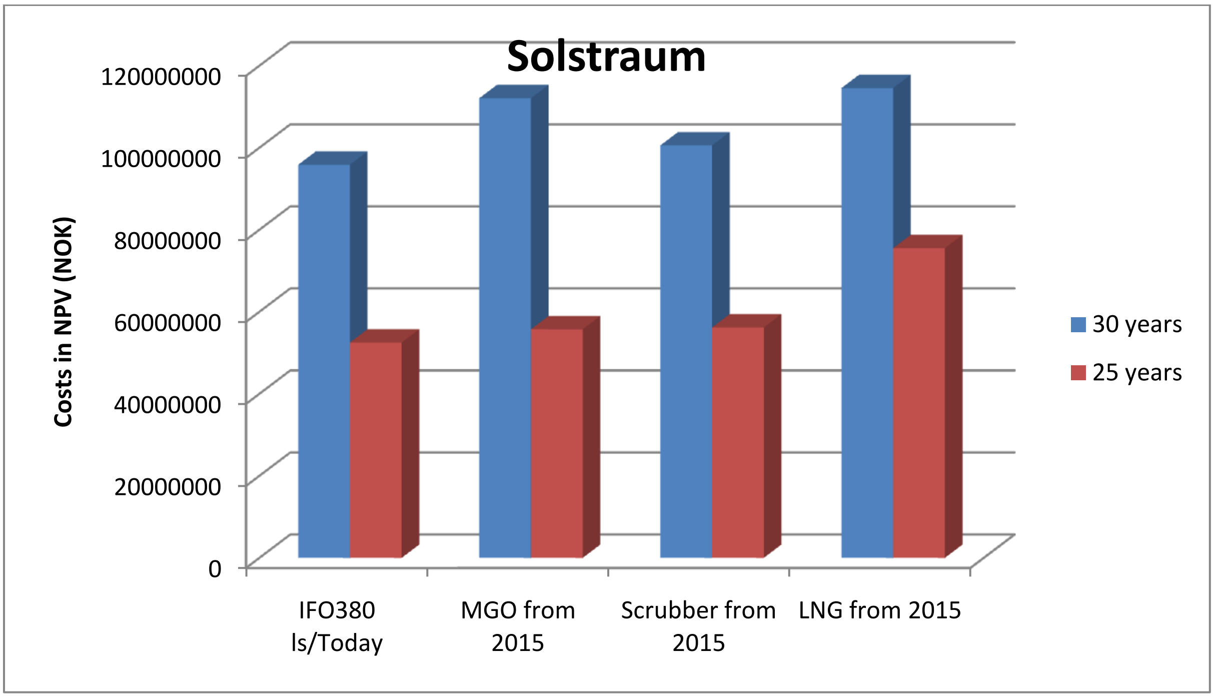

Figure 22: Sum of discounted lifetime costs for Solstraum: Scenario 1.

Solstraum will be 25 years in 2015 and it would be assumed any upgrades for continued sailing in the ECAs this last year to be unnecessary. The numbers confirm this as the MGO alternative gives the lowest NPV of costs, but the scrubbing alternative is in this case practically the same, which again shows how short the repayment period for a scrubber system can be. For a lifetime of 30 years it would then be expected that instalment of a SOx scrubber gives the lowest costs and figure 22 show that is indeed the case. Since the vessel's remaining lifetime is short, changes in initial fuel prices/fuel price growth/WACC does not change the results under this scenario. Scrubbing and MGO are the two most relevant alternatives for this vessel and they are both closely linked to the oil price. A WACC of 88% would be necessary to make MGO equivalent to scrubbing over a 30 year lifetime, meaning the vessel is very insensitive to changes in the variables.

In this first scenario the calculations have shown us how the three vessels analyzed will require different alternatives in order to minimize costs if they are to continue sailing inside of the ECAs.

7.1.5 Scenario 2: Low average bunker prices

Input to scenario 2

Scenario 2 use initial bunker prices lower than today. That is because present bunker prices can be said to be high seen over the last few years (see figure 12, page 32), and when looking as far ahead as 2035 a more representable price estimate should be used. According to the Platts data in figure 12, average monthly IFO 380 ls and MGO prices for the period March 2006 – April 2011 have been 420 and 691 \$/mt. Except for those two prices, everything is identical to scenario 1. The LNG price is still set to 893 \$/mt. Average annual price change is the same (3% for IFO/MGO and 0% for LNG) and the WACC is also here 7%.

Results from scenario 2

By reducing the IFO and MGO price to this level the scrubbing solution is now given an edge over the LNG alternative. Over longer periods of time, LNG is still more economical than MGO for relatively new vessels such as Straum.

In this scenario the model has produced output as below for Straum:

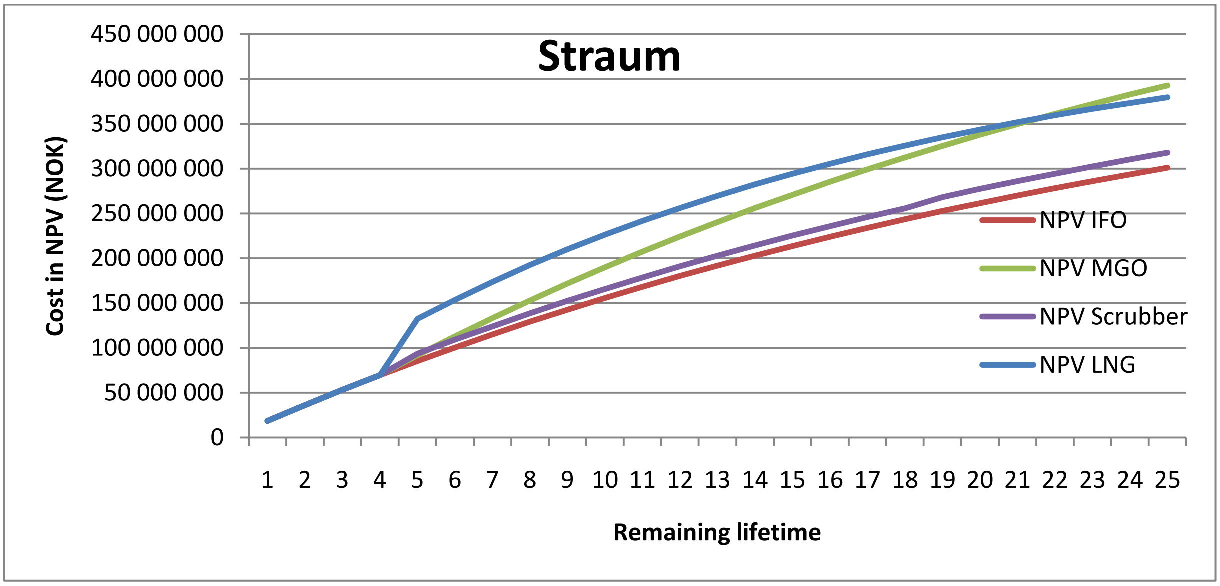

Figure 23: NPV of costs for Straum: Scenario 2.

Compared to the fuel used today all of the alternatives are more expensive for Straum and as figure 23 shows, the scrubbing alternative gives the lowest costs while the MGO alternative gives the highest costs. That MGO gives a higher cost than LNG, even with low MGO prices as input should act as a heads up to shipowners that from a cost perspective, MGO is not a very good choice for relatively new vessels. Changing the WACC in this case does not alter the results. A very high rate will only make the LNG alternative more expensive compared to the other alternatives. If the annual IFO and MGO growth rate is set to 5% instead of 3%, LNG will actually be competitive with scrubbing.

Also for Xanthia, lower initial bunker prices will make scrubbing most economical:

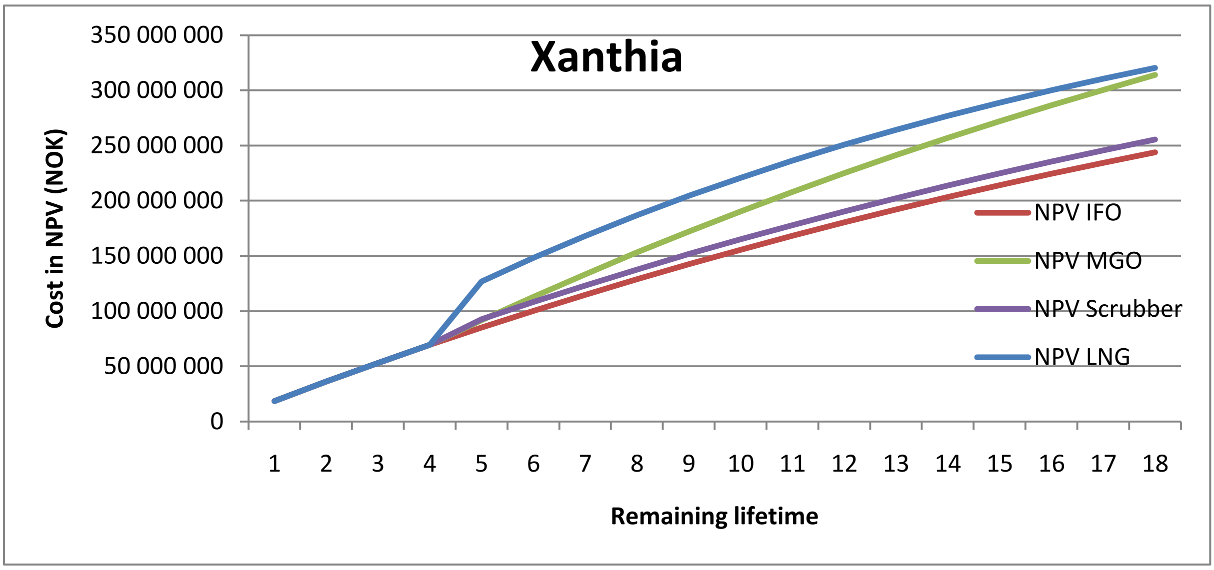

Figure 24: NPV of costs for Xanthia: Scenario 2.

Under this scenario, we can see how MGO actually is cheaper than LNG for Xanthia. So if a shipowner expects a MGO price level equivalent to these average prices while the LNG price stays at its current level, LNG can be ruled out as an option for medium aged vessels such as Xanthia. This observation is further strengthened by the fact that LNG in this scenario is set to 0% annual growth while MGO increases with 3% each year. It is also interesting to see how none of the lines in figure 24 cross. If the WACC is reduced to 4,6% LNG will match MGO on costs, but none of the other alternatives' ranking changes. One way for LNG to match scrubbing would be if the LNG price decreases with 4,5% instead of 0% each year.

Under the current scenario it can be argued that LNG price input is too high compared to IFO and MGO. On the other hand, it has already been argued how the price for natural gas and crude oil possibly will become independent from each other in the near future. And obviously, if prices for the two commodities are closely linked, we already know the results with today's price levels from scenario 1. Therefore, the purpose with scenario 2 is to illustrate the model's results under other MGO/IFO price inputs.

In the case of Solstraum, scenario 2 conveys the same results as scenario 1:

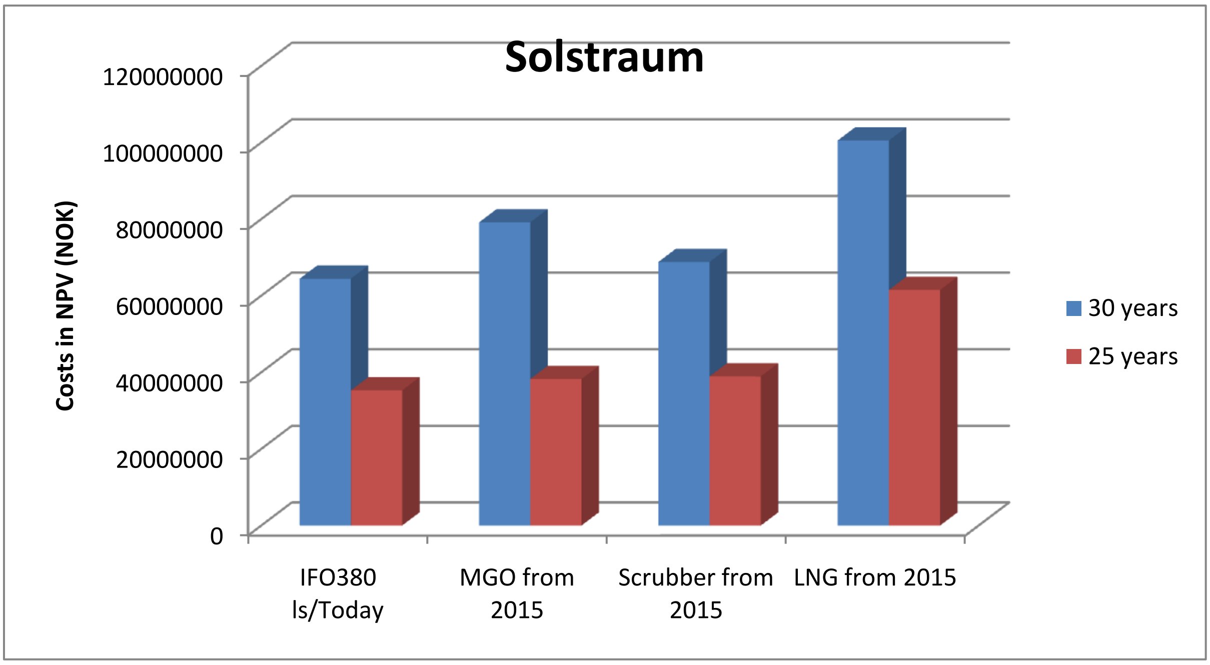

Figure 25: Sum of discounted lifetime costs for Solstraum: Scenario 2.

From figure 25 we see how MGO still is the marginally cheapest option for Solstraum if the vessels economical lifetime is set to 25 years. If we assume a 30 year lifetime the scrubbing alternative will give a NPV of 68,8 million NOK while the MGO alternative costs 79,1 million NOK. These results are consistent with the findings in scenario 1. Following the logic from scenario 1, MGO and scrubbing costs are both closely related to the oil price and therefore the results from figure 25 are insensitive to changes in fuel price input. Since the period analyzed is relatively short this is also true for changes in the WACC.

7.1.6 Scenario 3: Medium bunker prices

Input to scenario 3

In this third scenario the main focus is still on initial MGO and IFO prices since these variables have a significant impact on the results. Bunker prices are this time set between today's high prices and the low average prices. Thus, MGO=832 \$/mt, IFO 380ls=542 \$/mt and LNG is still 893 \$/mt. Annual average price change in voyage costs is this time set to 4% for all alternatives except LNG which still is 0%. 4% is being used since global average inflation for the last ten years has been around this level (IMF 2011). Furthermore, the WACC has in this scenario been set to 10%. The WACC will fluctuate over such a long time perspective as this thesis has and by using a high WACC we certainly do not underestimate this variable. Except from the input listed in this section, everything else is equal to the first scenario.

Scenario 3 results

Like scenario 1, also here LNG comes out as the most economical alternative for Straum:

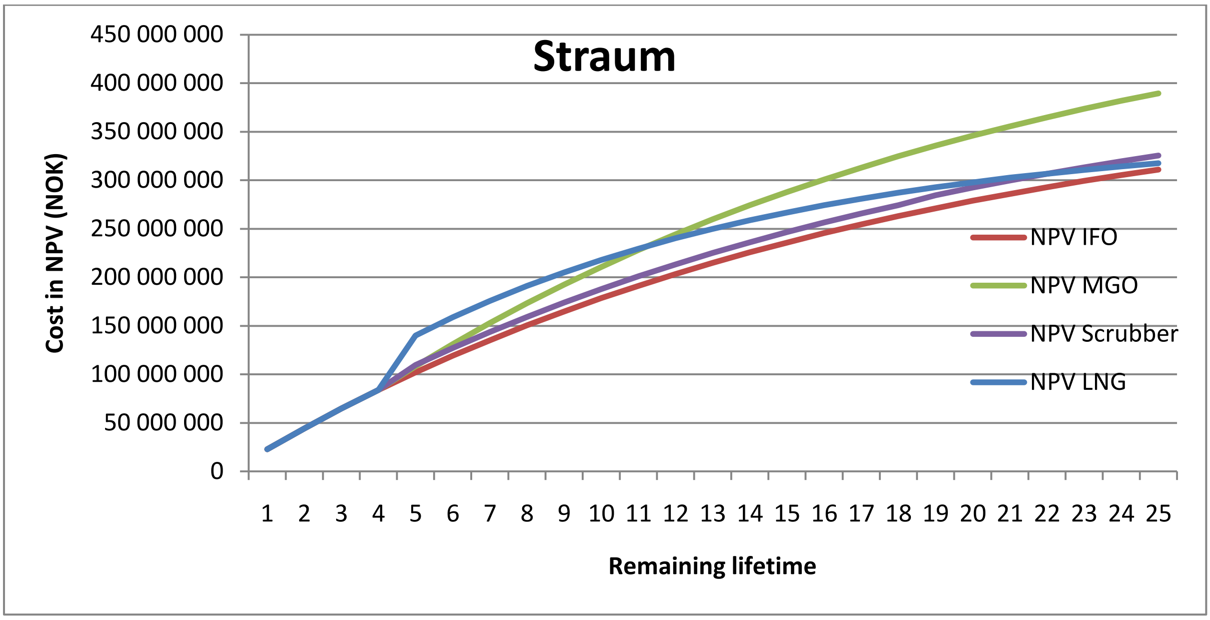

Figure 26: NPV of costs for Straum: Scenario 3.

Figure 26 depicts how scrubbing still just requires one year overcoming MGO. LNG now requires seven years to overcome MGO and 17 years to offer lower costs than the scrubbing alternative. We have to keep in mind the relatively high WACC in this scenario. If it was 7% like in the other scenarios the time required for LNG to match scrubbing would only be 14 years. A WACC of 12,2% would be needed to make the alternatives equal under this scenario. Reducing annual growth in bunker prices to 3,6% or increasing LNG prices with 0,5% would also make the alternatives equal. These numbers show how the most economical alternative is very sensitive to changes in input under this scenario.

Scrubbing becomes the most economical alternative for Xanthia:

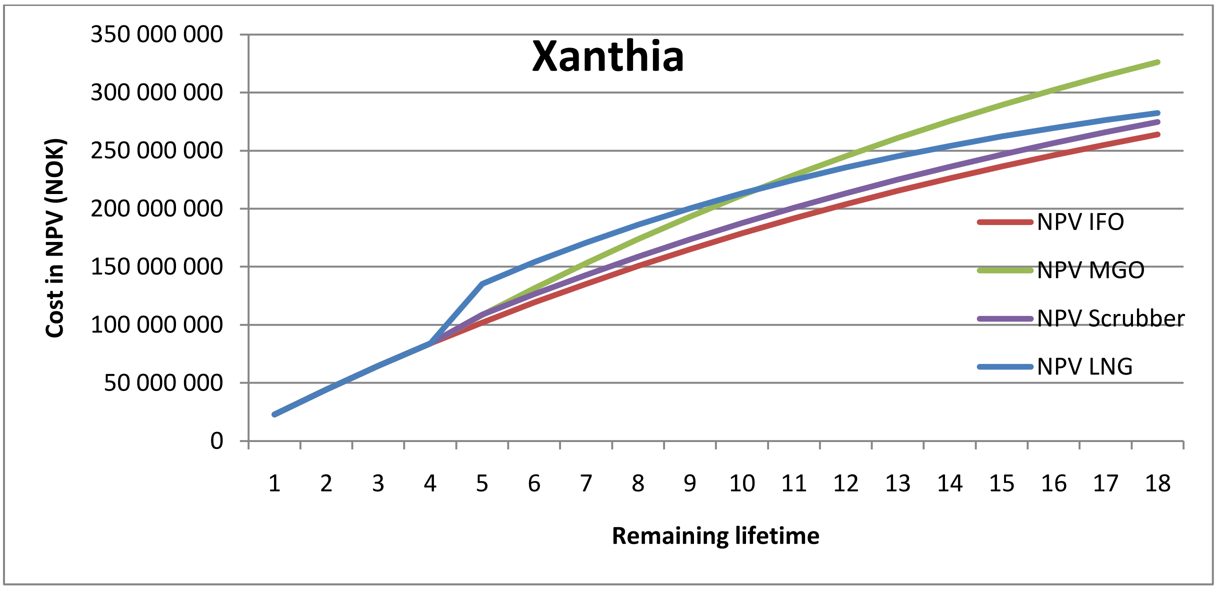

Figure 27: NPV of costs for Straum: Scenario 3.

Figure 27 shows how all of the alternatives represent increased costs compared to today's solution (red line). MGO is the most expensive alternative and LNG is the second most expensive, but the difference between LNG and scrubbing in the end of the vessel's lifetime is not that big. A WACC reduced to 6,3% would make scrubbing and LNG equal in terms of cost. Increasing annual growth in IFO380 ls to 4,5% instead of 4% would also make the alternatives equal in costs. Xanthia is again very sensitive to changes in input data and this medium scenario has made the vessel even more sensitive to changes than what we found in scenario 1 and 2.

For Solstraum on the other hand, the model still conveys the same results for this scenario as for the other two. MGO is best for a 25 year lifetime and scrubbing is best with a 30 year perspective.

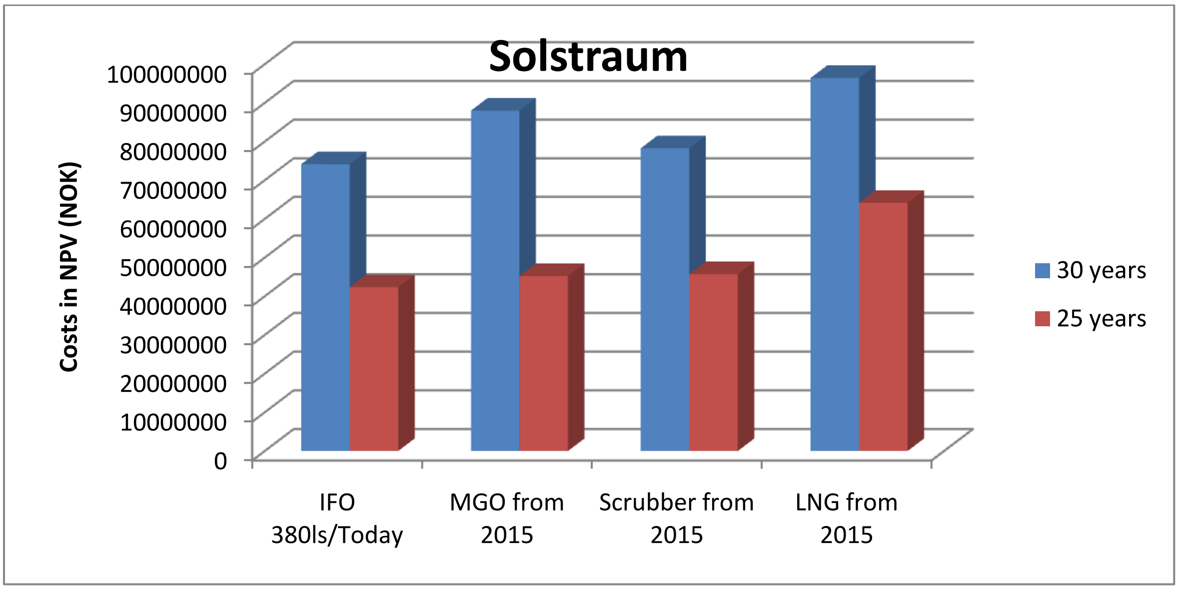

Figure 28: Sum of discounted lifetime costs for Solstraum: Scenario 3.

The reason for the consistent findings for Solstraum and the vessels insensitivity to changes in the model is mainly based on its short remaining lifetime. Because the LNG investment is so high the short remaining lifetime will not be enough to defend such an investment. MGO and scrubbing are both sensitive to the oil price, so changes in that variable will not alter the results. Furthermore, because of vessel's age and the similarity between MGO and scrubbing costs in the first years, changes in the WACC are also of less importance here (See tornado chart for Solstraum in the appendices).

7.1.7 Summarizing the results and looking into other scenarios

The purpose of table 4 and 5 below is to show how changes in the three most important variables can affect the most economical alternative. From these tables it is also possible to see a pattern, i.e. which vessel is less sensitive to changes in the model. As can be seen, this is especially the case for Solstraum.

Input to table 4 and 5 covers the three scenarios already presented. It also includes some other possibilities when it comes to annual changes in fuel prices. These numbers are not based on future projections or historical figures, but have been included in order to illustrate the model's results under a very high growth (MGO/IFO: 6% , LNG: 2%) and a very low growth (MGO/IFO: 0% , LNG: -2%) in fuel prices. Initial LNG price in both tables is still 893 $/mt.

	WACC 7%	Annual development of fuel prices (MGO-IFO / LNG)			
		6% / 2%	4% / 0%	3% / 0%	0% / -2%
Initial MGO/IFO price ($/mt)	Straum: High (973/663)	LNG	LNG	LNG	LNG*
	Straum: Medium (832/542)	LNG	LNG	Scrubber*	Scrubber
	Straum: Low (691/420)	Scrubber	Scrubber	Scrubber	Scrubber
	Xanthia: High	LNG	LNG	LNG	Scrubber*
	Xanthia: Medium	LNG*	Scrubber*	Scrubber	Scrubber
	Xanthia: Low	Scrubber	Scrubber	Scrubber	Scrubber
	Solstraum: High	MGO*/Scrubber	MGO*/Scrubber	MGO*/Scrubber	MGO*/Scrubber*
	Solstraum: Medium	MGO*/Scrubber	MGO*/Scrubber	MGO*/Scrubber	MGO*/Scrubber*
	Solstraum: Low	MGO*/Scrubber	MGO*/Scrubber	MGO*/Scrubber	MGO*/Scrubber*

	WACC 10%	Annual development of fuel prices (MGO-IFO / LNG)			
		6% / 2%	4% / 0%	3% / 0%	0% / -2%
Initial MGO/IFO price ($/mt)	Straum: High (973/663)	LNG	LNG	LNG	Scrubber*
	Straum: Medium (832/542)	LNG	LNG*	Scrubber	Scrubber
	Straum: Low (691/420)	Scrubber	Scrubber	Scrubber	Scrubber
	Xanthia: High	LNG	LNG	LNG	Scrubber*
	Xanthia: Medium	Scrubber*	Scrubber*	Scrubber	Scrubber
	Xanthia: Low	Scrubber	Scrubber	Scrubber	Scrubber
	Solstraum: High	MGO*/Scrubber	MGO*/Scrubber	MGO*/Scrubber*	MGO*/Scrubber*
	Solstraum: Medium	MGO*/Scrubber	MGO*/Scrubber*	MGO*/Scrubber*	MGO*/Scrubber*
	Solstraum: Low	MGO*/Scrubber	MGO*/Scrubber*	MGO*/Scrubber*	MGO*/Scrubber*

Table 4 and 5: Most economical alternatives under different input variables. Solstraum has been analyzed for 25/30 years lifetime. * means the results are ambiguous.

It is important to keep in mind how the difference between the best and second best alternative many times are miniscule. In all the cells in table 4 and 5 marked with a: *, the difference between the best and second best alternative is less than 10 million NOK. The tables support the tornado chart presented earlier, as initial bunker price seems to be more decisive for the outcome than annual development of fuel prices and the WACC.

The tables presented in this section gives some guidance on how to respond depending on expectations one has to the fuel price development and what is seen as appropriate IFO and MGO price input to start the analysis with. High initial IFO and MGO prices correspond to the present price level and some would argue these prices are the most realistic ones. Others will claim that a medium fuel price level is more appropriate. From a pure cost perspective Straum seems to be a candidate for LNG as long as we do not expect low average bunker prices. Xanthia is more unclear since costs are more alike so other considerations can here be decisive for choice of alternative. SOx scrubbing emerge as a very relevant possibility for Xanthia given the results from table 4 and 5. Xanthia is also the vessel that is most sensitive to changes in the input variables. In the case of Solstraum this section contributes to strengthening the impression already given in scenario 1, 2 and 3. For a 25 year lifetime MGO is the right solution and for a 30 year lifetime scrubbing gives the lowest costs.

Following the above discussion it is interesting to look more into the case of Xanthia. We have already seen that from a cost-perspective, LNG or scrubbing is most economical. If we now use different IFO and LNG prices it is possible to decide which solution is best, based on expectations towards fuel prices. All other inputs are identical to scenario 1.

NPV NOK in millions. Cost difference between scrubbing and LNG for Xanthia.

IFO 380 ls price ($/mt)	LNG price ($/mt)																
	300	350	400	450	500	550	600	650	700	750	800	850	900	950	1000	1050	1100
300	19	8	-2	-13	-24	-34	-45	-55	-66	-77	-87	-98	-108	-119	-130	-140	-151
350	37	26	15	5	-6	-16	-27	-38	-48	-59	-69	-80	-90	-101	-112	-122	-133
400	54	44	33	23	12	1	-9	-20	-31	-41	-52	-62	-73	-83	-94	-104	-115
450	72	61	51	40	30	19	8	-2	-13	-23	-34	-45	-55	-66	-76	-87	-97
500	90	79	69	58	47	37	26	16	5	-6	-16	-27	-37	-48	-59	-69	-80
550	108	97	86	76	65	54	44	33	23	12	1	-9	-20	-30	-41	-52	-62
600	125	115	104	93	83	72	61	51	40	30	19	9	-2	-13	-23	-34	-44
650	143	132	122	111	101	90	79	69	58	48	37	26	16	5	-5	-16	-26
700	161	150	139	129	118	108	97	86	76	65	54	44	33	23	12	2	-9
750	178	168	157	147	136	125	115	104	93	83	72	62	51	41	30	19	9
800	196	186	175	164	154	143	133	122	111	101	90	80	69	58	48	37	27
850	214	203	193	182	171	161	150	140	129	118	108	97	87	76	65	55	44
900	232	221	210	200	189	179	168	157	147	136	126	115	104	94	83	73	62
950	249	239	228	218	207	196	186	175	165	154	143	133	122	112	101	90	80
1000	267	256	246	235	225	214	203	193	182	172	161	150	140	129	119	108	97
1050	285	274	264	253	242	232	221	211	200	189	179	168	158	147	136	126	115
1100	303	292	281	271	260	250	238	228	218	207	197	186	175	165	154	143	133

Table 6: Cost difference for Xanthia between scrubber and LNG for different price combinations. Blue cells give LNG the advantage. Green gives scrubber the advantage. Cells are white when the difference in cost is < 25 million NOK.

The assumptions behind table 6 will of course affect the results presented. A 3 % annual increase in IFO prices while LNG prices are set at a steady rate gives the LNG alternative some added value, but this is not an unrealistic assumption. In the white area the cost difference between the two alternatives is less than 25 million NOK and that is where we are with the prices from scenario 1. The numbers from scenario 2 favors the scrubbing alternative and a price level in between will also favor the scrubbing alternative. Although LNG is given a small edge with today's fuel prices, the scrubbing alternative may be more appropriate given qualitative considerations. Another reason is Xanthia being the vessel that is most sensitive to changes in fuel price input, so small changes here will change which alternative comes out on top. From a quantitative point of view it is clear that Xanthia falls in between two different alternatives, but if initial IFO prices are below the price level in scenario 1, the scrubbing alternative will definitely be preferable.

7.2 First-mover advantage/disadvantage?

First-mover advantages for Utkilen can come as a result of being the first company in their line of business to offer vessels with a SOx scrubber system or LNG fuelled vessels. The big question is whether customers will be willing to pay extra for this. From section 6.1 we saw how the transportation of chemicals is an industry with close customer relations and offering of homogeneous services. Utkilen has a close relationship with many of their charterers, but at the same time, the service they offer can also be obtained from many of their closest competitors such as Crystal Pool, Finbeta, Essberger or Nordic Tankers. The extent of first-mover advantages will also depend on the market, since when there is overcapacity, charterers tend to be more selective and would probably choose a green vessel over a standard one at the same cost. So while charterers may be unwilling to pay extra for such a vessel, it can generate income in a weak market. Still, based on conversations with players in the industry it is not expected that customers will be willing to pay a premium for these types of ships. First-movers are neither very likely to get new contracts. If we also take into account the disadvantages of being a first-mover, it does not seem to be a profitable strategy at first glance. There is definitely a risk of investing in inferior or obsolete technology with regards to SOx scrubbers, but also LNG will probably see technological advances and reduced costs as the market continue to expand. First-movers will also bear some pioneering costs with regards to discovering areas for improvement. If Utkilen could get some kind of first-mover advantage from such an investment, keeping a sustainable first-mover advantage is also subject to discussion since complementary assets are limited, height of barriers to imitation are low and several capable competitors would follow.

Another way of being a first-mover can be together with a partner, for example Omya which Utkilen already share ownership of some vessels with. Such a strategy is the most logical choice in order to reduce some of the financial risk associated with an investment of this magnitude. The gain for Omya could be reduced fuel costs leading to lower freight rates. Furthermore they would see a marketing effect of having a green vessel sailing for them, but whether or not this effect would lead to financial gains is questionable. Being among the first with a LNG fuelled chemical tanker would certainly be possible if Utkilen and Omya shared the risk in such a project. From the quantitative analysis we have seen that for a vessel like

Straum, it is the most economical choice under scenario 1 with present fuel prices. It can also be a possibility with medium fuel price inputs like in scenario 2. Such cooperation could yield advantages for both companies and stand out as a very positive alternative compared to using MGO. It would certainly be possible for Utkilen in cooperation with Omya to together explore this opportunity further. A LNG fuelled vessel sailing in the calcium carbonate trade between Elnesvaagen and the Continent is a good start when considering alternative routes. The vessel would have access to a highly developed LNG bunkering grid (Norwegian west coast), but at the same time the vessel's sailing flexibility would initially be somewhat reduced. Even within the ECAs, LNG supply is limited compared to MGO or IFO.

At the time of writing LNG prices are higher than IFO prices. This means that adaptation before 2015 would have to come as a result of the customers being willing to pay an environmental premium, and such a requirement in this concentrated industry may not be possible. When entering 2015 it will definitely be a strategy that is worthwhile taking into consideration, but at that time it cannot be called a first-mover strategy since others will adapt earlier. As the quantitative analysis in section 7.1 has demonstrated, when the alternative is MGO, a vessel like Straum will reduce costs by choosing LNG or at least a SOx scrubber. Whether or not such cooperation would yield some first-mover advantages for both Utkilen and Omya is difficult to predict, but it is definitely the way to go if just considering being a first-mover and absolutely a possibility when entering 2015. The reason for such an investment could of course be linked to having a green profile for both companies, but in the end, this would be a smart business decision that simply is the most cost effective one when going into 2015. Alternatively, Omya can pay higher freight rates in order to cover Utkilen's MGO expenses.

So summarized, being a first-mover today might not be possible for Utkilen. But as we are getting closer to 2015 it is worth looking more into the LNG alternative for a vessel like Straum. Such a project should preferably be undertaken together with a partner such as Omya. Other factors can of course also affect a decision like this. If Omya's calcium carbonate slurry is facing a very good market they may be more inclined to invest in a LNG fuelled vessel together with Utkilen.

7.3 Strengths and weaknesses of the three first alternatives

Alternative 1: Distillates		
+ Very low investment/capital costs	-	Very high fuel costs
+ Especially good MGO availability today	-	Possible to meet demand after 2015?
+ Vessel sailing flexibility	-	Increase in price after 2015?
+ Easy maintenance and increased engine reliability	-	(Does not comply with NOx limits for newbuildings from 2016)

Alternative 2: Scrubbers for exhaust gas purification		
+ Low fuel costs	-	Novel technology/limited experience
+ Especially good fuel availability today	-	Medium investment/capital cost
	-	Limited application of SWS in the Baltic Sea
	-	(Integration challenges with NOx cleaning systems)

Alternative 3: LNG as a marine fuel		
+ Environmentally a winner	-	High capital costs
+ Growing price disparity oil/gas predicted	-	Limited availability today and thus, reduced sailing flexibility
+ (Meets both SOx and NOx requirements)	-	Volume intensive

Table 7: Strengths and weaknesses of the three first alternatives.

7.3.1 Investment cost vs. fuel cost

Among the most important factors in table 7 is the initial investment and fuel cost. One simply does not retrofit an old ship with a SOx scrubber or a LNG fuel system unless the reduced fuel costs will pay back the added investment, but it can be difficult to set a boundary on how old the ship must be since it will differ for individual ships. In Utkilen’s case we analyzed this in section 7.1. As a general rule, we can say that old ships will not be suited for the LNG alternative since it simply is not economically viable. The savings from reduced fuel costs will not outweigh the initial investment due to the old vessels limited remaining lifetime. This implies some sort of tradeoff between investment and voyage costs in the long run, meaning high investments leads to low voyage costs and vice versa. When looking at the MGO solution the assumption holds since the investment is low and fuel costs are very high. The assumption also holds for the scrubbing alternative as a medium investment gives lower voyage costs. Under this alternative the relationship is not as extreme as for the MGO alternative, but there is still a relationship since the investment has an impact on the fuel costs. For the LNG case however, a high investment leads to medium/high voyage costs in the short run. We can see the assumption does not hold for the LNG case today, but anticipations on the gas price development is expected to change this, and compared to MGO's current price level an investment in LNG actually reduces voyage costs. Another important remark is which input is being used. In scenario 2 for Xanthia, MGO was cheaper than LNG. For Straum LNG was cheaper, so it is quite clear that remaining lifetime plays an important role here. With a long term perspective, the assumption is thus expected to be valid. If a shipowner right before 2015 builds or retrofits a vessel into LNG propulsion it is because of expectations of a higher oil price and a lower price for natural gas. Based on these expectations the shipowner also assumes that a high investment actually leads to lower voyage costs. Unfortunately, only the future will tell if this tradeoff really exists for the LNG alternative, but based on expectations on oil and natural gas prices it is anticipated to do so.

7.3.2 Utkilen's vessels

As we have seen from the cost analysis, MGO is the most expensive alternative over a longer period of time due to high fuel prices today and expectations of a rising oil price. For Solstraum with a lifetime set to 25 years, the qualitative sides will actually support the numbers and MGO is the best choice. The high price is MGO's largest disadvantage, so when the numbers give MGO the advantage, the choice is easy.

If we assume a lifetime of 30 years for Solstraum, the alternative which gave the lowest costs was scrubbing. SOx scrubbing were also an alternative relevant for Xanthia since this solution was able to match LNG on costs in most scenarios. In fact, seen from a pure cost-perspective, scrubbing technology looks like one of the best solutions for many of the vessels operating in the ECAs today. Under scenario 1, figure 20 and 21 shows how the scrubbing alternative gives the lowest cost for vessels similar to Straum and Xanthia with remaining lifetime < 14 years. If we just change the input slightly, the advantage of scrubbing will increase. From a cost perspective it has a lower investment than LNG and it offers lower fuel costs than LNG in the short and medium run, and MGO in the medium and long run. Compared to MGO the repayment time can be as low as one year, and fuel is readily available everywhere. The main reason LNG can overcome scrubbing is because of long term expectations on higher oil prices and lower prices for natural gas. For relatively new vessels such as Straum the LNG alternative can therefore be preferable. If we look into table 7, the main drawback with SWS is its limited practical experience and its limited application in the Baltic Sea. The main reason for lack of practical experience of this technology has up until now been limited demand, but when we reach 2015 it is very likely demand for this alternative will increase. Making recommendations for Solstraum and Xanthia when future development of this technology is uncertain is not an easy task, but if they are expected to sail outside of the Baltic Sea a SOx scrubber will definitely be the best choice. With continued development of SWSs or use of a FWS that also can work efficiently inside of the Baltic the choice is more obvious. If the SOx scrubbing alternative indeed is as good as claimed by many of the suppliers, it will be an excellent alternative to MGO and LNG for medium aged vessels. But in order to increase the adoption of this alternative it is essential to have a system that also can work efficiently in the Baltic Sea.

Besides from the prices, fuel availability is of course also a decisive factor and low availability is often linked with a high price since it can mean an oligopoly market. In the case of LNG this means that if it should prove to be economically viable, it is still limited to certain geographical areas. For instance, Norway has Europe’s most developed LNG bunkering grid, while availability of LNG in the Baltic is limited at present. As a result, LNG fuelled vessels are currently subject to a restricted sailing pattern, even within the ECA zones. That is another reason for not recommending LNG for Xanthia, even though it is slightly cheaper in scenario 1. Since the initial investment is so high, candidates for this alternative seem to be relatively new vessels. As the quantitative analysis in this paper has demonstrated, MT Straum is best suited for LNG when only considering remaining lifetime and associated costs. But the estimation of costs is only one side of the situation. It is also important to assess the availability of fuel. Because of this, an investment in LNG is not as clear-cut as the cost analysis would suggest. If a chemical tanker is to be retrofitted into LNG propulsion it would be necessary to initially have a sailing pattern where LNG is readily available. In section 7.2 the voyage between Elnesvaagen and the Continent was suggested as such a route for Utkilen. It would limit the vessels geographical flexibility, but as long as the ship has access to the LNG bunkering grid, costs will be reduced compared to MGO or scrubbing. For Straum in scenario 1, these costs amounted to 53 MNOK vs. scrubber and 135 MNOK vs. MGO. Thus, if Utkilen plan to operate the vessel until the end of its economical lifetime, LNG will be the most economical choice. As we saw in section 3.3.4, it may not take too long before LNG is available throughout all of the ECAs. Since this remains to be seen and given the currently reduced sailing flexibility, retrofitting both Straum and Xanthia may be too much for Utkilen. Besides, the age of Xanthia makes the cost analysis very sensitive to fluctuations in fuel prices.

7.3.3 Some real options to consider

Values of real options are usually linked to the expectations to get more information later on and thereby make a better decision. One kind of such information is what competitors choose to do. A few maritime real options stand out as particularly important in this setting.

As mentioned under general assumptions there is a real option in waiting. Present fuel costs are lower when strict ECA regulations are not enforced. Furthermore, as we get closer to 2015 and the market for compliance solutions expands, it will be possible to make a better decision since more information is available. Technology will most likely improve and the actual cost level of the different alternatives will be known. On the other hand, large demand for yard capacity can put an upward pressure on retrofitting prices. That is because restricted yard capacity allows the yards to take a higher price. One reason to adapt early is to get investment support from the NOx fund. Since it is planned to exist until 2017, waiting to 2015 should not represent a major problem for the shipowners. In case ESA disapproves of the continuance, a decision to wait has to be weighed against the loss of support from the fund. ESA is expected to approve or disapprove the continuance of the fund by August/September of 2011.

There is another possible real option in switching input and there is also the location option. If the vessel is running on a dual fuel engine, it will have a larger geographical range, also outside of the ECAs. Due to the limited availability of LNG today, a vessel that is only able to use LNG as fuel will have fewer markets in which it can trade. It is also possible it will have a reduced second-hand value due to fewer markets to sell the vessel in. These LNG-engines are under constant development and the longer one is willing to wait, the better engine will most likely be available. Regarding location options, ships, in contrast to other capital incentive investments, usually have lower asset specificity and can be switched to a new trade (Bendall 2010). More about this follows in section 7.4 below.

7.4 Giving up trade in the ECAs: The four markets that control shipping

This last alternative has been included in order to make the reader aware of the shipowners' options. While possible to list up in theory, getting an actual overview of the possible gains and associated opportunity costs from these markets can be a complex task for all shipping companies, Utkilen included.

The freight market outside of the ECAs is of course a possibility if Utkilen would like to avoid the strict emission regulations. That being said, such a strategy will not be effortless since it will depend on the markets for freight and demand for shipping which is closely linked to the world economy. If Utkilen want to take advantage of this option, a favorable global economy can make it easier to accomplish and an economic downturn will make matters worse. Because most of their ships operate inside of the ECAs today and has been for some time, finding alternative employment in other geographical markets will not be simple as these markets already are occupied by skilled players that has been there for some time. So seeing that Utkilen's core competence and its customers are in Northern Europe, going into freight markets in other areas will be difficult, but still a possibility which can be considered.

If giving up trade in the ECAs, sale of the ship is another relevant possibility. Since the shipping industry is a very volatile one, many shipowners are running a risk of bankruptcy. To avoid this they are sometimes forced to sell ships. One reason for the resistance to build or retrofit LNG fuelled vessels is the risk of not being able to sell a ship, meaning there is a link between sailing flexibility and second-hand value. Today most LNG fuelled ships except for some ferries have dual fuel engines. A vessel that is fueled only by LNG, without the possibility to use MGO will not be very attractive outside of the ECAs. These vessels' second-hand value will most likely be reduced in markets that are not as strictly regulated. One can say that the loss of operational flexibility reduces the markets in which the vessels can be sold. The fear of "locking" a vessel to a certain geographic area does not seem to affect Utkilen to any large degree. They have a long term perspective and tend to operate their vessels as long as possible. One example is how most of their vessels have the highest ice class[16]. Like a scrubber system, the investment in ice class will probably not be reflected in a sales price if the vessels were to be sold to a company operating outside of the ECAs. For the vessel Solstraum in scenario 1, a changeover to MGO in its last year of operation[17] will result in a NPV difference of 3,2 MNOK compared to IFO. In case these extra expenses make continued operation difficult, a sale of the vessel is one possibility. Even though an age of 25 years is too old for Utkilen, many other companies inside and outside of the ECAs can use the vessel in other trades.

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[16] Ships with an ice class have a strengthened hull to allow them to navigate through icy waters.
[17] Solstraum's last year of operation is 2015 if we assume an economical lifetime of 25 years.

It is reasonable to say there will be some sort of link between a vessel's sailing flexibility and second-hand value, meaning a vessel that has limited markets in which it can operate also has a limited number of potential buyers. Few buyers will mean more buyer power when it comes to price. With time, flexibility inside of the ECAs will not be reduced as a result of upgrades and it follows that second-hand value is not reduced. This means it will be riskier to retrofit these ships in the earliest periods of the ECAs since it will be more difficult to sell the vessels. The link between flexibility and second-hand value will thus follow the development of the market for these ships. The assumption is therefore valid, meaning low flexibility today reduces second-hand value today. Or said in another way, makes the second-hand market for these ships much more difficult. When these vessels' flexibility increases with time, (this can be due to an expanding market for LNG or improved scrubbing technology) this will also be reflected in the second hand markets that will have more buyers for these vessels.

Like the freight market and the second-hand market, the demolition market will also be good or bad depending on shipping market cycles. Obviously, when there is overcapacity and many new ships, scrapping of old vessels are necessary, especially if these old vessels require upgrades and added voyage costs because of strict emission regulations. The key to success in this market (as in other markets) is to know when to act before it is common knowledge. From figure 17 we saw that Utkilen today only have two vessels between 21-25 years and four vessels between 16-20 years. In 2015 these vessels will be old and scrapping of the oldest vessels is an option. Such a decision will be depending on the development in the shipping markets, but sales in the second-hand market is a perhaps a better alternative.

If deciding to act in one of these markets one should strive to find the opportunity cost, as this is the benefit that is given up when selecting one alternative over another. Such knowledge is necessary in order to know the decision made is the best possible given the current situation and the information at hand. Even though the four shipping markets definitely is a way to respond to the ECA regulations in 2015, it is not expected to be the main alternative for Utkilen. This is because it would mean giving up much of their core competency as the company has its main business inside of these regulated zones. Since all companies will face these strict emission regulations it is even possible some of Utkilen's smaller competitors will decide to give up ECA trade.

8 CONCLUSIONS AND DIRECTIONS FOR FUTURE RESEARCH

8.1 Conclusions

In this paper we have seen that in the time to come, shipowners are facing some tough challenges related to the Northern European ECAs. Getting an overview of their most relevant alternatives and starting to analyze how to adapt can lead to reduced cost. The main RQ that has been pursued throughout this thesis has been which emission reducing alternative can be most economical for chemical tankers with differing remaining lifetime.

From the analysis of the three Utkilen ships, we have learned how these vessels with differing remaining lifetime actually will require different emission reducing alternatives in order to minimize costs. This means each vessel will have to be evaluated based on its age (and sailing pattern) before choosing how to comply with the ECA regulations. For the vessels analyzed, three different alternatives emerged as the most economical. If we assumed a 25 year lifetime for the oldest vessel, Solstraum, the MGO alternative stood out as the most economical one under all scenarios. In the case of Solstraum over 30 years or Xanthia which is a medium aged vessel, SOx scrubbing was identified as the most economical alternative. For a relatively new vessel such as Straum, LNG came out on top in the first and third scenario with high and medium bunker prices used as input.

Moreover, we have seen how the cost side is not the only one, and choice of alternative is not as clear cut as the cost analysis would suggest. Today, lacking experience and application of SOx scrubbing technology and low availability of LNG limits the adoption of these alternatives, especially for segments with a more irregular sailing pattern such as the chemicals segment. Since we still are some years away from the enforcement of the strict SOx regulations, shipping companies are wise to wait for improvements in these areas. Unless someone else is willing to bear the extra cost of complying before 2015, the shipping companies are saving costs by postponing compliance.

Based on expectations regarding future development of the alternatives, the same recommendations we found in the cost analysis are also given if we look into the more qualitative aspects of the alternatives. An expanding market for LNG is to be expected, while SOx scrubbing technology also most likely will see further development. As already mentioned in chapter 5: Methods one should not generalize the findings of this study too much. But if we look at vessels similar to those in this thesis and a company similar to Utkilen, we can summarize from the analysis:

- MGO seems to be a too expensive solution that only will be appropriate for very old vessels. This alternative is the easiest switch, but also the most expensive in the medium and long run. Shipowners should become aware of the substantial costs associated with this alternative.
- Scrubbing technology can be the best choice for medium aged and old vessels. We have seen in the analysis how a SWS system could require as little as a one year period to offer lower costs than MGO.
- LNG is an alternative reserved for relatively new vessels and will initially give the vessels reduced sailing flexibility. The shipowner needs to weigh this disadvantage against the advantage of reduced expenditures. Moreover, it is important to remember that the cost advantage of LNG compared to a scrubber system is based on expectations of a higher growth in oil prices than natural gas prices.

Based on a future development as outlined in this thesis, it would seem there is a tradeoff between investment cost and voyage costs in the long run, meaning that a high investment in LNG will lead to reduced fuel costs in the future. Likewise, a low investment in MGO will lead to very high fuel costs. The tradeoff is only valid for relatively new vessels, since a long term perspective is necessary for it to be valid. There also seems to be a link between sailing flexibility and second-hand value which probably is an important reason why many shipowners still do not want to retrofit vessels unless having secured long term employment for their ships.

Finally, it should be noted there is a fair amount of uncertainty related to this topic. An unexpected development of the oil price will change the results from the cost analysis. This means that if we see a declining oil price in the future, LNG will not be an economical choice even for very new vessels. Choice of other input variables such as a very high or low WACC will also have an impact on the results. Furthermore, technological development of SOx scrubbers and LNG infrastructure development will be crucial for the adoption of these alternatives.

8.2 Directions for future research

An interesting theme that is closely related to this one is how ships entering and exiting the ECAs regularly should adapt. Many vessels are calling the ARA area today, a large number of them come from different continents, i.e. deep sea shipping. The owners of these ships will probably have to consider different alternatives. For example, how many Rotterdam port calls are required to make a scrubber system economical compared to running on MGO in the ECAs? LNG for a ship that spends most of its time outside of the ECAs does not sound like a good choice given the presently limited availability. On the other hand, these vessels can buy cheaper LNG at large import terminals. Obviously, each ship will have to undergo individual analyses. A ship operating 10% of the time inside of the ECAs will perhaps choose MGO while a ship operating there 60% of the time should choose a scrubbing system? As we already know, the global emission limits will also be tightened so perhaps the newest ships entering and exiting the ECAs in 2015 should be designed to also comply outside due to the upcoming global restrictions? These questions will definitely have to be explored by shipowners in the near future as they are important in order to keep costs as low as possible and at the same time comply with maritime regulations.

Another aspect for further research is how the four shipping markets offer alternatives to many of the ships presently sailing in the ECAs. Due to time and resource limitations I have not been able to include it in this thesis, but it would have been very interesting to include the income side in other markets. By doing this it would also have been possible to decide if it is more economical to sell or scrap an old vessel instead of complying with the ECA regulations.

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APPENDICES

Abbreviations

ARA	Antwerp-Rotterdam-Amsterdam
DNV	Det Norske Veritas
ECA	Emission control area
HFO	Heavy fuel oil
IEA	International Energy Agency
IFO	Intermediate fuel oil
IMO	International maritime organization
kWh	Kilowatt hour
LNG	Liquid natural gas
lwt	Light weight tons
m^3	Cubic meter
MDO	Marine diesel oil
MGO	Marine gas oil
mt	Metric ton
MWh	Megawatt hour
NO_2	Nitrogen dioxide
NOx	Nitrogenous oxides
NPV	Net present value
ROA	Real options analysis
RQ	Research question
SECA	Sulphur emission control area
SG	Specific gravity
SO_2	Sulphur dioxide
SOx	Sulphur oxides
SSS	Short sea shipping
SWS	Sea water scrubbers
WACC	Weighted average cost of capital

Excel sheets

Full model of Scenario 1: Xanthia

Input to model.	Scenario 1: Xanthia					
				Comments		
Current Year	2011					
Lifetime vessels	25	Years				
Nominal WACC	7,00 %					
Vessel information	Xanthia					
Built	2003					
Age	8	Years				
Vessel becomes obsolete in year	2028					
Dwt	17000					
Engine load (only used for maint cost)	75 %					
Fuel type today	IFO380ls					
Installed power	7200	kW				
Steaming hrs in 1 yr	5400	h				
Historical Nox emissions last yr	14286	kg				

Project figures	IFO380ls (Used today/Not possible)	Only MGO	IFO380ls + Scrubber	LNG	
Investment cost	0	400 000	9 434 880	50 544 000	NOK
Fuel consumption	6 538	6 125	6 669	5 305	mt/year
Subsidies from the Nox fund	0	0	0	5 000 100	NOK
Maintenance cost	0,018	0,012	0,019	0,018	$/kWh
Estimated capital cost per installed kW	-	-	168	900	€/kW

Yearly increase in prices	IFO380ls (Used today/Not possible)	Only MGO	IFO380ls + Scrubber	LNG
CapEx	2,50 %	2,50 %	0,00 %	0,00 %
VoyEx	3,00 %	3,00 %	3,00 %	0,00 %
TaxEx	3,50 %	3,50 %	3,50 %	3,50 %
OpEx	2,50 %	2,50 %	2,50 %	2,50 %

Fuel prices and Exchange rates		
Fuel price LNG - Norway	893	$/mt
Fuel price IFO 380ls - Rdam	663	$/mt
Fuel price MGO - Rdam	973	$/mt
$/kr excange rate	5,6	$/kr
€/kr exchange rate	7,8	€/kr
€/$ exchange rate	1,4	€/$
NOx tax	4	NOK/kg
Nox tax after 2017	16,14	NOK/kg
Possible subsidies if LNG	350	NOK/kg taxable emissions
Nox reduction potential with LNG	90 %	
Nox tax last yr	57 144	kr

Output and results

2011 values / year 1	IFO380ls (Used today/Not possible)	MGO from 2015	Scrubber from 2015	LNG from 2015
CapEx	0	-400 000	-9 434 880	-45 543 900
VoyEx	-24 274 286	-33 371 667	-24 759 772	-26 527 570
TaxEx	-57 144	-57 144	-57 144	-5 714
OpEx	-2 939 328	-1 910 563	-3 102 624	-2 939 328
Total	-27 270 758	-35 739 374	-37 354 420	-75 016 513

Accumulated cost	IFO380ls (Used today/Not possible)	MGO from 2015	Scrubber from 2015	LNG from 2015
CapEx	0	-336 837	-7 701 673	-34 745 223
VoyEx	-322 273 492	-408 653 971	-326 883 225	-281 164 727
TaxEx	-2 073 963	-2 073 963	-2 073 963	-403 239
OpEx	-37 639 858	-28 328 574	-39 117 840	-37 639 858
Total accumulated cost	-361 987 313	-439 393 346	-375 776 700	-353 953 048
Cost difference compared to HFO	0	77 406 032	13 789 387	-8 034 266
In percentage	0 %	-21 %	-4 %	2 %

NPV Calculations

IFO 380 ls (today/Not possible from 2015)	NPV	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
							CASH FLOW												
Revenue	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Capex	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Voyex	-322 273 492	-24 274 286	-25 002 515	-25 752 590	-26 525 168	-27 320 923	-28 140 551	-28 984 767	-29 854 310	-30 749 940	-31 672 438	-32 622 611	-33 601 289	-34 609 328	-35 647 608	-36 717 036	-37 818 547	-38 953 104	-40 121 697
TaxEx	-2 073 963	-57 144	-59 144	-61 214	-63 357	-65 574	-67 869	-70 245	-293 357	-303 625	-314 251	-325 250	-336 634	-348 416	-360 611	-373 232	-386 295	-399 816	-413 809
Opex	-37 639 858	-2 939 328	-3 012 811	-3 088 131	-3 165 335	-3 244 468	-3 325 580	-3 408 719	-3 493 937	-3 581 286	-3 670 818	-3 762 588	-3 856 653	-3 953 069	-4 051 896	-4 153 194	-4 257 023	-4 363 449	-4 472 535
Result	-361 987 313	-27 270 758	-28 074 470	-28 901 936	-29 753 859	-30 630 965	-31 534 000	-32 463 731	-33 641 605	-34 634 850	-35 657 507	-36 710 450	-37 794 577	-38 910 814	-40 060 115	-41 243 462	-42 461 866	-43 716 368	-45 008 041

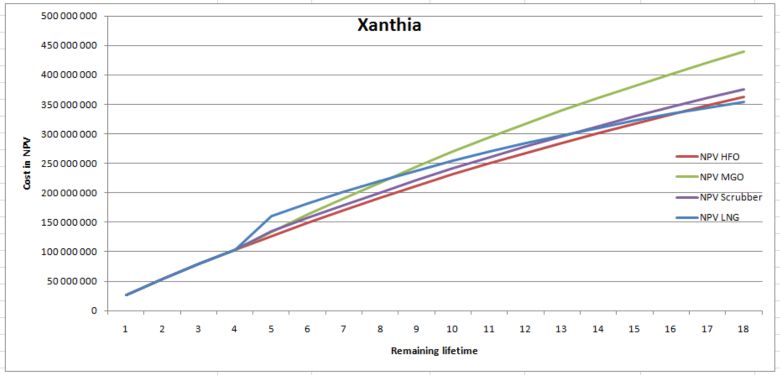
MGO from 2015	NPV	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
							CASH FLOW												
Revenue	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Capex	-336 837	0	0	0	0	-441 525	0	0	0	0	0	0	0	0	0	0	0	0	0
Voyex	-408 653 971	-24 274 286	-25 002 515	-25 752 590	-26 525 168	-37 560 105	-38 686 908	-39 847 515	-41 042 941	-42 274 229	-43 542 456	-44 848 730	-46 194 192	-47 580 017	-49 007 418	-50 477 640	-51 991 970	-53 551 729	-55 158 281
TaxEx	-2 073 963	-57 144	-59 144	-61 214	-63 357	-65 574	-67 869	-70 245	-293 357	-303 625	-314 251	-325 250	-336 634	-348 416	-360 611	-373 232	-386 295	-399 816	-413 809
Opex	-28 328 574	-2 939 328	-3 012 811	-3 088 131	-3 165 335	-2 108 904	-2 161 627	-2 215 668	-2 271 059	-2 327 836	-2 386 032	-2 445 682	-2 506 824	-2 569 495	-2 633 732	-2 699 576	-2 767 065	-2 836 242	-2 907 148
Result	-439 393 346	-27 270 758	-28 074 470	-28 901 936	-29 753 859	-40 176 109	-40 916 404	-42 133 428	-43 607 357	-44 905 690	-46 242 739	-47 619 662	-49 037 650	-50 497 929	-52 001 761	-53 550 448	-55 145 330	-56 787 786	-58 479 238

IFO 380 ls + Scrubber from 2015	NPV	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
							CASH FLOW												
Revenue	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0
Capex	-7 701 673	0	0	0		-9 434 880	0	0	0	0	0	0	0	0	0	0	0	0	0
Voyex	-326 883 225	-24 274 286	-25 002 515	-25 752 590	-26 525 168	-27 867 342	-28 703 362	-29 564 463	-30 451 397	-31 364 939	-32 305 887	-33 275 063	-34 273 315	-35 301 515	-36 360 560	-37 451 377	-38 574 918	-39 732 166	-40 924 131
TaxEx	-2 073 963	-57 144	-59 144	-61 214	-63 357	-65 574	-67 869	-70 245	-293 357	-303 625	-314 251	-325 250	-336 634	-348 416	-360 611	-373 232	-386 295	-399 816	-413 809
Opex	-39 117 840	-2 939 328	-3 012 811	-3 088 131	-3 165 335	-3 424 716	-3 510 334	-3 598 093	-3 688 045	-3 780 246	-3 874 752	-3 971 621	-4 070 912	-4 172 684	-4 277 001	-4 383 926	-4 493 525	-4 605 863	-4 721 009
Result	-375 776 700	-27 270 758	-28 074 470	-28 901 936	-29 753 859	-40 792 512	-32 281 565	-33 232 800	-34 432 799	-35 448 809	-36 494 890	-37 571 935	-38 680 861	-39 822 615	-40 998 172	-42 208 536	-43 454 738	-44 737 844	-46 058 949

LNG from 2015	NPV	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
							CASH FLOW												
Revenue	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Capex	-34 745 223	0	0	0	0	-45 543 900	0	0	0	0	0	0	0	0	0	0	0	0	0
Voyex	-281 164 727	-24 274 286	-25 002 515	-25 752 590	-26 525 168	-26 527 570	-26 527 570	-26 527 570	-26 527 570	-26 527 570	-26 527 570	-26 527 570	-26 527 570	-26 527 570	-26 527 570	-26 527 570	-26 527 570	-26 527 570	-26 527 570
TaxEx	-403 239	-57 144	-59 144	-61 214	-63 357	-6 557	-6 787	-7 024	-29 336	-30 362	-31 425	-32 525	-33 663	-34 842	-36 061	-37 323	-38 630	-39 982	-41 381
Opex	-37 639 858	-2 939 328	-3 012 811	-3 088 131	-3 165 335	-3 244 468	-3 325 580	-3 408 719	-3 493 937	-3 581 286	-3 670 818	-3 762 588	-3 856 653	-3 953 069	-4 051 896	-4 153 194	-4 257 023	-4 363 449	-4 472 535
Result	-353 953 048	-27 270 758	-28 074 470	-28 901 936	-29 753 859	-75 322 496	-29 859 937	-29 943 314	-30 050 843	-30 139 219	-30 229 813	-30 322 684	-30 417 887	-30 515 481	-30 615 527	-30 718 087	-30 823 223	-30 931 001	-31 041 486

Model of most economic choice of alternative for a vessel like Xanthia with various remaining lifetime

Remaining lifetime	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
NPV HFO	27 270 758	53 508 581	78 752 651	103 040 664	126 408 880	148 892 187	170 524 141	191 474 442	211 632 240	231 027 562	249 689 293	267 645 224	284 922 091	301 545 614	317 540 540	332 930 674	347 738 920	361 987 313
NPV MGO	27 270 758	53 508 581	78 752 651	103 040 664	133 690 824	162 863 655	190 938 937	218 095 408	244 230 928	269 383 914	293 591 336	316 888 770	339 310 454	360 889 336	381 657 123	401 644 329	420 880 317	439 393 346
NPV Scrubber	27 270 758	53 508 581	78 752 651	103 040 664	134 161 076	157 177 386	179 321 804	200 764 820	221 396 350	241 247 152	260 346 818	278 723 817	296 405 534	313 418 318	329 787 516	345 537 513	360 691 769	375 272 852
NPV LNG	27 270 758	53 508 581	78 752 651	103 040 664	160 503 835	181 793 557	201 746 052	220 460 207	238 001 507	254 444 522	269 859 037	284 310 356	297 859 594	310 563 950	322 476 954	333 648 708	344 126 108	353 953 048



Input Scenario 1: Straum

Input to model.	Scenario 1: Straum					
					Comments	
Current Year	2011					
Lifetime vessels	25	Years				
Nominal WACC	7,00 %					
Vessel information	Straum					
Built	2010					
Age	1	Years				
Vessel becomes obsolete in year	2035					
Dwt	19540					
Engine load (only used for maint cost)	75 %					
Fuel type today	IFO380ls					
Installed power	7860	kW				
Steaming hrs in 1 yr	5200	h				
Historical Nox emissions last yr	7356	kg				
Project figures	IFO380ls (Used today/Not possible)		Only MGO	IFO380ls + Scrubber	LNG	
Investment cost	0		400 000	10 299 744	55 177 200	NOK
Fuel consumption	6 492		6 081	6 622	5 267	mt/year
Subsidies from the Nox fund	0		0	0	2 574 600	NOK
Maintenance cost	0,018		0,012	0,019	0,018	$/kWh
Estimated capital cost per installed kW	-		-	168	900	€/kW
Yearly increase in prices	IFO380ls (Used today/Not possible)		Only MGO	IFO380ls + Scrubber	LNG	
CapEx	2,50 %		2,50 %	0,00 %	0,00 %	
VoyEx	3,00 %		3,00 %	3,00 %	0,00 %	
TaxEx	3,50 %		3,50 %	3,50 %	3,50 %	
OpEx	2,50 %		2,50 %	2,50 %	2,50 %	
Fuel prices and Exchange rates						
Fuel price LNG - Norway	893	$/mt				
Fuel price IFO 380ls - Rdam	663	$/mt				
Fuel price MGO - Rdam	973	$/mt				
$/kr excange rate	5,6	$/kr				
€/kr exchange rate	7,8	€/kr				
€/$ exchange rate	1,4	€/$				
NOx tax	4	NOK/kg				
Nox tax after 2017	16,14	NOK/kg				
Possible subsidies if LNG	350	NOK/kg taxable emissions				
Nox reduction potential with LNG	90 %					
Nox tax last yr	29 424	kr				

Input Scenario 1: Solstraum (25 years)

Input to model.	**Scenario 1: Solstraum**					
					Comments	
Current Year	2011					
Lifetime vessels	25	Years				
Nominal WACC	7,00 %					
Vessel information	Solstraum					
Built	1990					
Age	21	Years				
Vessel becomes obsolete in year	2015					
Dwt	6519					
Engine load (only used for maint cost)	75 %					
Fuel type today	IFO380ls					
Installed power	3235	kW				
Steaming hrs in 1 yr	4900	h				
Historical Nox emissions last yr	3057	kg				
Project figures	IFO380ls (Used today/Not possible)		Only MGO	IFO380ls + Scrubber	LNG	
Investment cost	0		400 000	4 239 144	31 594 085	NOK
Fuel consumption	2 724		2 552	2 778	2 210	mt/year
Subsidies from the Nox fund	0		0	0	1 069 950	NOK
Maintenance cost	0,018		0,012	0,019	0,018	$/kWh
Estimated capital cost per installed kW	-		-	168	-	€/kW
Yearly increase in prices	IFO380ls (Used today/Not possible)		Only MGO	IFO380ls + Scrubber	LNG	
CapEx	2,50 %		2,50 %	0,00 %	0,00 %	
VoyEx	3,00 %		3,00 %	3,00 %	0,00 %	
TaxEx	3,50 %		3,50 %	3,50 %	3,50 %	
OpEx	2,50 %		2,50 %	2,50 %	2,50 %	
Fuel prices and Exchange rates						
Fuel price LNG - Norway	893	$/mt				
Fuel price IFO 380ls - Rdam	663	$/mt				
Fuel price MGO - Rdam	973	$/mt				
$/kr excange rate	5,6	$/kr				
€/kr exchange rate	7,8	€/kr				
€/$ exchange rate	1,4	€/$				
NOx tax	4	NOK/kg				
Nox tax after 2017	16,14	NOK/kg				
Possible subsidies if LNG	350	NOK/kg taxable emissions				
Nox reduction potential with LNG	90 %					
Nox tax last yr	12 228	kr				

Tornado charts

Straum: Scenario 1

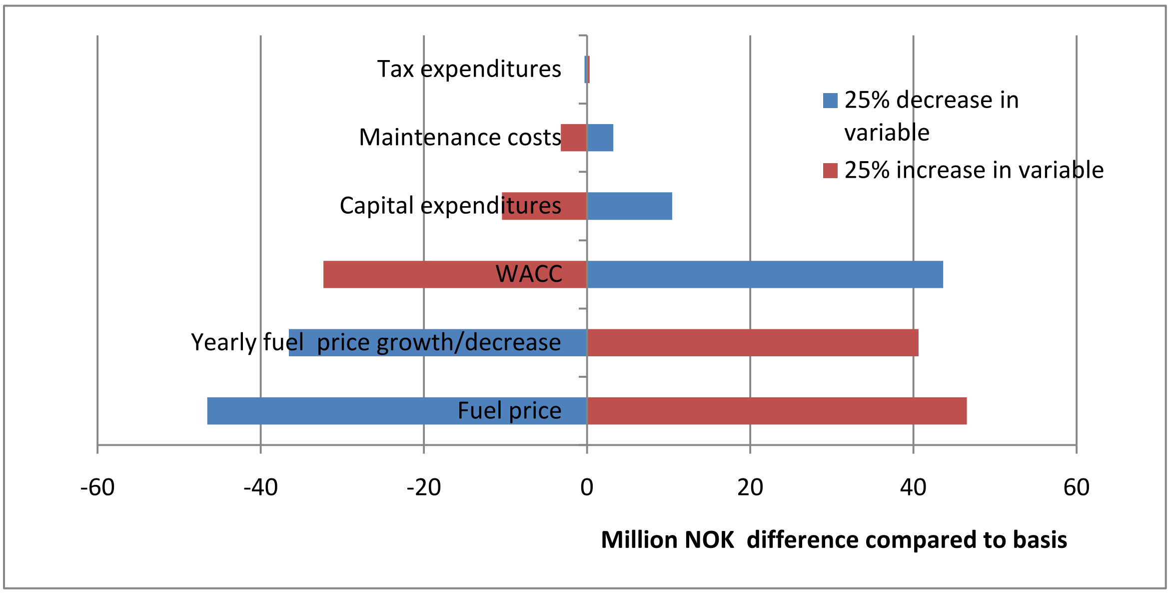


Figure 29: Tornado chart based on scenario 1 input for the vessel Straum: Basis is cost difference LNG - MGO. In this case the cost difference is 134 739 094 in favor of LNG.

Solstraum 30 years: Scenario 1

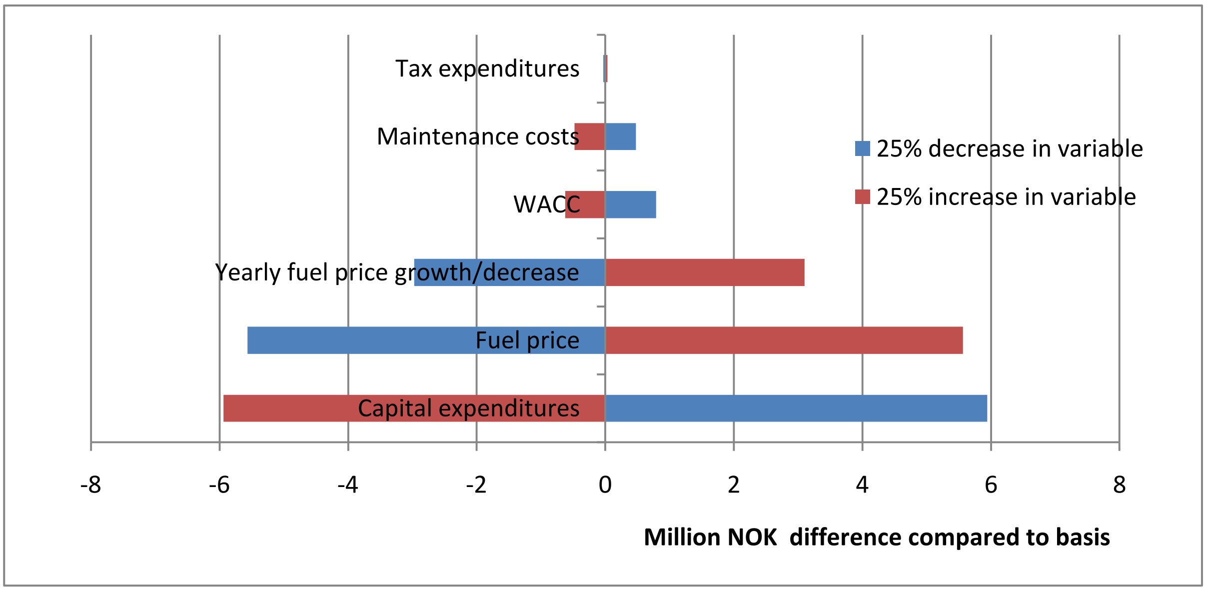


Figure 30: Tornado chart based on scenario 1 input for the vessel Solstraum: Basis is cost difference LNG - MGO. In this case the cost difference is -2 470 938 in favor of MGO. (Negative number means MGO is cheaper). The big impact of capital expenditures in this case is due to the vessel's low remaining lifetime.