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An assessment of optimal investment decision for emission control compliance for Odfjell SE.

Comparison of traditional DCF valuation and Real Option valuation as decision tools.

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Abstract

Increased focus on emission from the shipping sector has enforced new stringent regulations for the international maritime industry. Ship owners are forced to innovate and respond to the new regulations in a cost effective manner. The objective of this paper is to present the most prominent abatement solutions and assess the economical aspects associated with these. Our final analysis intend to identify the optimal investment decision from a traditional discounted cash flow (DCF) model and compare with results from a more comprehensive real option analysis (ROA). More precisely we hope to convince that the option to defer an investment decision offers managerial flexibility that should be given a considerable value.

The applied valuation methodology for the real option pricing is the binominal approach with risk neutral probabilities. The framework, method and type of option is explained, and visualized thru diagrams in our thesis. The principal conclusion is that the optimal investment decision from both NPV analysis and ROA is dependent on the expected remaining lifetime of the vessels. ROA incorporates the value of deferral and the reduction of risk by postponing the decision. Our result from the ROA indicates a change in optimal investment horizon from the standard DCF.

Preface

This thesis is submitted by two students for the Master of Science in Economics and Business Administration at the Norwegian School of Economics (NHH) in Bergen, Norway.

The authors have specialized in different disciplines: "Financial Economics" and "Business Analysis and Performance Management". Our common interest for investments and the shipping sector led to our rewarding collaboration.

Participation in the shipping course ENE431 Shipping and Offshore Markets entailed the increased interest for ship management and the inherent risk in this business. During a summer internship at one of the world largest chemical tanker operators Odfjell, discussions regarding forthcoming global emission restrictions came up at the lunch table. The topic was discussed by the authors of this thesis and marked the start of our master thesis. After initial literature review and contact with industry actors, our impression was a near state of laissez faire attitude among shipowners with regard to possible impacts of the forthcoming regulations. This observation became the motivation to explore possible approaches to adapt to new situations in the most cost effective manner.

Working with this dissertation has been challenging but rewarding. Odfjell deserves credits for their accommodation and especially Knut Erik Fredriksen and Erik Hjortland for providing vessel data and technical insight. Thanks to Michele Acciaro, assistant professor at the Kühne Logistics University for guidance in methodology and model development. And finally, thanks to our supervisor Roar Os Aadland for helpful guidance and comments during the process.

Bergen, June 2015.

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1.0 Introduction

Global shipping is environmentally superior compared to other transport sectors e.g. road transportation or trains; nevertheless it makes a substantial contribution to global air pollution and greenhouse gas (GHG) emissions. The environmental impacts from shipping have not been sufficiently emphasized during the last century. Until recently, reduction of more observable emissions recognized onshore e.g. in road transportation has taken most of the focus. Emissions from global maritime transport accounted for approximately 3% of the total global GHG emissions in 2007 and are expected to increase along with expected population and GDP growth (IMO, 2014). Demand for shipping is closely linked to GDP development and approximately 90% of international world trade is carried by maritime transport. As the world population and GDP are expected to grow in the future, action must be taken to prevent emission from shipping to rise further.

The regulatory context for environmental performance of global shipping is the International Maritime Organization (IMO) through its International Convention for the Prevention of Pollution from Ships (MARPOL) and its Annex VI. The first Emission Control Areas (ECAs) were established by IMO in 2005 through the MARPOL convention, but had rather limited consequences due to non-stringent regulation. From January 2015 far more stringent regulations were enforced with maximum sulphur oxide (SOx) emission limit of 0.1% in ECAs. The legislation becomes even more intricate from 2020 when new global restriction limits of 0.5% SOx emission content will come into enforcement. The purpose of this study is to assess conceivable approaches for Odfjell to adapt to global 2020 regulations. Practically these restrictions implies that 100% of Odfjell`s operations are subject for 0.5% SOx restriction limits. For a deep-sea operator three options for compliance is commercially available, thus considered in this paper: LNG conversion, scrubber retrofit or propulsion on distillates.

Decisions regarding LNG, scrubber or distillates are affected by a trade-off between high investment costs and low operational costs; or a low initial cost with high operational costs. The optimal achieved value is a function of the vessels remaining lifetime and expected future fuel prices. Despite uncertain future fuel prices, a discounted cash flow model (DCF) is typically applied as decision tool. The problems with applying a simple DCF model for this purpose is the omission of uncertainty in price differentials between oil derived fuel, LNG and uncertain capital expenditures. DCF models are based on basic financial principles and

use a constant capital cost as discount factor. This solely implies a focus on the value of investing now or never (Trigeorgis, 2002). However, it is evident that a non-profitable investment in one period can turn out to be profitable in the next time period. This implies that there is a value of deferring an investment decision. To incorporate the value of deferral, we have approached a Real Option Analysis (ROA). The model has a discrete investment horizon over a five-year period and reveals the optimal time for the optimal investment.

1.1 Literature review

With increased focus on global warming and environmental concerns over the last years, increasingly stringent emission control in the maritime sector comes as a natural consequence. Accordingly, the contribution from research and reports regarding environmental compliance and cost optimization has experienced a steady growth. The introduced restrictions are obviously a supplementary risk factor in a business that is already highly exposed for uncertainties and jeopardized environments. Kavussanos and Visvikis (2008) elaborates financial instruments e.g. futures/forward contracts and how these are applied to mitigate price risk, credit risk, pure risk etc. Alizadeh and Nomikos (2009) also illustrate the application of financial options as a hedging tool. Financial instruments are crucial in risk management for shipping and this paper presents an approach based on the same principles as a financial option.

The rapid growth of international shipping has been prominent since the 1970`s and its share of anthropogenic emissions of Sulphur oxides (SOx) and Nitrogen oxides (NOx) is significant. In the period from 2007-2012, SOx and NOx emissions from international shipping accounted for respectively 13% and 15% of global anthropogenic emissions. This corresponds to approximately 3% of global CO_2 emissions (DNV, 2014). Air pollutants have proven negative effects on climate, air quality and human health (Endresen et al. 2010; Fuglestvedt et al, 2009). However, technical solutions for compliance with IMO regulations are available to a certain extent. Adaption to new regulations implies increased costs for shipowners in terms of required investments or higher operational costs. In order to assess viability for available options, DNV (2012) presents a report considering technology uptake in the maritime industry based on several scenarios. The report concludes that GDP development, future fuel prices and regulatory incentives are decisive factors affecting how technology investment in the world fleet will develop towards 2020. Several reports claim LNG as the main alternative option to conventional fuels, depending on uncertain variation in future fuel prices

(MARINTEK, 2013; Greenship, 2012; DNV, 2012). Having said that, scrubbers appear to be preferred among shipowners due to beneficially low investment- and operational costs, and sufficient emission reductions (DNV, 2012). Another interesting finding comes from a comparison study of the total well-to-wake energy consumption for scrubber vs. distillates (Hongrui et al, 2012). Here it is evident that scrubber used with heavy fuel oil, potentially can reduce SOx emission with lower well-to-wake energy consumption and GHG emissions than switching to distillates.

An ECA study carried out by Lindstad et al (2015) claims that the optimal compliance investment is a function of engine size, annual fuel consumption inside ECAs, and fuel prices. It reveals that low oil price favours distillates or scrubber, while a LNG price equal to or below oil price makes LNG conversion advisable. Lindstad, also discuss the issues with substitution effects that may occur if LNG becomes more competitive versus heavy fuel oil (HFO). Refineries then have the option to sell HFO to power plants to a lower price than received from the shipping industry; or to make large investment to transform HFO to lighter fractions; or reduce price of HFO. DNV (2013) presents a stochastic two stages model to optimize choice of abatement solution and optimal time for installation. He emphasizes the risks associated with irreversible investments in immature technology and thus giving up opportunity to obtain the latest information and/or technology.

Previously published master theses by student from the Norwegian School of Economics have valuated different abatement solutions. Olsen and Baumgart (2010) find evidence for LNG as an environmentally friendly and cost competitive solution for Platform Supply Vessels and ferries operating in the Norwegian short sea segment. A study performed by Alvestad (2011) for short sea shipping ranks the alternative abatement solutions distillates, scrubbers and LNG as a function of expected remaining lifetime of vessels and future fuel prices. The findings in both studies are consistent with the general consensus in reports from DNV (2014) and Greenship (2012) where payback time for LNG, scrubber and distillates are proved to be a function of remaining lifetime of vessels and sailing days inside ECAs.

Use of real option analysis is a common decision tool in shipping industry (e.g. Alizadeh and Nomikos, 2009; Bendall and Stent, 2005;). However, literature regarding real options for investment in emission abatement solutions is rare. Acciaro (2013; 2014) presents a real option approach for investment in ECA compliance solutions. The result from his research

shows a promising method for the use of ROA within green shipping. It also shows that the method gives an additional value for the shipowners by deferring the decision into the future. This is due to the possibility of delaying an investment, where the shipowners avoid being locked in a technology that is not economically optimal. Our proposal as a contribution to the literature is an experiment to reveal how the method applied in Acciaro (2013; 2014) will alter the optimal investment decision when compared to a traditional NPV analysis. Unlike the majority of reviewed literature, the scope of this paper is limited to compliance with the forthcoming global restrictions of <0.5% SOx emissions only. The presentation is a two-staged analysis where both analyses are based on the same input data and key assumptions.

1.2 Research question

The purpose of this thesis is to shed light upon the value of managerial flexibility in terms of real options and the option to defer an investment decision, until more information about the market is available.

DCF methods do not incorporate the value of managerial flexibility while a real option approach does this. Our approach is to first perform a traditional DCF analysis and compare results from a real option analysis. This divides our research question in two parts:

The first part relates to the application of the DCF method for decision-making:

"What is the most economically favourable solution for emission control compliance of LNG retrofitting, scrubber installation or propulsion on distillates?"

Part two of our research question concerns the real option approach:

"Should shipowners invest in LNG or scrubber in 2020 to comply with ECA restrictions from 2020, or is it more advisable to run on distillates until more market information is at hand?"

Both research questions are related and rely on identical input data and key assumptions.

1.3 Scope and limitations

Our focus in this paper is the implementation of the global IMO limit of <0.5% SOx emission from 2020, or the possible postponement to 2025. Only existing vessels are considered and our results rely on known or assumed fuel availability, engine technology, and fuel costs. Energy Efficiency Design index (EEDI) and NOx compliance only applies for new-buildings and are kept outside our scope. A basic assumption for this thesis is that LNG propulsion is practically and technically viable for vessels operating in global waters. Thus, we implicitly assume that LNG bunker infrastructure will develop substantially with an increase in LNG propelled vessels. Low Sulphur Heavy Fuel Oil (LSHFO) with sulphur content <0.5% is already available and Odfjell have their own refineries to produce this. However, they were reluctant to share market prices with us. As no public sources offer price information on LSHFO we have assumed MGO and MDO as the only fuels that comply with global SOx limits from 2020. This eliminates concerns regarding routing of ships (e.g. time spent in ECAs, speed optimization etc.)

The ROA is based on the first five years after the emission regulation is implemented in 2020. Market assumptions for this timeframe makes the data prognosis uncertain and difficult. Changes in market outlook forward to the regulation will alter the option values, requiring new calculations for the vessels. Our analysis uses specific annual data from three case vessels of the Odfjell fleet. These data do not include port side consequences. Thereby the valuation model relies on few variables such as average annual fuel consumption, CapEx, and expected remaining lifetime of the vessels. It is important to keep in mind that the results from our analysis do not in any case advise a strategy for the total fleet of Odfjell, nor any other shipping enterprises. The results must be seen in connection with recognizable conditions.

1.4 Structure

The introductory chapters of this thesis are meant to provide the reader basic insight to the chosen topic and what to expect in further reading. Chapter two introduces existing maritime authorities and concretization of current emission legislation. In chapter three the available abatement solutions is presented with a brief introduction to the oil and gas market. These are informative sections providing the reader with useful background information necessary to understand the underlying assumptions that form the basis for our results. Finally, a short presentation of our case company Odfjell is given before the analysis and results are elaborated in the last two chapters.

2.0 Emission control regulation in shipping

Focus on green shipping is a result of increasing activity and the effect of the coherent air pollution emission. The legislation and regulative framework for the shipping industry is more complex then for other sectors, but not all maritime areas share the same characteristics. Due to heavy traffic, some areas are more vulnerable to air pollution than others. Shipowners in these sectors would either have to adapt to regional rules, or move their fleet.

2.1 Regulations

According to Stopford (2009), the regulatory system includes six principal participants: i) Classification societies that regulate technical and operational standards for ships. ii) The United Nations sets the broad framework for maritime law. iii) Flag States regulate taxes, compliance with the maritime safety conventions, crewing and naval protection for each vessel. iv) Port States ensures that the ship follows the accompanying law of the port state when trading. v) IMO the UN specialized agency is responsible for shipping safety, security and prevention of marine pollution. vi) The International Labour Organization (ILO) promotes social justice and internationally recognized human and labour rights.

SO_X emission regulation from IMO comes from MARPOL- Convention Annex VI from May 2005. Annex VI restricts the emissions of substances which attack the ozone layer, NO_X , SO_X, volatile organic compounds and exhaust of incinerators (DNV, 2009). This convention is aimed at preventing and minimizing pollution in the shipping industry. This includes both accidental pollution and routine operations. Today it includes six technical annexes (IMO, 2015). Since NO_X and SO_X are directly linked to quality of the fuel, it will give economic consequences for the shipowners. NO_X emission is regulated by MARPOL 73/78, Annex VI, Regulation 13 (DNV, 2009). In addition, Norway has it own NO_X tax system, created to work as an incentive for ships in Norwegian waters to reduce emissions (Finansdepartementet, 2013). Odfjell do not get support from the NOx fund as their operations are in international waters.

2.2 SOx, NOx and emission limits

The primary source of NOx is the burning of fossil fuel. It includes nitric oxide (NO), nitrogen dioxide (NO2) and other oxides of nitrogen. NOx emissions depend on fuel quality and the vessels engine type. The basis for the NO_X regulation is due to the damaging of the

ozone layer, which leads to damage on vegetation, human health and contributes to global warming. It will also lead to eutrophication (over-fertilisation), which negatively affects biodiversity both on land and in coastal waters (AirClim et al, 2011b). The main oxides of sulphur are sulphur monoxide (SO) and sulphur dioxide (SO_2), with SO_2 being the main oxide. In general, shipping uses HFO with high content of SO_X. HFO is 2,700 times dirtier than the fuel used in the road sector (AirClim et al, 2011a). SO_X regulation is implemented to reduce the damages SO_2 has when it is mixed with rain. This forms sulphuric acid, also called acid rain. The effects on the environment due to acid rain are among others acidification of lakes and fish death.

The ECA zone including the North Sea, Baltic and North America have stricter regulations of NOx and SOx than the rest of the world. For the ECA zone the maximum limit is 0.1% from 2015, while today's global limits outside ECA are maximum 3.5% SOx content. In 2020, a new global limit of maximum 0.5% sulphur content will be implemented outside ECA (see Figure 1). A review for the time of implementation will take place in 2018 with a possible consequence of delaying the implementation date until 2025 (DNV, 2009)
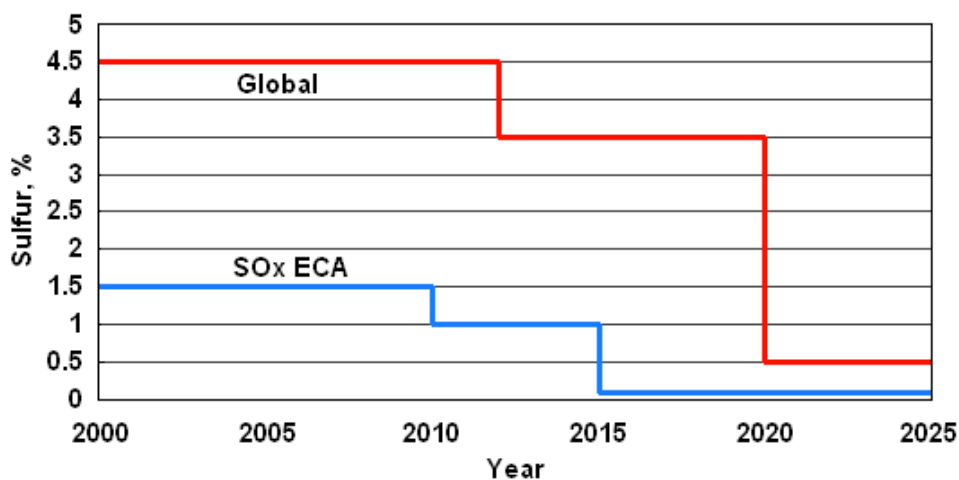
Figure 1: Evolvement of the emission limits for SO_X inside ECA and globally (DNV, 2009)

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The NO_X regulation deals with the emission limits for new constructed ships. In 2011 the NO_X emission limit was globally reduced to tier 2 for ships constructed on or after 2011. After January 1st, 2016 this limit will be reduced to tier 3, but only inside the ECA (see Figure 2).

The below graph illustrates the allowable NOx emissions from diesel engines:
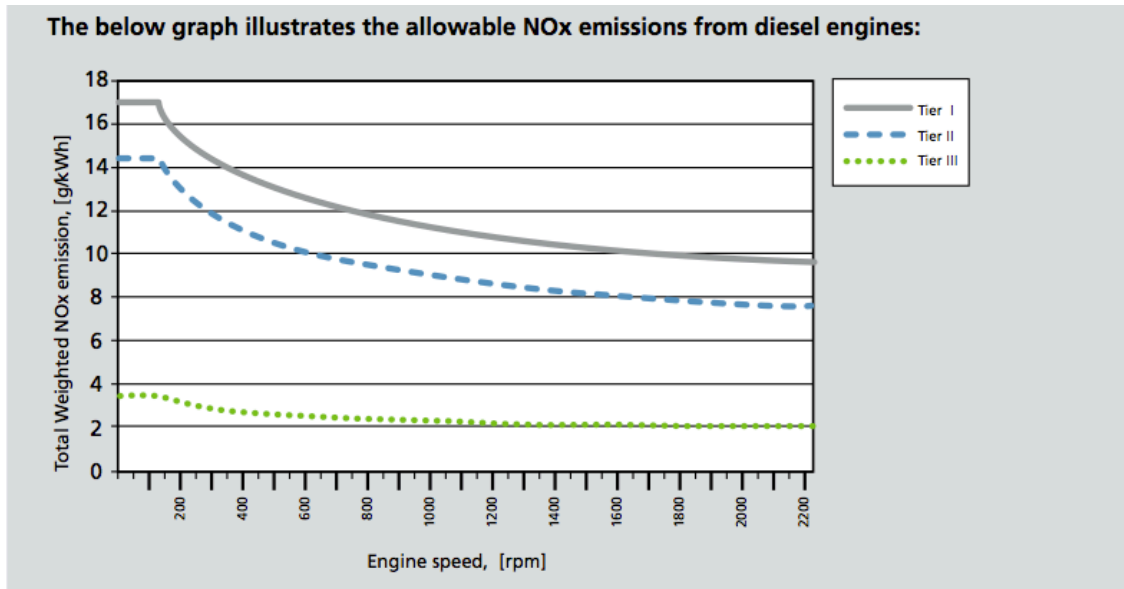
Figure 2: NO_X emission limits for different tier levels (IMO, 2014).

Today the coasts outside Norway, Mexico, Japan and the Mediterranean are seen as potential new zones for ECA (Clarksons, 2014). There are also other regulations that the shipping industry has to take into consideration. MARPOL Annex VI- Energy Efficiency Design Index (EEDI) regulates Vessel Design/Efficient Technology. This gives new regulations on the efficiency on the technology of hull, propeller, rudder and engine. Also, the Hong Kong Convention can enter into force, which regulates the recycling of ships. This convention will enter into force 24 months after 15 states have ratified it. Today Norway is the only signatory. This will ensure that shipowners have an inventory of hazardous materials, a ship recycling plan, permission from the flag state to conduct a final survey and an international ready for recycling certificate (Clarksons, 2014).

3.0 Technical and commercial aspects of abatement solutions

Chapter three mainly provides the reader a better understanding of distinctions between available abatement solutions and associated costs. A short introduction to the oil- and gas market characteristics is given to substantiate underlying assumptions taken for price scenario projections.

New regulations encourage innovation in maritime sector and forces reliable, technical- and commercially viable abatement solutions. Basically the most prominent and mature technologies are considered in this paper.

Technical
- Robust solution
- Future viability
- Compatibility with future fuels
- Maintenance

Commercial
- CAPEX vs OPEX
- Commercial advantage
- Future cost of fuel
- Change to resale value

Secure/reliable
- Global availability
- Infrastructure
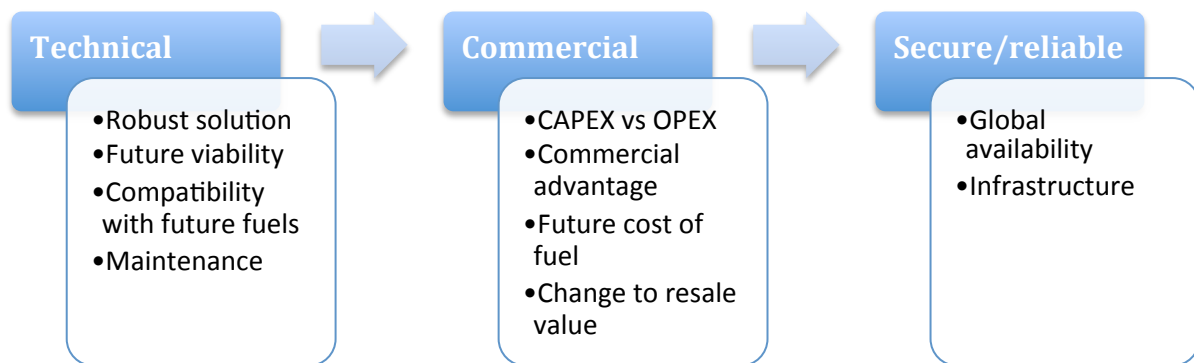
Figure 3: Summary of three essential criteria for a viable abatement solution.

Figure 3 illustrates three essential criteria for a successful abatement solution. Intuitively, innovative technical solutions must be robust and compatible with existing and expected future technology. Abatement solutions considered in this paper are mature technologies considered to be conventional for several purposes. However, all abatement solutions represent a change from traditional technology and thus have an inherent risk for technical failure. Regardless of technical challenges, CapEx and OpEx are two other elements affecting the investment decision. The trade-off between high upfront investment costs and low operational costs, or the opposite, is a function of the expected remaining lifetime of the vessel. This implies different optimal solution for vessels with different remaining lifetime. Based on a review of existing marine engine technology and expected technology development, DNV (2012) suggest the most realistic fuel options for SOx compliance to be distillates, scrubber or liquid natural gas (LNG).

3.1 Alternative 1: Distillates

The first and least comprehensive solution for the SOx compliance is a fuel switch from residual fuels to refined distillates. Switching to distillates is a permanent conversion of the primary fuel- and engine system and is required to be compatible for propulsion on distillates. The technical adjustment implies a moderate investment cost compared to a retrofit for LNG or scrubber. Distillate fuel is one of three major types of marine fuels. The second type is residual fuel e.g. HFO, and the third type is a combination of the two to create intermediate fuel oil e.g. IFO 380 (EPA, 2008). Distillates are pure quality products refined from crude oil, containing less sulphur and residual particles. The refining and desulphurization process is costly and the price of distillates is significantly higher than for traditional fuel. For international shipping, Marine Gas Oil (MGO) or Marine Diesel Oil (MDO) is the commercially available distillates fuel that complies with the 2015 ECA restrictions of 0.1% sulphur content. Recently, another LSHFO product has evolved with a maximum sulphur content of 0.5%, in order to be an alternative fuel compliant with the global 2020 restrictions. However, as there is no current available public price for 0.5% LSHFO, calculations in this paper is based on available prices for distillates. One of the main drawbacks by switching to distillates is the significantly higher fuel price compared to traditional fuels. The price spread between distillates and traditional fuels are illustrated in Figure 4. As the case vessels in this thesis mainly bunker IFO 380, Rotterdam IFO 380 prices are used as a basis for comparison. For distillates, Rotterdam MDO prices are considered as representative.
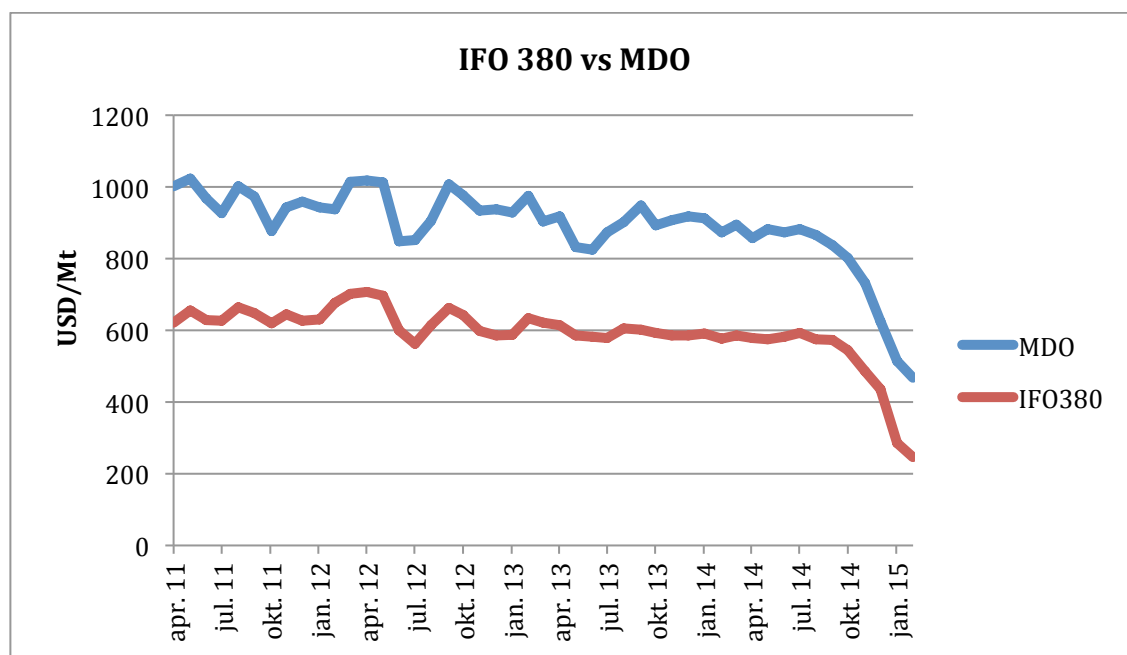

Figure 4: Illustrates the spread between IFO380 and MDO prices, time period 2011- 2015 (Bloomberg, 2015).

On average, MDO is priced 62% higher than IFO 380 on an USD/mt basis over the last 5 years. Our analysis revealed a positive correlation rate between the two fuel types (Appendix O). If the MDO/IFO is constant, this implies a higher spread in absolute numbers when the price levels are high, and opposite when price levels are low. MDO is a pure product with a higher calorific value than IFO 380, which means that less MDO is required to create the same amount of energy as with IFO 380. Recalculated on a dollar per unit of energy, price for MDO is on average 66% higher than IFO 380 on a USD/MJ basis. Note that energy content will vary depending on sourcing location (EMSA, 2010). Historically the price of IFO 380 has followed the oil price closely. The volatility in the oil price and thus the volatility of IFO 380 and MDO make forecasting of future fuel prices highly uncertain. A technical report published by EMSA (2010) expresses uncertainty whether the infrastructure and supply of distillate fuels is sufficient to meet the new demands in the market. Several studies suggest that infrastructure and supply of low sulphur fuel inside ECAs is sufficient to meet the expected increase in demand when 2015 restrictions are implemented. Nevertheless, it is uncertain how the demand for refined fuel products will develop beyond this date, and if the global refining capacity and supply is sufficient to satisfy the expected increase in demand due to the 2020 implementation (EMSA, 2010).

3.2 Alternative 2: Scrubbers

Scrubber is an exhaust cleaning technology that simply wash out SOx from exhaust and keeps emissions below the current and planned ECA restriction limits. Thus, scrubbers allow propulsion on fuels with high sulphur content. The cleaning performance of scrubbers have been widely discussed and adequately tested in different test regimes. One test regime revealed a scrubber performance ratio for SOx cleaning between 65% to 94% efficiency (Ritchie et al, 2005). For comparison, scrubber manufacturers report a cleaning performance rate from 90-99% with favourable operating conditions. We distinguish between Open-Loop-System (OLS), Closed-Loop-System (CLS) and Hybrid scrubbers due to different technology and performance ratio. Water flow rate and size of scrubbers are crucial to the performance ratio (DEPA, 2012). Typically, the water flow rate of an OLS is higher than for a CLS, thus the cleaning performance is higher for OLS. The hybrid scrubber, which is a combination of the two systems have a performance ratio in between OLS and CLS. Table 1 summarize the capacity of SOx cleaning for the different types of scrubbers.

Parameter	Modes	Max sulphur content in fuel in %
SOx	OLS	3 to no limit*
	CLS	3.5
	Hybrid	3.5-5

Table 1: SOx cleaning performance with different operating modes. Limits for maximum sulphur content in fuel required achieving air emissions equivalent of 0.1% sulphur. Numbers refers to standard commercial offers from vendors (DEPA, 2012). *No limit requires oversize scrubber, free water flow rate and/or high chemical consumption.

In the scrubbing process, additive chemicals convert the sulphur to a sulphuric acid, also known as wastewater. There is an on-going discussion on how to store and handle the waste in an environmentally friendly matter. Waste-handling systems differs with type and specifications of the scrubber, and in some waters regulations regarding use of scrubbers has occurred. In accordance with divergent global restrictions and requirements, manufacturers now offer a range of scrubbers to meet operators' demands based on required technology in their operating areas (Bureau Veritas, 2014).

Open loop scrubbers are open systems utilizing ambient seawater for exhaust scrubbing (Bureau Veritas, 2014). Seawater is alkaline caused by its natural content of calcium-based salts in solution. In a chemical process, the calcium-based solution reacts with, and neutralizes SOx from the exhaust. This implies that the efficiency of the OLS is also dependent on the alkalinity of the ambient seawater. Thus, OLS are best suited for open ocean voyages where alkalinity is high when compared to areas with a higher content of fresh water (e.g. The Baltic Sea). The principle of the open loop scrubber is to cool down the temperature of the exhaust to near ambient. Hydrocarbons will then condense on soot particles in the exhaust and suspend in the drain water. After scrubbing, the seawater goes through a filtering process where heavy metals and particulate matter is removed before discharged into the sea as wastewater, containing sulphur from the exhaust (Kjølholt et al, 2012).

The closed system, also referred to as Fresh Water System, operates with use of fresh water chemically treated with caustic soda (NaOH). The chemicals react with, and neutralize the sulphur in the exhaust (Wärtsilä, 2013). To minimize the water intake and effluent discharge water, the water used for scrubbing is recycled in a closed system that creates waste. Accordingly, this requires facilities for waste handling and storage on-board and in ports, thus implying a more costly and complex solution than OLS (Bureau Veritas, 2014). There is an

on-going discussion regarding the environmental impact from OLS scrubbers and in some areas this type of scrubbers are already prohibited. Hybrid scrubbers combine the closed loop system and the open loop system to use the advantages of both technologies. This gives operators the flexibility to switch to a closed loop system when arriving if necessary.

3.2.1 Challenges

A scrubber retrofit enables shipowners to comply with the new regulations with a moderate up-front investment cost and low operating costs compared to propulsion on distillates. The profitability and payback time for a scrubber retrofit is accordingly dependent on future development in fuel prices and the spread between IFO 380 and MDO. Depending on ship specific design and specifications, a scrubber installation potentially confiscates valuable space otherwise used for cargo carrying. However, a scrubber retrofit only has a minimum of the space, weight and instability challenges experienced with a LNG conversion. In the chemical tanker segment, volume is the limiting factor and loss of freight volumes could be a decisive argument for choosing scrubbers over LNG when retrofitting. For new-buildings, designing the ship for use of such equipment will minimize the space problem. A drawback with scrubber is the decrease in cleaning performance ratio when slow steaming and operations in waters with insufficient alkalinity. To compensate this, a 10-25% increase in scrubber size will improve the efficiency and thus implies potential cost savings for operations in open waters (Greenship, 2012).

3.3 Liquid Natural Gas (LNG)

LNG is natural gas in liquid form after a liquefaction process involving removal of certain components such as dust, acid gases, helium, water and heavy hydrocarbons. The gas is then condensed into a liquid at close to atmospheric pressure and cooled down to approximately -162 degrees. LNG is compressed to $1/600^{th}$ the volume of natural gas in gaseous state and thus opens up for a more flexible use of natural gas. Natural gas is a non-renewable energy source formed in organic layers in the crust of the earth, exposed for high pressure and intense heat for millions of years. Natural gas extraction and usage have roots from ancient times in varying scale and for different purposes. It was first in the 20th century that the construction of effective pipelines and infrastructure commercialized natural gas for common application e.g. electricity production, home cooking and heating (AGPA, 2015).

World* total primary energy consumption 2012

- Natural Gas 15 %
- Oil 41 %
- Coal** 10 %
- Other*** 4 %
- Biofuels and waste**** 12 %
- Electricity 18 %

Legend: Natural Gas ▫ Oil ▫ Coal** ▫ Other*** ▫ Biofuels and waste**** ▫ Electricity
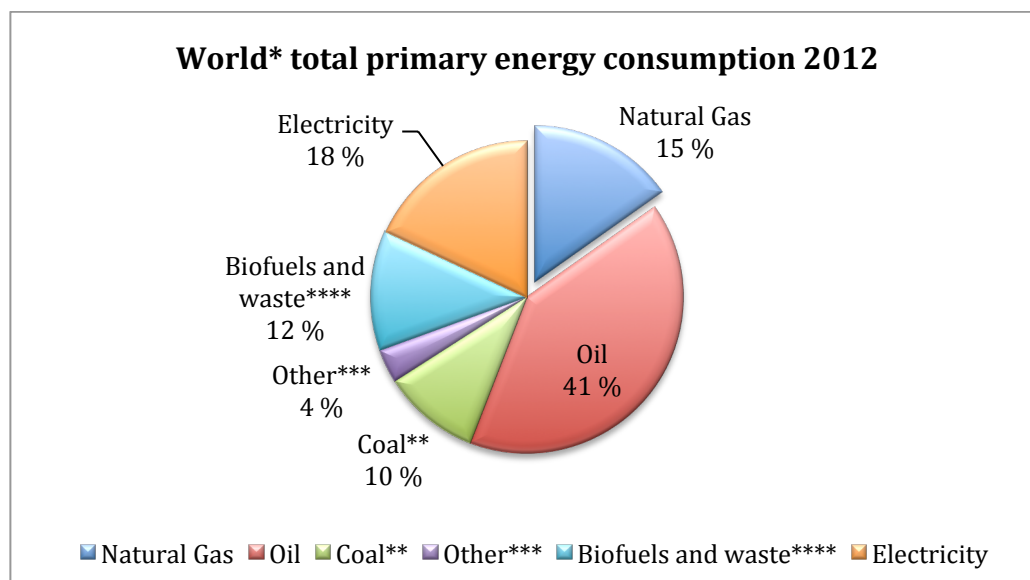
Figure 5: Illustrates the world primary energy supply in 2012. *World includes international aviation and international marine bunkers. **Peat and oil shale are aggregated with coal. ***Includes geothermal, solar, wind, heat, etc. ****Data for biofuels and waste consumption have been estimated for a number of countries (IEA, 2014).

Approximately 15% (see Figure 5) of world energy consumption in 2012 came from natural gas (IEA, 2014). According to a report written by Fevre (2014) regarding prospects for natural gas as transport fuel in Europe, use of natural gas in transport and shipping sector represents only a tiny fraction of the total world natural gas consumption. Immature technology, high costs and poor infrastructure is part of the explanation for a moderate development in natural gas as a preferred mode for powering a vehicle or a ship. However, improvements in technology, cost efficiency and availability of LNG have caused an increase

in LNG powered vehicles in road transportation during the last decades. Most recently, LNG powered ships is more prevalent, especially for route going shipping in ECAs.

Natural gas is the cleanest of all fossil fuels and a superior fuel in order to comply with the new emission regulations. In addition to SOx compliance, LNG is the only commercial alternative fuel that complies with NOx emission restrictions without additional exhaust cleaning technology. Thus, LNG propulsion will ensure emissions kept at a minimum level below any restriction limits. In Table 2, LNG is found with the lowest emission levels in 5 of 6 parameters when compared to oil and coal.

Fossil Fuel Emission Levels			
- Pounds per Billion Btu of Energy Input			
Pollutant	**Natural Gas (LNG)**	**Oil**	**Coal**
Carbon Dioxide	117	164	208
Carbon Monoxide	40	33	208
Nitrogen Oxides (NOx)	92	448	457
Sulphur Dioxide (SOx)	1.0	1.1	2.6
Particulates	7.0	84.0	2.7
Mercury	0.000	0.007	0.016

Table 2: Overview of emission level from three fossil fuels: natural gas, oil and coal (EIA, 1999).

Based on the superiority illustrated in Table 2, LNG is not inconceivable to be the fuel of choice in a future energy mix for shipowners. Mature gas engine technology is now available for all types of piston engines, and can be delivered as pure gas concept or as a dual fuel-concept that enables switching between different liquid fuels.

3.3.1 Challenges
One of the main issues with natural gas as bunker fuel is its natural appearance in a gaseous state. Despite the fact that the LNG volume is only 1/600 of the volume in gaseous state, the energy density is low and requires 1.8 times higher volume than traditional fuel oil to produce equal amount of energy. In addition, storing of LNG requires insulated tanks with a maximum filling rate of 95%. Consequently, the required tank volumes for storing require 2.3 times

more space than traditional fuel tanks (DNV, 2010). Accordingly, the question of efficiency and practical feasibility for LNG propulsion in the deep-sea segment is raised. Odfjell sails across vast distances every year, which in turn will require large LNG storage tanks that may conflict with the original autonomy of the vessel. Depending on ship design and physical constraints, placement of storage tanks may affect the stability centre of the vessel, which in turn may affect cargo intake. The actual instability effect and possible cargo intake reduction needs proper assessment in each specific case. In this paper we assume that a LNG conversion will not have a significant impact on vessel stabilization and accordingly no effect on the operability or cargo volumes. A sufficient grid of LNG bunker facilities and a sound global infrastructure for storage and distribution is essential if LNG intends to be a viable fuel option in the future. For shipowners considering LNG conversion, the slow development of new LNG bunker facilities creates uncertainty and appears to be an impediment for investing in LNG (DMA, 2012).
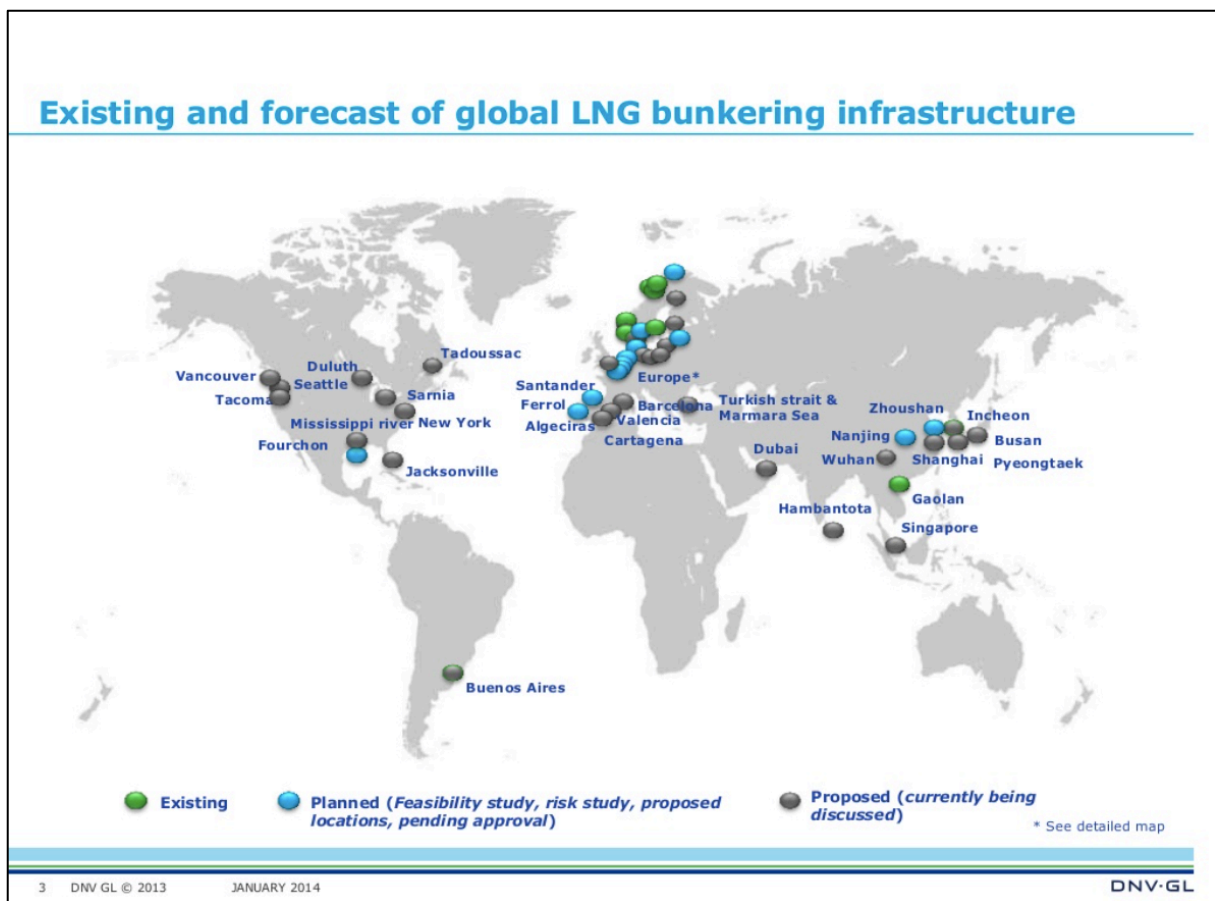

Figure 6: Existing and future planned or proposed bunker facilities (DNV, 2014).

The map in Figure 6 shows a geographical distribution of already existing LNG bunker facilities and a number of facilities being proposed or planned. As we can see, the main clusters are located in US, Europe and Asia. In addition, a DNV-led joint industry project

from 2013 identified 10 advantageous locations in Australia where LNG bunkering is possible (DNV, 2013). A potential shift in LNG supply from Middle East to Australia enlarges availability of LNG for Europe. Project development and investment in natural gas is capital intensive, complex and time consuming; an aspect that hold back investors. To compensate this, investors in natural gas facilities have traditionally sought to cover their future production with long-term sale and purchase agreements (SPAs). The arrangement of such agreements is one of the time consuming processes and involves several parties for risk sharing. SPA enable risk sharing between seller and buyers where seller bear the price risk and buyers bear the volume risk (Zhuraleva, 2009). However, we expect SPA to be inconvenient for shipowners to accept, due to uncertainty in future fleet composition and their actual demand for this commodity.

As the fleet performance manager from Odfjell SE well explained it:

"No shipowners, with daily variations in trade routes is willing to buy long-term contracts before they even have a LNG propelled vessel."

Eirik Hjortland, Fleet Performance Manager – Odfjell SE

Intuitively this cause a causality dilemma, insinuating that potential developers and investors in LNG bunker facilities will be on hold in anticipation of an increase in demand for LNG. On the other side, shipowners are reluctant to invest in expensive LNG powered vessel due to the great uncertainty regarding future LNG bunkering facilities. For Odfjell, it is visible in the map from Figure 6 that LNG bunker facilities are already available for the frequently traded route Houston – Rotterdam. Another frequently visited port by Odfjell, Singapore has proposed construction of LNG bunkering. This may imply LNG as a feasible option for parts of Odfjell`s fleet before LNG infrastructure is fully developed.

3.4 Natural Gas market characteristics

To substantiate underlying assumptions for fuel price scenarios applied in the final analysis it is relevant to describe some market characteristics for natural gas and LNG trading. The global LNG market is divided into distinct regional markets. What is left of correlations between the markets has eroded since 2009 (see Figure 7). From the figure, we consider the

current world LNG market as separate markets with varying underlying price drivers within each region.
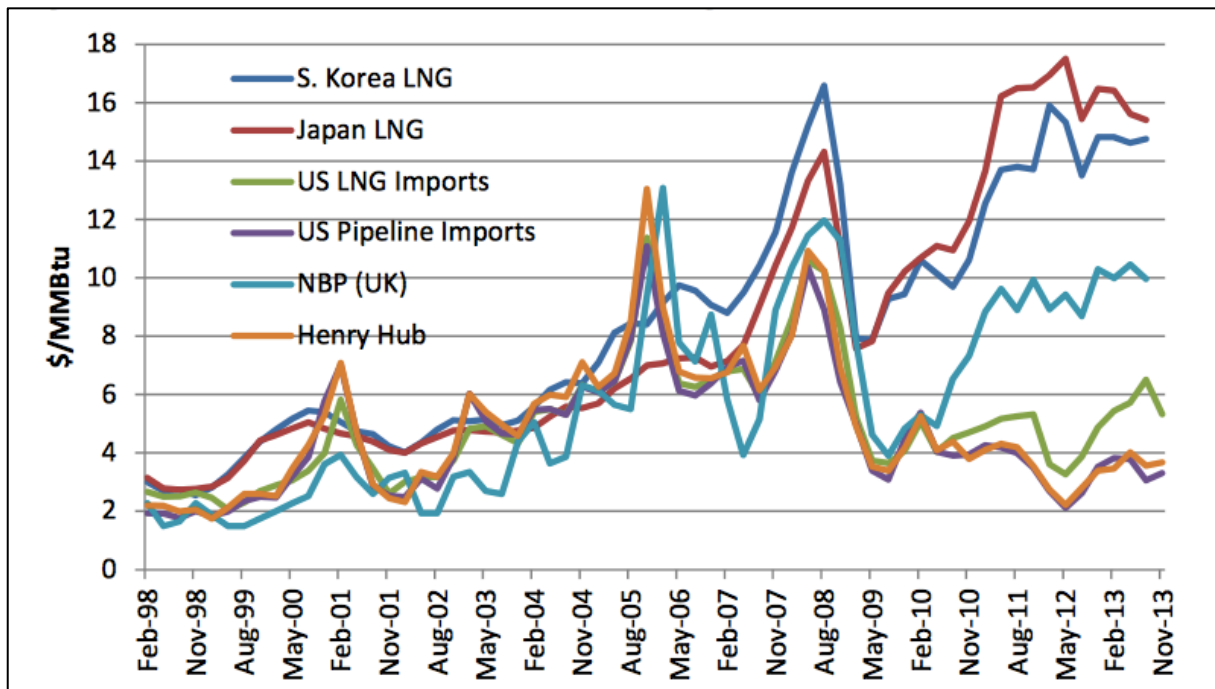
Figure 7: Development of distinct natural gas markets by region in the period 1998-2013 (Leidos Inc, 2014)

The reason for the prominent distinctions between the US, European and Asian LNG market is related to differences in political regulation and the indexation of prices. In the low price region (US), natural gas prices are determined by domestic supply and demand, also referred to as gas-to-gas competition. In recent years, lack of export facilities and domestic oversupply in the US has forcefully contributed to low natural gas prices in this region. In Europe, price of natural gas is two folded with partially gas-to-gas competition in combination with a benchmark to low-sulphur residual fuel oil. In Asia, LNG prices are mainly benchmarked against the price of imported crude oil (IGU, 2012).

Figure 8: Share of gas-to-gas competitive natural gas vs. oil indexed natural gas in different regions (IEA, 2013).

A variety of reports and research papers all seem to be unanimous that there is an on-going change in the global LNG market structure. In Europe, emerging gas hubs in Belgium, Unite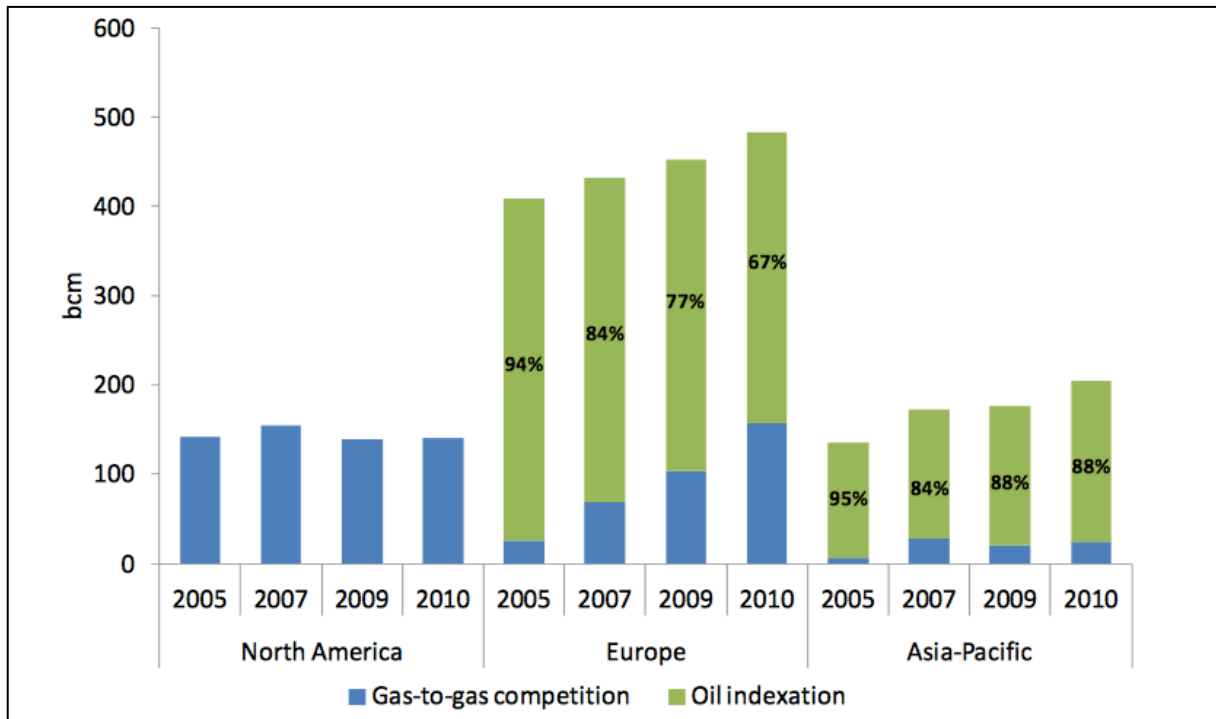d Kingdom and other countries have led to a more liquid market presenting opportunities for arbitrage trade between convergent markets. The hubs trades both pipelined gas and LNG, which in turn opens up for an increased share of gas-to-gas competition. This presumption is verified in Figure 8 where a continuously increase in European gas-to-gas pricing is illustrated in the period 2005-2010. Concurrently with the abovementioned incidents, United States experienced an extraordinary boom in natural shale gas production. Governmental incentives to develop technological innovations and private entrepreneurship enabled engineers to extract unconventional oil and gas. Since 2000, shale gas contribution to US natural gas production has increased from approximately 1.6% to 23.1% in 2010 (Wang and Krupnick, 2013). This led to a surplus of natural gas, and consequently US imported less LNG. At the same time, commercial start-up of multiple large LNG projects in Europe resulted in oversupply of natural gas in the European region as well. The competition in the market pushed the gas-to-gas prices downward and the spread between low gas-to-gas prices versus high oil indexed prices then became too obvious in Europe. This led to liberalization of the European market and strengthened the share of gas-to-gas pricing further in this region (Leidos Inc., 2014). In addition, the European Parliament introduced sanctions against Russia as a consequence of the Ukraine conflict started in 2014. This resulted in a EU obligation to

boost the energy security in Europe to avoid dependency on Russian pipelined gas in the future (De Micco et al, 2014). Secession from a Russian controlled pipeline gas import underpins our assumption of a more transparent European natural gas market.
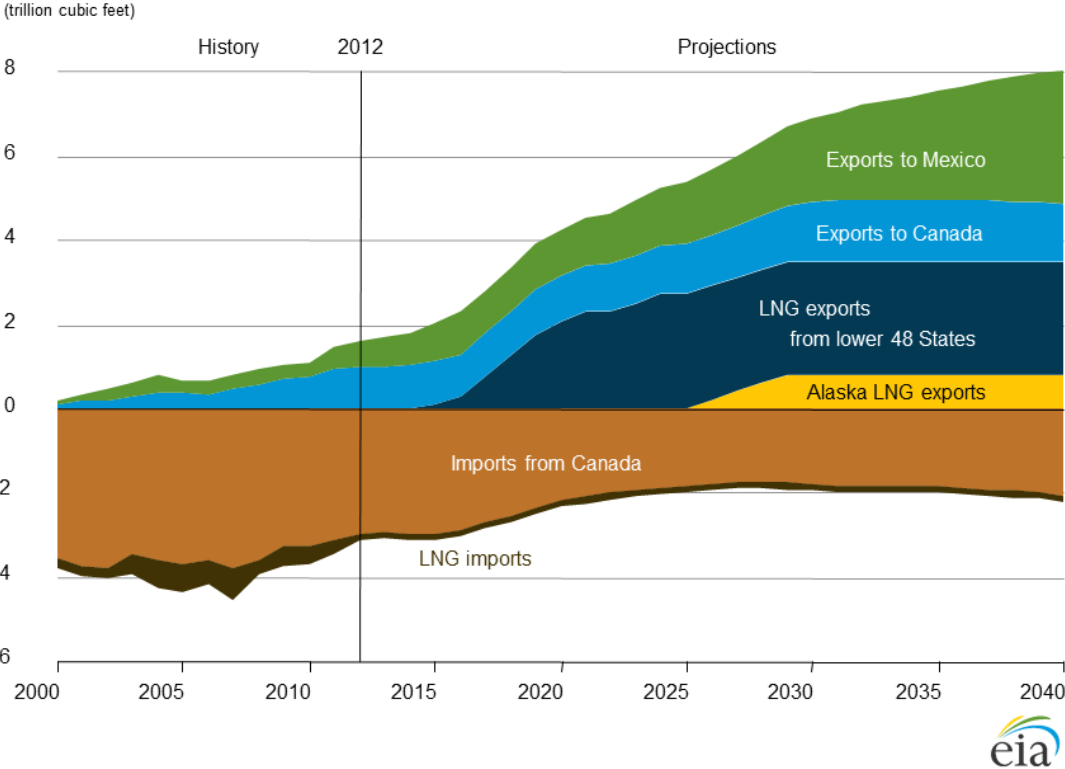
Figure 9: Historical and projected import/export balance for natural gas in US. (EIA, 2013)

It is uncertain how shale gas development in the United States will affect the global energy trades on a long-term basis. As shown in Figure 9, the shale gas boom is expected to change US from being a net importer of natural gas to be a net exporter in the future. This is in contrast to the market expectations prior to the shale gas boom. Before the boom, new LNG import terminals were planned to satisfy domestic demand. Nevertheless, lack of export facilities led to the domestic surplus that pressured US gas prices downwards. Current LNG export facilities under construction are assumed to boost the natural gas flow out from US in the future, mainly to Asia where prices have surged after the reduction in nuclear production in Japan (Hayashi and Hughes, 2013).

Market outlook

In EIA´s Annual Energy Outlook it is revealed that increase in marginal production costs and resource recovery rate leads to higher natural gas prices on a long-term basis. The same report further presents a link between the oil price and natural gas price in the European and Asian

region due to the oil price indexation. Concurrently, substitution effects are mentioned with reference to a pecking order theory, saying that levels of natural gas production, use, and export, is affected by the spread between oil- and gas price; this implies that if oil price is high, natural gas is preferred before oil as fuel for transportation, electricity production etc. (EIA, 2015a). With increased volumes of low-priced LNG export from US to the rest of the world in the years to come, it is reasonable to assume higher shares of gas-to-gas pricing and decreased distinction between regions. In theory this also implies a weaker correlation between oil prices and natural gas prices, and thus opens up for low natural gas prices even with a high oil price. The distinction between markets is however likely to be maintained due to physical constraints (shipping distances, liquefaction costs etc.), political regulation and the known energy resource allocation. As reviewed in Figure 7, Henry Hub US natural gas prices are fairly low compared to rest of the world. Increased export of LNG from the US will lead to higher exposure for high priced markets in Asia and Europe. This may entail increased US Henry Hub gas prices in the future. Asian prices are fairly high at the moment, and we believe import of low priced LNG from the US will contribute to reduce the price level in this region. In Europe, the market tends to be more liquid and prices may stabilize on todays level with increased supply of US LNG exports and higher gas-to-gas competition.

3.5 Oil market characteristics

The oil market is complex with different types of quality, both high and low sulphur content, and heavy and light crude oil. Crude oil has three different benchmarks in the world. Dubai representing the benchmark for crude in Middle East, Brent crude for the North Sea and West Texas Intermediate (WTI) for the Western Hemisphere crude oils (LLC, 2008). The different types of crude oil, which are bought and sold around the world, are priced with a discount or premium to benchmark crudes. Since crude oil is bought and sold on the open market, the market price is decided from those taking positions in buying and selling, and ultimately guided by supply and demand. Demand of crude oil is in many ways affected by economic growth. With growth comes increased production of goods, transportation and general energy consumption. As a consequence this will increase the oil price, as an effect of supply and demand. With higher oil prices comes more exploitation of oil fields as they become profitable. This will stabilize equilibrium between supply and demand. A benchmark for market supply and demand is the strategic petroleum reserves. With higher reserves than

anticipated, markets expect that the supply is higher than the demand, and opposed with lower reserves.

OPEC`s (Organization of the Petroleum Exporting Countries) function is to stabilize the oil markets by securing efficient, economic and regular supply of petroleum to consumers. They also ensure a steady income to the producers in petroleum and a fair capital return for the investors (OPEC, 2015). OPEC are heavily criticised for being a cartel, and use their market control to guide the supply of oil to benefit the member countries inside OPEC. They are capable of guiding the supply due to their 60% control of the total traded petroleum. Countries inside OPEC produce about 40% of the world's crude oil EIA (2015b). The world energy consumption is estimated to increase from 97.1 quadrillion Btu in 2013 to 105.7 quadrillion Btu in 2040 EIA (2015a). Natural gas and renewable energy stands for most of the growth. Petroleum and other liquids are unchanged from today's total Btu consumption, but decreases in the context of the total world energy demand, see Figure 10 underneath.
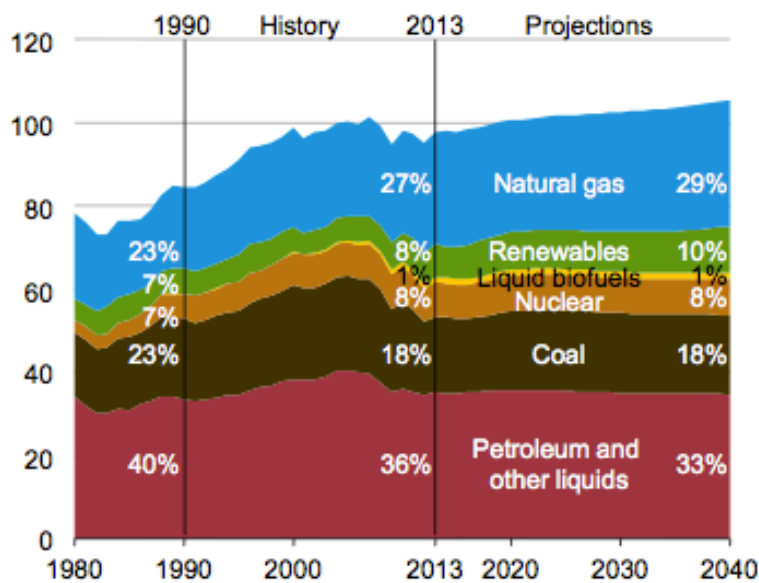
Figure 10: World energy consumption, 1980-2040 (quadrillion Btu) (EIA, 2015a)

Future crude oil price is uncertain and dependent on storage level, production level within and outside OPEC, worldwide consumption level of energy, development of renewable energy, political stability in the east and general economical growth in the global market. With this many variables it is difficult to estimate future fuel prices. EIA (2015a) has therefore assumed a wide spread between their different scenarios in the future outlook between 2015 and 2040.

4.0 Framework and Methodology

4.1 Cost Classification

In shipping, the cost structure changes for different types of vessels. In practice, all costs are variable depending on external developments such as changes in oil prices and the way shipowners manage and finance the business. There is also a relationship between cost and ship-size, usually referred to as *economies of scale*. Also, the age of the ship plays an important role in the total cost structure of the vessel. As the ship ages, its capital cost reduces, but its operating and voyage costs increases relative to newer ships. This is due to the fact that newer vessels have technical improvements, which gives higher effects (Stopford, 2009).

We can classify the different cost of shipping in five categories (Stopford, 2009): Operating costs that involves expenses related to the day-to-day running of the ship; crew, stores and maintenance. Periodic maintenance costs when the ship is dry- docked for special services. For older ships this may involve considerable expenses. Voyage costs e.g. fuel costs, port charges and canal dues. Capital costs; dividends to equity and interest and capital payments on debt financing. And at last, cargo- handling costs related to loading, stowing and discharging cargo. Odfjell has made a cost analysis for a typical large chemical tanker (Odfjell SE, 2014):
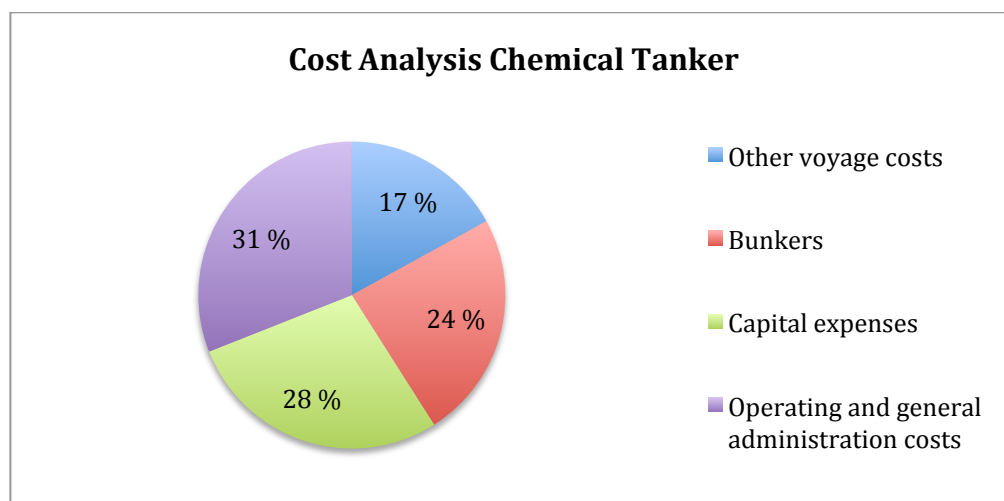

Figure 11: Cost Analysis for a typical Odfjell chemical tanker (Odfjell SE, 2014).

It is reasonable to expect changes in operating and maintenance cost as a result of scrubber installation, LNG conversion or propulsion on distillates. Nevertheless, details regarding

OpEx and VoyEx are confidential information for Odfjell. Hence, we obtained a selection of general figures for expected changes in OpEx and VoyEx after a change of engine system. Due to inconsistence in cost figures obtained from varying sources, the consequences of changes in OpEx and VoyEx (except fuel costs) were tested in the DCF model. The test revealed that general expected changes in OpEx and VoyEx only had negligible impact on our results in absolute terms. For the purpose of comparing different abatement solutions, we assume CapEx and fuel costs as the most important variables. General changes in OpEx and VoyEx are accordingly kept outside the model.

4.2 Capital Budgeting

In financial comparison we can use different methods for cost assessment, where each has its strengths and weaknesses. Although, they all use periodical cash flow when running the analysis. The three most applied methods are payback method, DCF and the internal rate of return (IRR). As IRR and payback method is considered to be too simple for evaluating and compare these types of projects, a DCF analysis is applied in the first part of our analysis. The DCF method uses the company`s weighted average cost of capital (WACC) to discount annual future cash flows and deduct the initial investment cost. For mutually exclusive projects, which are the case for this thesis, the project with the highest NPV is accepted and those with lowest values are rejected. In this thesis only the costs are considered, and accordingly we will accept the project with the lowest NPV. A weakness with the discounted cash flow method is the use of a rate of interest to specify time preferences and opportunity costs. It can be challenging to specify a rate of interest representable for the total lifetime of the project. At the same time the applied rate has important impact on the outcome of the calculation. The reliance on forecasted future cash flows entails high degree of uncertainty, thus implying unreliability in calculated net present value. DCF methods may be appropriate when applied to narrowly defined problems but is inadequate when uncertainty and strategic consideration are paramount. A real option analysis can be comprised to solve this problem. ROA captures value of managerial flexibility, with the possibility to adapt the decisions in sudden market developments (Grammenos, 2010). DCF models enable comparison between different vessels and different lifetime costs. In addition, the possibility to analyse and include evaluations of the market and macro perspective is given.

4.3 Capital Cost

There are several approaches to estimate capital cost. Here, cash flow for both equity and total assets are considered and implies use of Weighted Average Cost of Capital (WACC) to get the total asset rate of return. The WACC is given by *(Berk and DeMarzo, 2014)*:

$$WACC = \frac{E}{E+D} * rE + \frac{D}{E+D} * rD \qquad\qquad WACC\ (4.1)$$

From general investment theory we know that WACC is crucial for the value of the investment when used as discount factor. The WACC calculation for Odfjell is elaborated in two steps in the following sections. First, we present the use of Capital Asset Pricing Model (CAPM) to get the cost of equity, and secondly the calculation for cost of debt.

CAPM defines the investments risk to the degree of correlation with the market, which is defined in the Beta. The CAPM formula is given by (Koller et al, 2010):

$$K_i = r_f + \beta_i * (E(R_m) - r_f) \qquad\qquad CAPM\ (4.2)$$

CAPM implies that the investor, in this case the investors in Odfjell, are risk averse and diversified. The five major investors in Odfjell stand for 56.66% of the total shareholder structure and 49.81% of those are international shareholders (Odfjell, 2014). Based on this, we can assume that the investors are diversified and that CAPM is applicable.
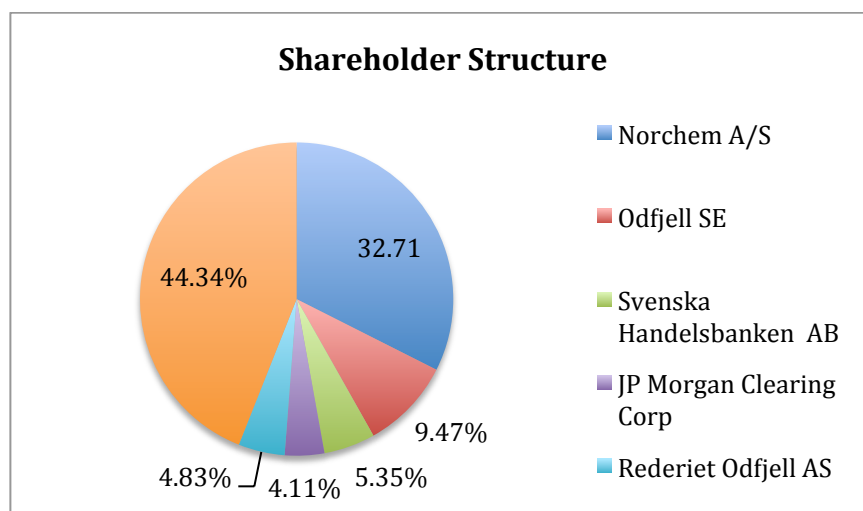

Figure 12: Odfjell shareholder structure

The first step in the CAPM estimation is the choice of *risk free rate*. Government default-free bonds are commonly used as the risk free rate of return. The bonds comes in different maturity and ideally each cash flow should be discounted using a zero coupon government bonds with the same maturity. In reality, 10-year government zero-coupon bond is often applied. Today (February 19, 2015) the rate of a ten-year Norwegian government default-free bond is 1.41% (Norges Bank, 2015). When assessing a firm listed on the Norwegian stock exchange, we use the Norwegian default- free bond rate of 1.41%. These are not zero- coupon bonds like the theory implicates, but normal practice suggest the use of this, as there are small differences (PWC, 2014)

Market Risk Premium (MRP) is the difference between estimated market return (MR) and the risk free rate. Although the premium varies over time and depends on business cycles and general market conditions, CAPM assume a constant market premium over multiple periods (Bodie et at, 2011). According to Magma (2013), the average MRP on the Oslo Stock Exchange (OSE) is 5.5%. In addition, a report from PWC (2014) revealed that the Norwegian MRP median at OSE has remained unchanged at 5% in the period from 2011 to 2014. For a long-term estimation of MRP we assume it will between 5-5.5%, further in this thesis we will use 5.5%.

Beta measures the correlation between stock and market movements. This is not directly observable, but can be obtained through a regression analysis. To avoid systematic biases, Alexander and Chervany (1980) recommend using monthly data instead of daily or weekly data. We have chosen a five-year period with monthly data after the principle of CAPM and subsequent tests of optimal measurement periods (Alexander and Chervany, 1980). The regression analysis performed with OSE as a benchmark gives a Beta of 0.9052 with an R square of 0.09566 (Appendix L). This indicates that OSE as a variable only counts for 9.57% of the stocks variance. To adjust the beta against mean reversion we applied Marshall Blumes method (Koller et al, 2010)

$$\beta_{adj} = \frac{1}{3} * 1 + \frac{2}{3} * 0.9052 = 0.9398 \qquad \textit{Marshall Blumes (4.3)}$$

Shipping is a cyclical segment, and a general rule of thumb is that those segments have a higher beta than the general market (Beta>1). Academic researchers show that this rule may

not apply to shipping. Drobetz and Schroder (2014) tested systematic risk in shipping with 248 shipping companies. The result was rather moderate on average and could document a strong beta variation over time. Variations where concluded to be closely tied to the freight rates. The statement above indicates that risk in shipping is not determined by the general stock exchange market and accordingly have less systematic risk. Research has also been done separately for the tanker segments of shipping, concluding that Beta, with the use of CAPM, appear to be 1.213 on average (Drobetz et al, 2014). Our estimated beta for Odfjell is close to this result. We believe that Odfjell`s beta is lower due to their diversification with investing in the terminal segment. In our further calculations we will use an equity Beta of 0.9398.

4.3.1 Cost of equity and debt

In the previous sections we have analysed the elements of the CAPM. As Odfjell have a small group of investors that holds a significant percentage of the shares, it is reasonable to add a liquidity premium to the cost of equity. The annualised turnover rate for the Odfjell stocks is 17.5%. In other words this means a holding period for this stock of (12m/17%) 70.6 months, or almost 6 years. This is very low for a publicly traded stock, where the average holding period in the stock market is approximately one year (Næs and Ødegaard, 2007). In Appendix P the table shows a low variation and low average daily trades last three years. A low turnover may indicate an illiquid stock, and inertia in the market for trading with high volumes. If an investor want to sell a large quantity of Odfjell stocks it can be hard to find a buyer. In this situation it is common to add a liquidity premium of 2-3% (Gjesdal and Johnsen, 1999). We assess the stock turnover in Odfjell to be very low in comparison to the market, and assume a premium of 3%.

Summarized, the rate of return on equity including liquidity premium is as follows:

$$K_i = r_f + \beta_i * (E(R_m) - r_f *) + L \qquad \textit{CAPM with liquidity premium (4.4)}$$

$r_f = 1.41\%$

$\beta_i = 0.9398$

$E(R_m) = 5.5\%$

$L = 3\%$

We insert this to the equation and get a rate of return on equity of 9.58%

The cost of debt represents the effective rate that a company pays on current debt. According to Odfjell`s annual report (2013), the total average interest rate is calculated to 3.29% based on interest rates from financial institutions, finance leases and bonds. For comparison, Odfjell is credit rated to B+ by Danske Bank (2014). When using Damodaran`s default spread for B+ rated companies of 4%, and adding a risk free rate (1.41%) we get the pre-tax cost of borrowing for the firm of 5.41% (Damodaran, 2015). In Norway the shipping segment has a zero rate corporate tax level on earning from shipping activities (OECD, 2014). This leaves us at the rate of 5.41%. Since most of the shipping companies borrow at LIBOR rate, we choose to use the calculations from Odfjell in this thesis, hence cost of debt 3.29%

4.3.2 WACC

Before the final WACC calculation, the cost of capital should be weighted in market values. To do this, we have normalised Odfjell`s annual reported accounting between 2009- 2013. This gave us their total market equity and financial debt level in percentage. To get the market value of equity we multiplied the total of A and B shares with their corresponding average reported stock price in NOK. Dividing this by the annual average exchange rate between NOK and USD, gave us Odfjell`s total market capitalization in USD.

Year						
	2009	**2010**	**2011**	**2012**	**2013**	**Average**
Financial Debt	64%	59%	58%	58%	60%	**60%**
Market Equity	36%	41%	42%	42%	40%	**40%**

Table 3: Odfjell, normalised financial debt and market equity, between 2009 and 2013

Based on the information from the sections above we are able to calculate WACC:

$$0.6 * 3.29\% + 0.4 * 9.58\% = 5.8\% \qquad\qquad WACC\ (4.5)$$

Basically, the WACC should be stable over time. However, Odfjell is not traded in high volumes, therefore our Beta calculation cannot be 100% reliable.

4.4 Real options

In finance, the option term is often used. A call option is the right to buy the underlying asset at exercise price, and a put option equivalently a right to sell an asset at exercise price. Exercise of options can either be European or American. A European option can only be exercised at expiry date, and the American at any time between buying the option and expiration date. By mixing different combinations of call and put options, we can create various derivatives. When we use the term option for physical and real values, we use the term Real option. Real option exists if the holder has the right but not the obligation to take a decision at one or more points in the future (Howell et al, 2001). Real option analysis (ROA) is the applications of financial options, together with decision science, corporate finance and statistics. This combination makes it possible to evaluate the value of a real or physical option. There is typically five different options assets: the option to defer, to expand, to contract or abandon, to abandon for salvage or to switch (Grammenos, 2010). Options give the decision-maker a possibility to build in flexibility to the models. Existing decision support tools are often based on standard DCF techniques. These do not incorporate the value of the flexibility to defer, or to change an investment based on additional external or internal information. Traditional DCF is a passive method, which is based on predetermined market conditions with little or no flexibility. This makes the investment decision risky for the management, as the change in market outlook can alter a "good" investment to a "bad" investment. Standard DCF, discount the cash flow at the cost of capital. Suggesting that the assumptions made in the beginning of the project holds throughout the lifetime. In reality this is not true, as markets evolve and risk change. Conversely ROA is based on risk neutral probabilities. These probabilities remain unchanged even with shifts in risk. Shipping is known for volatile markets, and decisions are often delayed until more information occurs or investment date is upon them. ROA take this uncertainty into consideration by calculating the value of delaying the decision.

Apart from an ROA study for ECA compliance regulations from Acciaro (2014), research with ROA approaches on investment for environmental compliance is rather limited. In this thesis our aim is to evaluate the managerial flexibility of deferring the decision until more information is at hand. In financial option terminology the option applied is called a Parisian barrier call option. A barrier option is an option where the payoff depends on the value of the underlying asset and whether the asset has reached a certain pre-defined threshold during the lifetime. The difference between a regular barrier option and a Parisian is that the time above

the threshold value has to be sustained for some period of time before the option is exercised. This is to ensure that the high level is not just a peak, but indicates a sustainable level. The Parisian barrier option expires and loses all option value only if the pre-determined lower and upper threshold is crossed for a prolonged period of time (Brach, 2003). In our case, management, which holds a perpetual Parisian barrier option, will exercise and retrofit the vessel once the lower barrier for fuel cost has been crossed for a prolonged period of time. The option would expire worthless if the fuel cost stabilize on a high level until the end of the vessels lifetime. One of the major challenges in our thesis is that there are no revenue differences in the options, only cost differences. This is in contrast to the traditional deferring option in shipping where it is used for timing a fleet renewal or investing in other markets.

If the worldwide regulation of SOx is not postponed in 2018, management has to make a decision toward 2020 to either invest in LNG, scrubber or run on distillates. By running on distillates they can delay the investment decision until more information is at hand. The ECA 2015 regulation is already implemented, so in the next five years there is a possibility of seeing a change in this market, which might affect the worldwide market. If not invested in 2020, they can consider investing forward. In this thesis, we have focused on the years 2020-2025. The managerial decision tree is illustrated in Figure 13. By investing in LNG or scrubber, further investment decisions are not required.
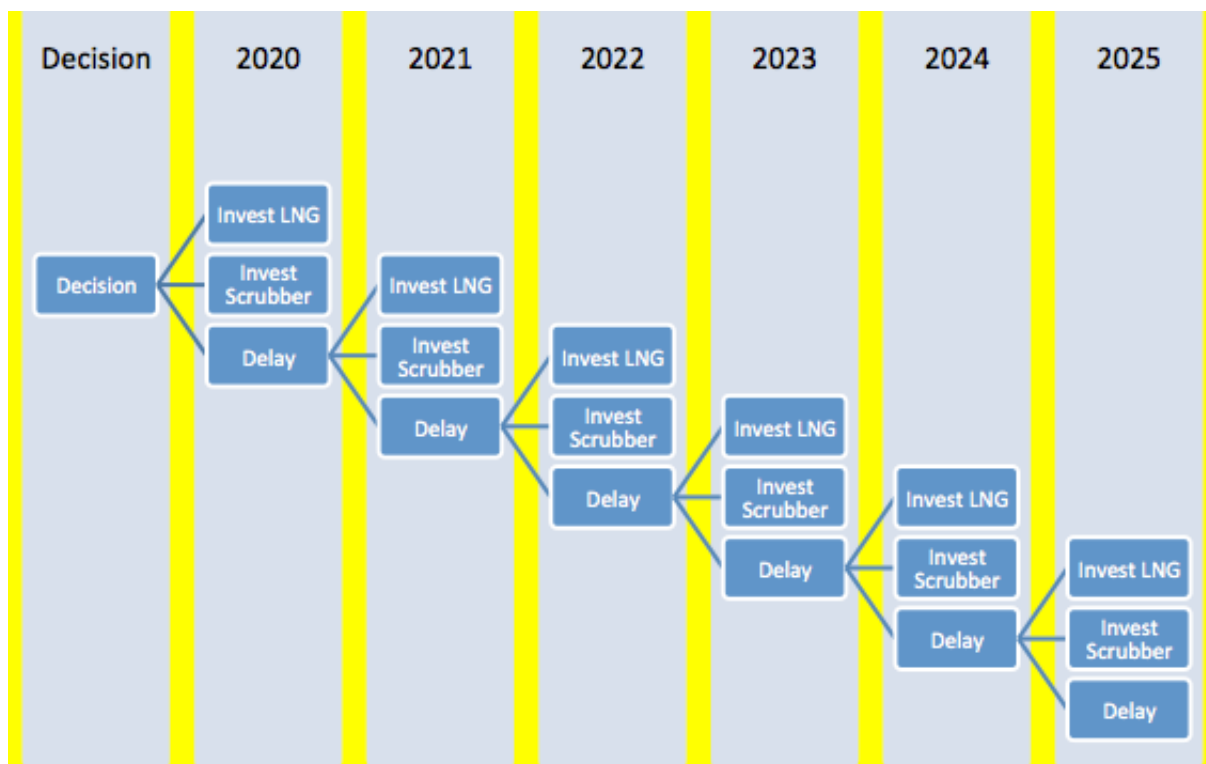
Figure 13: Shipowners alternative SOx regulation compliance strategies.

4.4.1 Model description

Calculating the value of real options has two different approaches. One is the binomial approach by Cox, Ross and Rubenstein, while Black, Scholes and Merton approaches the so-called Black and Scholes model. In this analysis, we want to find the call option price of investing in 2020 and the value of the deferring option. We will use the discrete binominal approach. The traditional Black & Scholes option-pricing model is not applicable as this thesis includes future revenues as the underlying asset. The future revenue is not tradable and the replication hypothesis required for applying the Black and Scholes formula does not hold (Trigeorgis, 2002). Like former real option approaches in this field, we have used the approach described in Brach (2003).

To calculate the call option value of investing in 2020, we first have to calculate the savings in fuel costs and the expected asset value. These two values are required to calculate the risk neutral probability, which is used for the estimation of the call option. The total value of the fuel cost savings are based on the differential between present value (PV) of bunkering with LNG/scrubber throughout the lifetime, rather than running on distillates. The savings is estimated for each vessel, fuel alternative and price scenario (high, neutral and low oil price).

We correspondingly obtain a high, medium and low value of the savings for all three vessels and for both alternatives. If the value of the savings becomes negative, it indicates that switching from distillates is not profitable. The value of savings is given by (Brach, 2003):

$$PV_X = \frac{CF_{Distillates}}{r} - \frac{CF_{alternative}}{r} \qquad \textit{Value of savings (4.6)}$$

PV_X = *Present value of fuel cost savings/losses*
$CF_{Distillates}$ = *Cash flow of total bunkering cost for distillates*
$CF_{alternative}$ = *Cash flow of total bunkering cost of LNG or scrubber investment in 2020*
r = *Discount factor for each year is WACC*

The expected asset value of savings is calculated for each vessel and fuel alternative, by weighting the different scenarios with the accompanying value of savings (4.7). We use the same probabilities here as in the cash flow analysis. Expected asset value is given by (Brach, 2003):

$$V_e = V_X^{High} * P_{High} + V_X^{Neutral} * P_{Neutral} + V_X^{Low} * P_{Low} \qquad \textit{Exp. asset value}$$

(4.7)

V_e = *Expected asset value*
V_X = *Value fuel savings/ loss, each scenario*
P_X = *Probabilities for each scenario*

The risk neutral probability is calculated for both investment alternatives, for all three vessels and is given by (Brach, 2003):

$$p = \frac{((1+r_f)*V_e) - V_{min}}{V_{max} - V_{min}} \qquad \text{Risk neutral probability (4.8)}$$

p = *risk neutral probability*
V_{max} = *Highest value of savings of the three scenarios*
V_{min} = *Lowest value of savings/ loss of the three scenarios*

To calculate the value of the call option we need two end states of savings; high savings and low savings. In our prognosis we have three end states. By using equation (4.9), which combine the value of savings and risk neutral probability it possible to end up with one high and one low state for the value of savings (Figure 14).

$$V_E = \frac{p*V_{max}+(1-p)*V_{min}}{(1+rf)^t}$$
Risk neutral states (4.9)

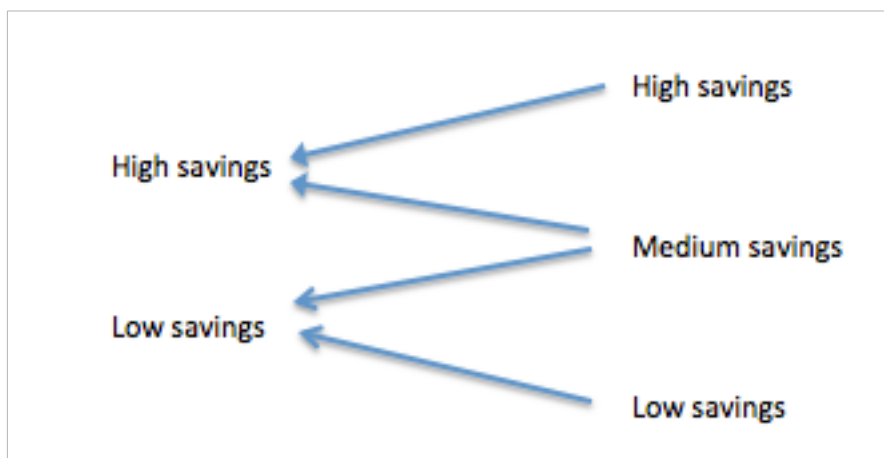V_E = *Value of savings in end state*

Figure 14: Path of savings. Illustrates the path to obtain the two end states V_{max} and V_{min}

It is now possible to calculate the value of the call option for investing in 2020. The exercise price is the cost of retrofitting the ships with LNG or installing scrubber. All investments have an opportunity cost; e.g. investment costs could alternatively been used in debt repayment or investment in other projects. To incorporate the opportunity cost we multiplied the company's WACC with the CapEx. The call option value is calculated for LNG and scrubber investment for each vessel, and is given by (Brach, 2003):

$$C = \max\left(0; \frac{p*V_{max}+(1-p)*V_{min}}{(1+rf)^t} - K*(1+r_c)^t\right)$$
Value 2020 call option (4.10)

K= CapEx (in 2020)
rf= risk free rate
r_c = *Opportunity cost (5.8%)*

We have now shown the method for calculating the call value of investing in 2020. To get a wider perspective of the CapEx (K) in the call option, management can calculate which exercise price that gets the option to be "at the money", referred to as K*. Standard call option formula (4.10) is used. *K** indicates the intersection where the call option goes from being unprofitable, to a value of zero, with the exercise price as a decisive variable. If K=K*, the call option is "at the money". If K>K*, the option is "out of the money", and opposite it is "in the money" if K<K*. Further in this section we will illustrate the method for calculating the value of deferring the investment.

If the management postpone the investment decision, more market information will be available, and hence gives the project a lower investment risk. This is also referred to as the option to defer. Furthermore, the management are able to monitor how the world shipping markets reacts to new demands. It is likely that some of the market uncertainty will be resolved in the future and improve the basis for decision-making. To calculate the option to defer for one year we have to make some changes in the total bunkering cost; if we defer one year, the vessels have to run on distillates this year. This means that the fuel costs in the first year must be changed from LNG/IFO to distillates for all vessels and scenarios. By deferring two years, costs for running on distillates for two years are added. The same procedure is then repeated for further years.

Calculation of the deferral option value requires the new values of savings, expected asset value, risk neutral probability, call value and revenue foregone. Value of savings for each investing alternative, LNG and scrubber, is calculated for all vessels and all oil price scenarios. Values of savings from deferral is given by (Brach, 2003):

$$PV_X = \frac{CF_{Distillates}}{r} - \left(\frac{CF_{alternative}}{r} + \frac{CF_{Distillates^t}}{r}\right) \quad \textit{Value of savings deferral (4.11)}$$

$PV_{Distillates^t}$= *Present value of the cost of years running on distillates as a consequence of deferring*

Then the investment cost with numerical values must be included in to the value of savings (equation 4.11). This corresponds to the total amount of savings (4.12), which cannot obtain a negative value. The reason for this is that management will not invest in an alternative fuel if

the expected value of savings does not correspond to a higher value than the investment cost. The value is calculated for all three scenarios, vessels and fuel alternatives (Brach, 2003):

$$Choose \rightarrow V_S = PV_X - K * (1 + r_c)^t > 0, \;\; if \; not \rightarrow V_S = K * (1 + r_c)^t - PV_X$$

Total amount of savings when deferring (4.12)

V_S =*Value of total savings of deferring*

The value given in equation (4.12) is then weighted with the same probabilities applied in the DCF analysis. This gives the expected asset value of total savings by deferring (4.13) (Brach, 2003):

$$V_e = V_S^{High} * P_{High} + V_S^{Neutral} * P_{Neutral} + V_S^{Low} * P_{Low}$$

Expected asset value of savings by deferring (4.13)

The method for calculating the total value of savings by deferring (4.12) is now elaborated, and is applied to obtain the expected asset value of savings (4.13). By combining these two it is possible to calculate the risk neutral probability, which is required to estimate the value of the call option. The equation for the risk neutral probability for deferring is based on the same variables as in equation (4.8), namely the highest and lowest total value of savings, and expected asset value of savings (Brach, 2003).

$$p = \frac{((1 + r_f) * V_e) - V_S^{Min}}{V_S^{Max} - V_S^{Min}}$$

Risk neutral probability (4.14)

Equation (4.9) can now be applied to obtain the two states of savings; max and min as illustrated in Figure 14. Combining the two states and the risk neutral probability enables calculation of the call option value by deferring (Brach, 2003).

$$C_q = \frac{V_S^{Max} p + (1 - p) * V_S^{Min}}{(1 + r)^t}$$

Value of call option by deferring (4.15)

To obtain the value of the deferral option, we first have to calculate the revenue forgone (RF). In the option of deferral, RF is the exercise price, which corresponds to the value of potential loss in savings when deferring the decision. Potential loss in savings is acquired by deducting

the total deferring fuel cost from the baseline[1]. The net present value of the total fuel cost is depending on the deferral period, which implies running on distillates until the investment period. This is performed for each deferral call option between 2021 and 2025. The revenue foregone is given by (Brach, 2003):

$$RF = PV_{Alternative^t} - (PV_{Alternative} + PV_{Distillates^t}) \qquad \textit{Revenue foregone (4.16)}$$

Finally, the value of the deferral call option can be obtained. This is estimated by deducting the exercise price RF in (4.16) from the accompanying call option value C_q in (4.15). (Brach, 2003):

$$C_0 = C_q - RF \qquad \textit{Value of deferral call option (4.17)}$$

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[1] Base line referes to the total cost of running on LNG or scrubber from 2020 to the obsolescence date.

5.0 Case: Odfjell

5.1 Deep-sea chemical transportation and storage

Deep-sea shipping refers to global carriage of commodity and other cargo across the world seas, as opposed to short sea shipping which cover short distances within limited regions. This is a business driven by global trends in imports and exports and is affected by the ever-changing macro picture. The demand for commodities and especially chemical products has enjoyed a solid growth on a worldwide basis for many years. In modern industrialized countries, chemicals have become an integral part of the production industry and we expect developing countries to follow and lead to a further increase in demands for chemicals. Modern chemical tankers are sophisticated vessels designed to handle several types of cargo simultaneously and keep each customer`s consignment segregated at all times. However, some products are more frequently transported than others; petrochemicals produced in the US and Europe is the conventionally largest contributor to transportation of chemical products, both in volumes and in diversity. As the production of petrochemicals often is situated where commodities are available, the production facilities in recent years have gradually spread to the parts of the world where access is easier (Odfjell, 2014). This implies that the need for transportation of petrochemicals between continents is increasing, and underpins the importance of having a global transportation and terminal network.

5.2 Odfjell

Odfjell is a Bergen based, fully integrated company, with chartering, operation and ship management as in-house functions. The company was established in 1914 and became a pioneer in the chemical tanker trading, tr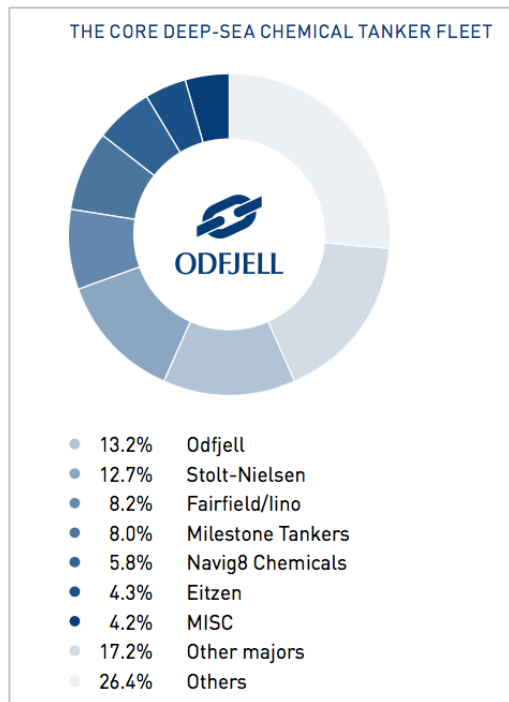ansport and storage business in the 1950`s and 1960`s. In the global deep-sea shipping segment for transportation and storage of chemical products, Odfjell is one of the world major players with a market share of 13.2% in 2013.

THE CORE DEEP-SEA CHEMICAL TANKER FLEET

ODFJELL

- 13.2%   Odfjell
- 12.7%   Stolt-Nielsen
- 8.2%   Fairfield/lino
- 8.0%   Milestone Tankers
- 5.8%   Navig8 Chemicals
- 4.3%   Eitzen
- 4.2%   MISC
- 17.2%   Other majors
- 26.4%   Others

Figure 15 Distribution of market shares in the core deep-sea chemical tanker fleet (Odfjell, 2014)

They are located in central places around the world and have operations in all major trade lanes. The Odfjell chemical tanker fleet consists of 77 ships whereas 43 is owned and 34 is time chartered and commercially managed vessels. The ships are traded worldwide with main trade lanes covering the US, Europe, Asia, India, the Middle East and South America. Approximately 25% of their operations are within Emission Control Areas (ECAs) and the company is thereby only partially affected by the 2015 sulphur emission regulations.

From 2020 it is likely to anticipate that Odfjell`s main competitors in the deep-sea chemical tanker segment are somehow equally exposed to the global forthcoming 2020 restrictions. Based on this, ceteris paribus, we can assume that the shipowner with the most cost-efficient solution for ECA compliance will have an advantage in the further rivalry. Beside the chemical tanker business and the LPG/Ethylene carriers, Odfjell owns and operates tank terminals on a worldwide basis. This yields synergies to the transportation activities and in turn provides high quality and efficiency across the entire transportation chain. As the revenue from the freight market is volatile, the tank terminal business contributes with stable revenues to the result of the company in total.

In 2014, after a longer period with unacceptable profitability, Odfjell went through a comprehensive restructuring process where more than 1/3 of their employees at the main office lost their jobs. In February 2015 the company itself announced that the restructuring of the company is estimated to provide annual cost savings of approximately USD 100M,

starting in 2016. The contribution from cost savings is expected to come from lower operating and administrative costs, more efficient bunker supply and improved efficiency in sailing pattern. Based on this, we believe this paper highlights some important aspects to consider for future planning and re-organization.

6.0 Analysis and discussion

In this chapter, the reasoning behind the results is explained in a chronological order to provide the reader a sound understanding of the main results. First, the case vessels used in our calculations are presented, followed by a specification of capital expenditures and fuel price projections. Further, the DCF analysis presents the cost competitiveness of LNG conversion, scrubber retrofit and propulsion on distillates for each vessel. The model ranks the different alternatives based on weighted probabilities for three different price-spread scenarios to occur. Finally the results from the ROA are presented. First we illustrate the "at the money" installation price for the alternatives of LNG and scrubber. This is followed by a presentation of call option values and deferral values. By comparing call option value from investing in 2020 and the deferral values we estimate the optimal investment period.

6.1 Case vessels

The optimal investment decision is reflected in the expected remaining lifetime of each specific vessel. The trade-off is in the choice of an up-front investment to earn a low level of operational costs, versus no initial investment and high operational costs in the future. The remaining lifetime of the vessel then returns a number of years to pay back the initial investment with savings from low annual operating costs. We have chosen three different case vessels from Odfjell`s fleet with different remaining lifetimes. Specifications for each vessel is summarized as follows:

	Case vessel 1	Case Vessel 2	Case Vessel 3
Name	Bow Flower	Bow Firda	Bow Saga
Year built	1995	2003	2007
Expected lifetime	28	28	28
Remaining lifetime	3	11	15
DWT/CBM	37221/41492	37427/40645	40085/52126
Installed effect (kW)	6300	6300	8000
Steaming days in 1 yr.	220	220	220
Fuel consumption Distillates (Mt/day)	26	26	33
Fuel consumption IFO 380 (Mt/day)	27	27	34
Fuel consumption LNG (Mt/day)	22	22	28
NOx Emissions (tonne/year)	540	540	680

Table 4: Specifications for the three case vessels applied in our model. Data received from Odfjell SE on demand, 2015.

Bow Flower and Bow Firda are close to identical except from the expected remaining lifetime. Bow Saga is the most recently built vessel with higher capacity, higher installed power and accordingly higher fuel consumption. Based on historical data, average annual operating profiles for the vessels are identical with 220 sailing days.

6.2 Capital expenditures

Accurate estimates of capital expenditures are difficult to obtain seeing that vessel type, engine size, off-hire costs etc. will affect total investment cost. Both vendors and shipowners are reluctant to share market prices to protect their market positions. Capital expenditures applied in this analysis are obtained from various sources as described in the sections below. Observed prices have great variations with no defined distinction in underlying assumptions. All prices obtained are adjusted to 2020 prices with inflation rate of 2.5%.

CapEx for scrubber ranges from USD 2.5M (Acciaro, 2014) for a 38 500 DWT chemical tanker to USD 7.1M (Greenship, 2012) for a 35 000 DWT handy size vessel. Cost variations for scrubber retrofit are assumed to depend on type, size and design for each specific scrubber. For deep-sea tankers assessed in this analysis the USD 7.1M is used as a conservative estimate.

Cost figures for LNG retrofitting of a chemical tanker are more uncertain and even more divergent between sources. DNV (2014) refers to uncertain future supply and demand for LNG retrofit services and the effect of possible economical gains due to improvements in LNG technology. At current, we expect LNG conversion for vessels operating in the deep-sea segment to be more complex compared to short-sea operated vessels, both in terms of complexity and materials required. Greenship (2012) proposes total LNG retrofit costs for a 38 500 DWT chemical tanker to USD 9.2M. This includes penalty cost for 40 days off-hire. In the high end of the scale, Acciaro (2014) suggests a cost of USD 20.9M for a 35 000 DWT handy size vessel operating in the deep-sea segment. USD 20.9M is considered to be a high estimate and inconsistent with several other studies reviewed. We find it reasonable to use the average of these observations as a reference CapEx (USD 15M). In addition, we have calculated DCF and ROA values under conditions of low and high CapEx to provide a wider perspective when discussing possible impacts of changes in CapEx for LNG. In Table 5 CapEx for scrubber is presented along with the variations in CapEx for LNG conversion.

CapEx projections (in 2020 prices)			
Technology	**CapEx Scenario**	**CapEx**	
Scrubber	Reference/low/high	7 115 473	USD
LNG	Low	9 211 126	USD
	Reference	15 042 804	USD
	High	20 874 482	USD

Table 5: Show CapEx projections for scrubber and LNG retrofit applied in this analysis. Prices are adjusted for inflation to 2020 prices

The initial cost of a fuel switch to distillates is related to small technical adjustments on the engine and fuel system. These costs are low compared to a scrubber or LNG investment and vary depending on the vendors offer and ship type. Our models were tested for variations in CapEx related to fuel switch and it revealed negligible impacts on the final results. Accordingly, up-front investment cost related to fuel switch is kept outside the model.

6.3 Fuel prices

After investment cost in 2020, annual future cash flows are solely based on expected future fuel prices for IFO 380, MDO and LNG. The projected annual cash flows are then applied for DCF model and ROA. In reality, the locations for bunkering and real-time prices vary for global traded vessels. Especially LNG fuel prices are subject to regional differences. For simplification, we assume one single price index for each fuel type. Price indexes are obtained from Bloomberg and are considered as representative for potential bunker destinations for Odfjell (See Table 6).

Fuel type	Description	Period	Index ticker
IFO 380	Bloomberg 380 Centistoke Bunker Fuel Spot Price. Rotterdam, Netherlands	2010-2015	BUKRD380 INDEX
MDO	LQM Petroleum Marine Diesel Oil Bunker Fuel Spot Price. Rotterdam, Netherlands	2011-2015	LQM2RDMD
LNG*	Bloomberg day Ahead Natural Gas Spot Price. Zeebrugge	2010-2015	ZEEBDAHD Comdty

Table 6: Price indexes obtained from BLOOMBERG as basis for price projections. * For LNG, natural gas prices are used with an additional premium for liquefaction-, shipping-, storage- and sales premium cost.

6.4 Fuel price scenarios

This subsection starts with a presentation of projected low, neutral and high price path scenarios for each fuel. Moreover, three subjectively scenarios with low, neutral and high oil price is selected to assess how spread in oil price vs. LNG price affect the investment decision. Forecasting energy prices for a time period up to 25 years is extremely challenging as it depends on a large number of unknowns. As a consequence, our assumptions for price path scenarios for IFO 380 and MDO are based on oil price projections from EIA´s Annual Energy Outlook 2015 (AEO2015). In AEO2015, fundamental variables like GDP growth,

future demand for petroleum products, crude oil production, and supply of other types of fuels are considered. This provides a sound evaluation of the current global energy market as well as possible future developments. Prices for LNG are based on a consideration of information from AEO2015 and how we expect the European natural gas market to develop. Prices are shown in real terms.

IFO 380

Price of IFO 380 is highly correlated with crude oil (see Appendix M). In line with AEO2015, an increase in oil price is expected in all scenarios. Neutral scenario reflects the market as it is in 2015 with low oil price, growth in crude oil productions and reassuring prospects for future production capacity. In a high scenario it is expected a reaction to the market situation as it is today, implying a stabilized market with decreased production and/or higher demand for petroleum products. Opposite, a low scenario represents a market in oversupply with low demand. Price path scenarios for IFO 380 are illustrated in Figure 16:
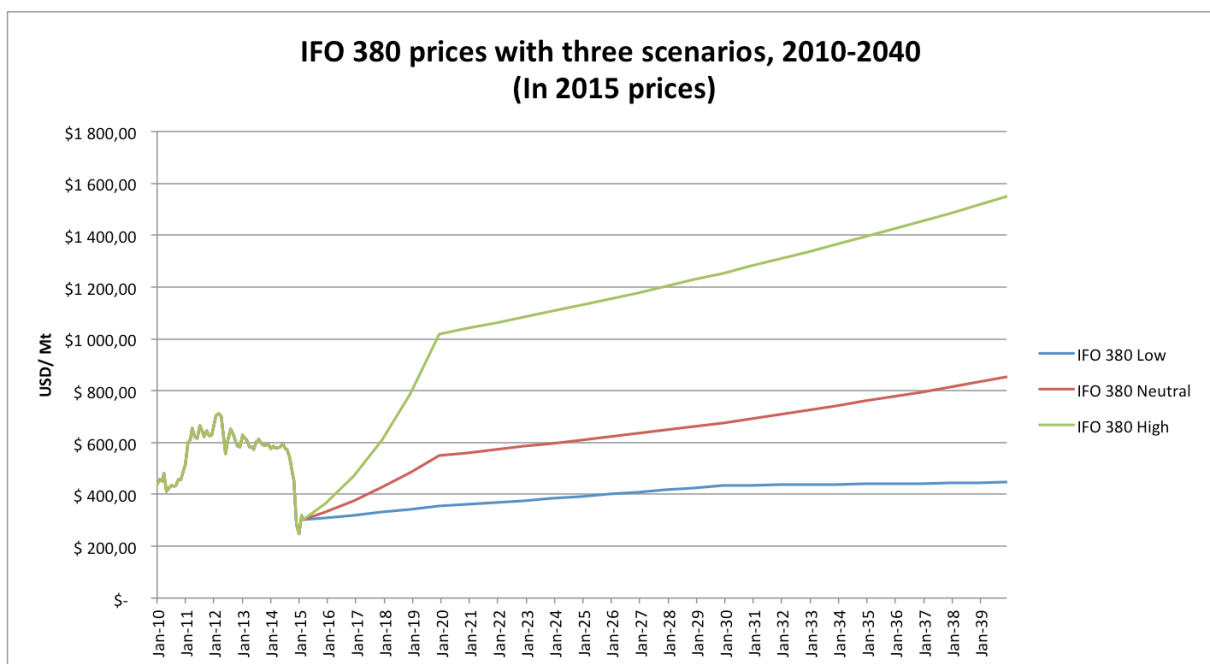
Figure 16: Price projections for IFO 380 with three different scenarios.

MDO

MDO prices are highly correlated with IFO 380 prices, fluctuating on a close to constant higher level (Appendix N). Projections for MDO prices rely on the same basic assumptions as for IFO 380. This means that MDO prices are multiplied with a factor representing the slope difference between the two variables to get future price scenarios (see equation 6.1):

$$P_t^{MDO} = P_{t-1}^{MDO} * (1 + g_t^{IFO380} - y_{IFO380 \ vs \ MDO})$$ (6.1)

P_t^{MDO} = *Price MDO for time X*

P_{t-1}^{MDO} = *Last calculated/observed price for MDO*

g_t^{IFO380} = *Calculated growth for IFO380 between time period t-1 and t*

$y_{IFO380 \ vs \ MDO}$ = *Slope between IFO380 and MDO*
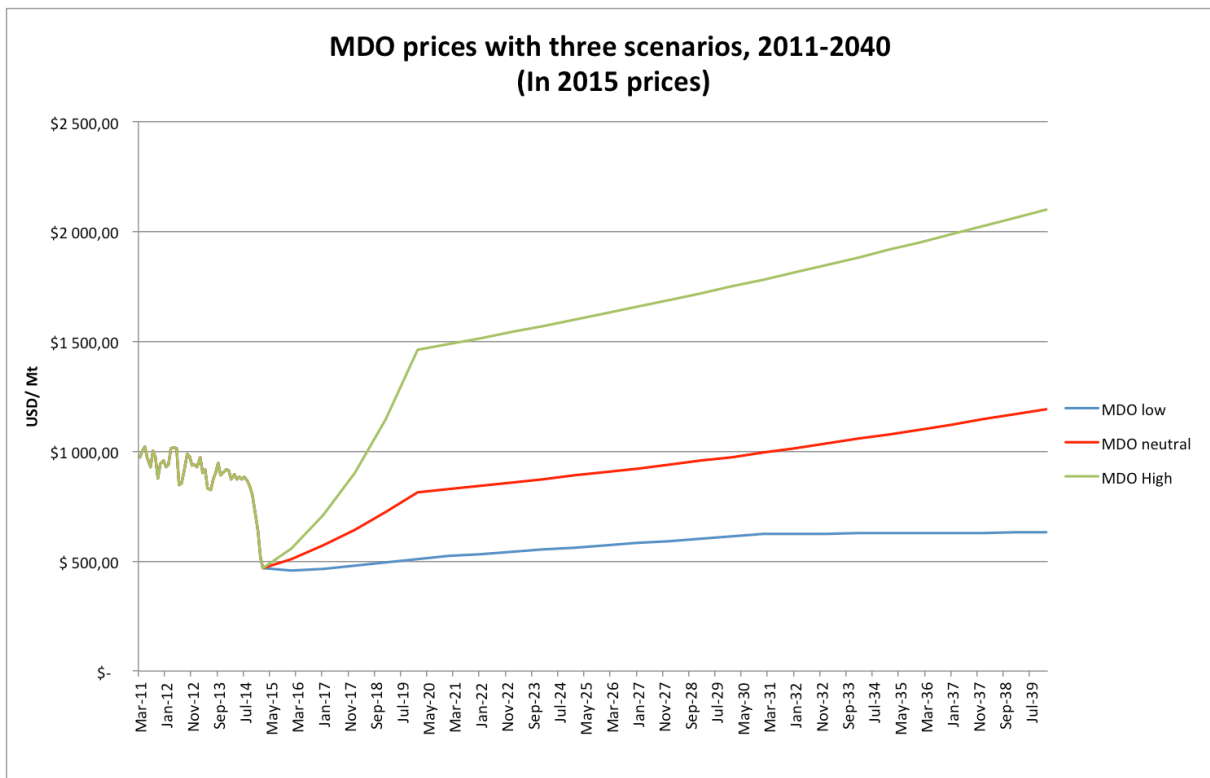
Figure 17: Price projections for MDO prices with three different scenarios.

From the regression analysis in Appendix M, it is evident that oil price variations account for 81% of the variation in IFO 380 prices. For MDO, IFO 380 account for 71% of the variation (Appendix N). The consistent MDO/IFO 380 ratio implies increased price spreads in absolute numbers when the oil price is high (See Figure 4). Based on this, it is likely to assume

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correlated price fluctuations in the two variables, meaning that both variables will be present in a low, neutral or high scenario simultaneously.

LNG

Non-commercial prices and distinct regional LNG markets make it difficult to obtain one single and plausible LNG fuel price for a globally traded tanker. For simplicity, European natural gas price is assumed as a representative for Odfjell, as one of their main ports is Rotterdam, Netherlands. A premium for liquefaction, shipping and storage cost of 4,05USD/Mmbtu[2] is added to convert obtained pipelined natural gas prices to LNG prices. For the European LNG price path scenarios it is important to recognize the market characteristics, and how we expect the interaction between the markets to develop. Our assumptions differentiate from AOE2015 on two points. First, the AOE2015 report mainly concentrates on US natural gas price growth when United States expands their LNG exports. With the low natural gas prices observed in US today, it is reasonable to expect increased US natural gas prices as a result of increased LNG export in the future. From a European perspective it is reasonable to anticipate low priced LNG exports from US to keep European prices on a low level, or even reduced prices. Secondly, our analysis emphasizes less oil dependency for future LNG prices due to the recently observed shifts in the European market. Increased access to low priced US LNG entail incentives for importers to seek gas-indexed purchase contracts in the future. Based on this, we expect a decrease in the US/RoW spread on a long-term perspective. This implies a lower expected long-term growth in European natural gas prices compared to AEO2015 projections for US natural gas prices. Based on historical price data from Zeebrugge Hub we have assumed three possible price path scenarios:

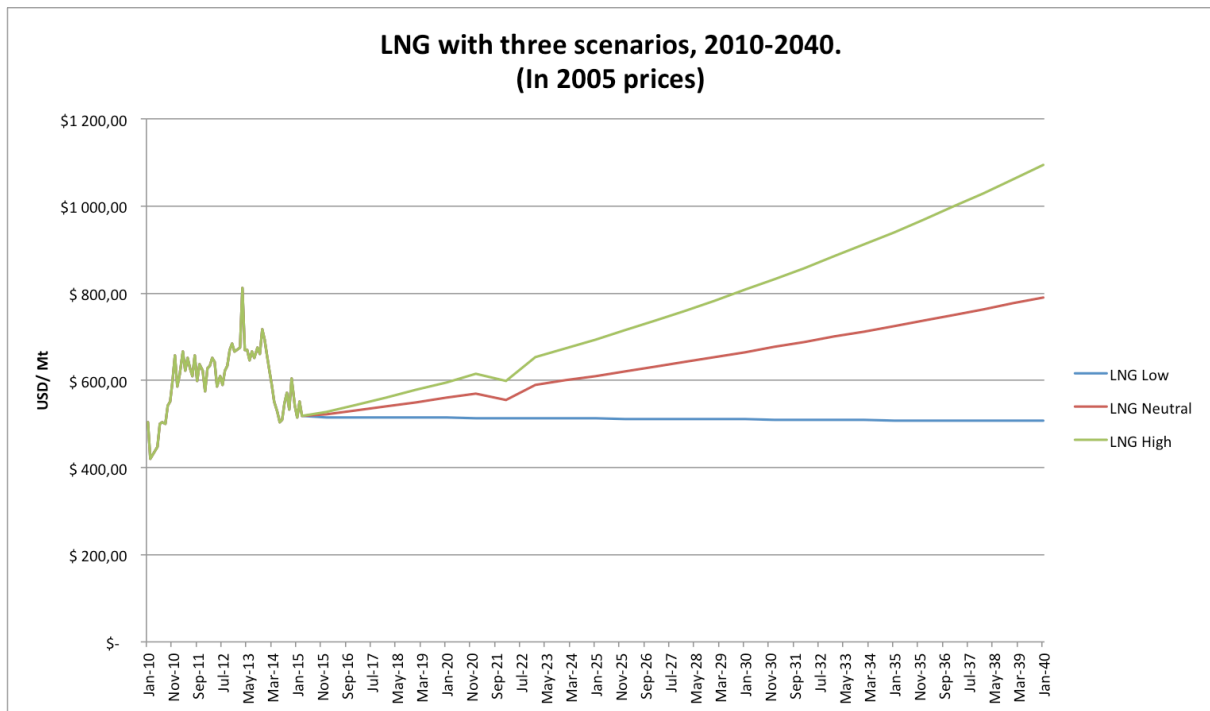
[2] Prices based on approximated data from Gasnor

Figure 18: Price projections for LNG with three different scenarios.

The non-stationary nature of oil and gas prices implies uncertainty whether today's market trends are permanent or if long-term co-integration exists. The question of co-integration in the oil and gas market is frequently studied with varying results depending on specific time periods. Such studies require comprehensive statistical analysis and are accordingly kept out of our scope. Nonetheless, the substitution effects between different energy commodities may cause a situation where one commodity outperforms the other. These are aspects that may influence our results in different directions; however, such aspects are not an integrated part of the analysis.

Price spread scenarios and weighting of NPVs

To incorporate several possible outcomes of fuel price movements, NPV is calculated under different price-spread scenarios and weighted with subjective probabilities. Our approach is designed to assess economical feasibility for investing in LNG under different market conditions. Simultaneously, the model ranks the profitability of scrubber vs. distillates. Three price-spread scenarios are chosen, where the price correlation between scrubber and distillates are segregated while LNG varies in opposite directions. The reasoning behind our probabilities relies on market characteristics elaborated in Ch. 3 and expected fuel price development described in the sections above.

In a neutral oil price scenario, it is assumed that the current market situation will be prominent also in the future; low oil- and gas prices with a moderate growth as a result of a more

stabilized supply and demand balance, and higher marginal production costs. High oil price scenario assumes higher oil independency and increased share of gas-to-gas competition in the European market. Accordingly, this enables high oil prices and low LNG prices simultaneously. These market conditions give incentives for LNG investments in the shipping sector, but also for a substitution from oil-fired power plants to LNG fired power plants, or more use of natural gas. Note that the substitution effects and co-integration may affect the market prices on a long-term basis. However, historical evidence show frequent occurrence of oil prices above LNG prices and we find this scenario relevant for a total evaluation of an investment. Low oil price scenario represents a market with low oil prices and high LNG prices. This scenario requires a decoupling of oil and gas prices and a higher demand for LNG. A situation like this is unlikely to be persistent as substitution effects imply higher demand for oil before LNG as energy source. Historically, this market situation has been evident for shorter periods and is not expected to be the prominent market situation in the future. Since this market situation represents a risk for LNG investments, it is integrated in our weighting with a 20% occurrence probability. The neutral and high case scenario is expected as most likely to incur with a probability of respectively 50% and 30% (summarized in Table 7)

Scenarios	Spreads	Probability
Low oil price	IFO 380 = Low MDO = Low LNG = High	20%
Neutral oil price	IFO 380 = Neutral MDO = Neutral LNG = Neutral	50%
High oil price	IFO 380 = High MDO = High LNG = Low	30%

Table 7: Description of scenarios combination used to assess weighted NPV of LNG under varying assumptions.

Note that the projections are subjectively chosen for analysis purposes and must not be seen as market forecasts in any circumstances.

6.5 DCF results

The DCF model calculates the weighted NPV of the expected estimated future cash flows for three different oil price scenarios and deduct CapEx (USD 15M). Note that all numbers in our model represents costs, implying that the investment with the lowest weighted NPV should be chosen.
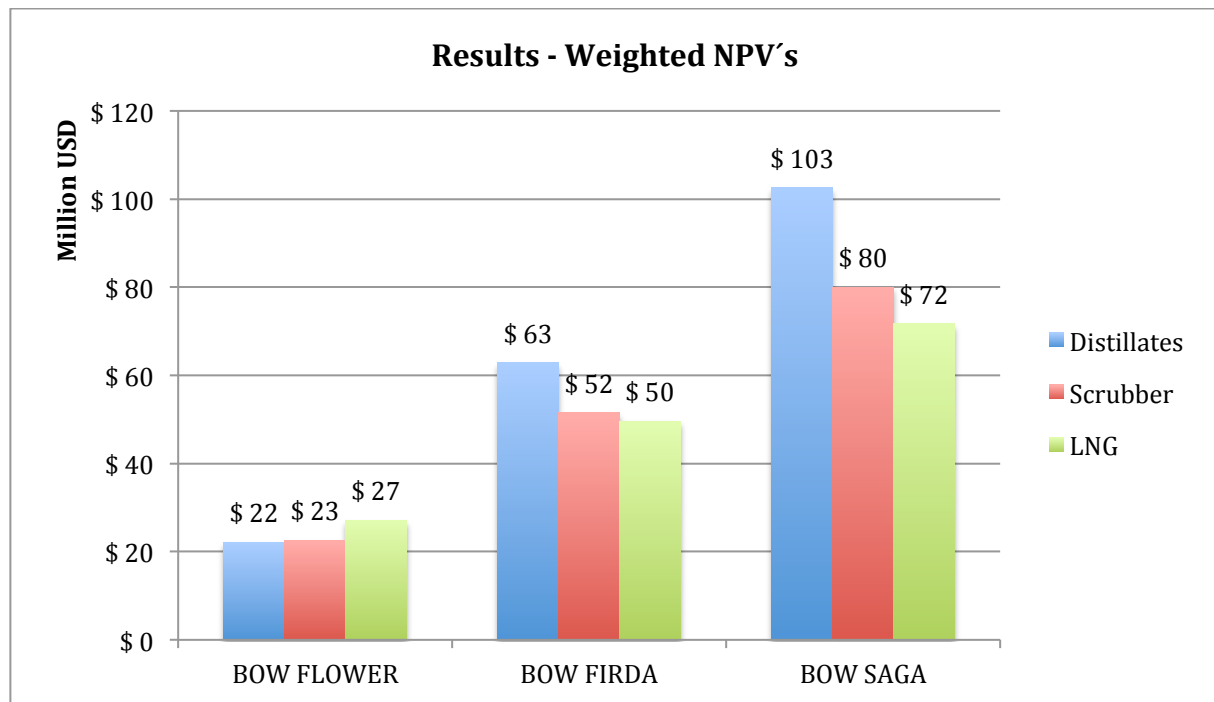

Figure 19: Results of weighted NPV for each vessel.

Bow Flower

Bow Flower is the oldest vessel with only 3 years to obsolescence. For a vessel close to obsolescence distillates are not surprisingly recommendable before scrubber. LNG is not considered as an option. As expected, distillates are advised before scrubber in both low- and neutral oil price scenarios (Appendix A; Appendix B). This is in line with our perception that low oil price leads to a low spread between IFO 380 and MDO in absolute values. Correspondingly this implies that a vessel close to obsolescence depends on a high oil price to make scrubber favourable instead of distillates. However, differences between the two options are marginal and changes in fuel prices and/or capital expenditures may influence the result.

Bow Firda

Bow Firda have 11 years to obsolescence. Surprisingly LNG appears to be advisable in the weighted scenario. However, the difference between LNG and scrubber is marginal and corresponds to approximately USD 2M. Note that a high CapEx (USD 20.1M) for LNG will

change the result to scrubber as the most attractive (Appendix E). Unlike the situation for Bow Flower, scrubber is now significantly more attractive than distillates. This is in line with our expectations. Accumulated savings in fuel costs by investing in scrubber instead of distillates outweighs the up-front investment cost related to a scrubber retrofit. It is remarkable that LNG retrofit is advised before propulsion on distillates even with a high CapEx of USD 20.1M (Appendix E).

Bow Saga

Bow Saga is the youngest vessel with 15 years to obsolescence. Here, LNG is a slightly more advantageous investment before scrubber and distillates. If we go in to the neutral oil price scenario it is evident that differences in NPVs are marginal, while LNG is superior in the case with low oil price. In these cases, potentially savings from low operating costs favour LNG as investment decision. Again the uncertainty in CapEx will be decisive along with uncertainty in fuel prices. Despite marginal cost savings by choosing LNG over scrubber for Bow Saga, this analysis provides an indication that around 15-18 years remaining lifetime is near the intersection of where LNG becomes profitable for this vessel.

6.6 ROA results

6.6.1 The "At the Money" - Exercise price vs. actual exercise price

This section shows the numerical results where the exercise prices give the 2020 call option an "at the money" value (K*). The "at the money" value provides the management information regarding which exercise values that move the option to invest in and out of the money. Exercise price (K) for the 2020 call option is the installation cost of LNG or scrubber. Our calculations show that the option of investing in 2020 in LNG for Bow Flower is "out of the money", thus the call value equals zero. We can see this from Figure 20, where K* is approximately 53% lower than the actual investment cost K for LNG in 2020. We consider it as unlikely to see such a significant decrease in CapEx for LNG. The high spread in K/K* is a result of the vessels low remaining economic lifetime (REL), which gives a limited time to make any revenue on the investments. The investment option for scrubber is also "out of the money", hence K* is lower than the actual investment cost K.
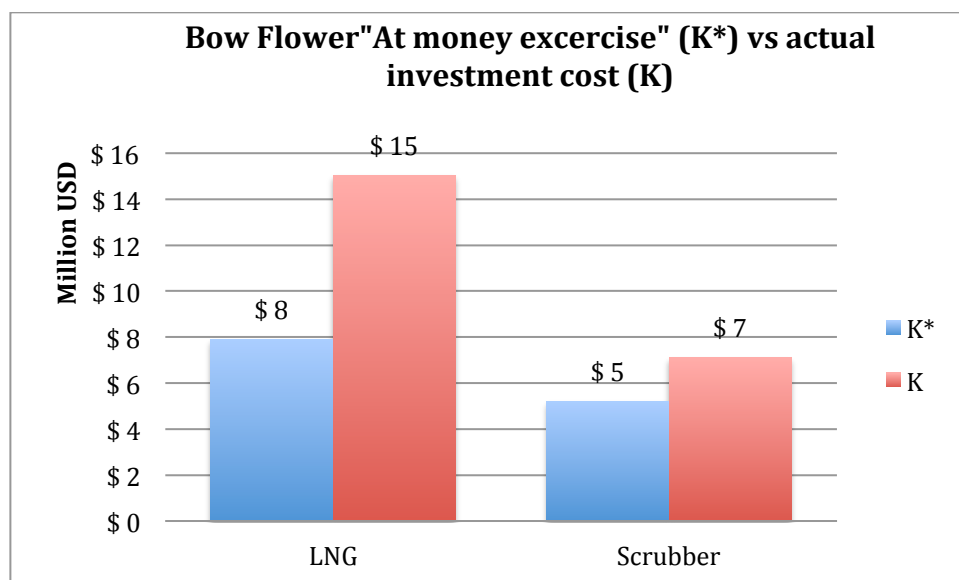
Figure 20: " At the money" K* vs. actual investment cost K for Bow Flower. Both investment alternatives, LNG and scrubber are represented.

Since Bow Firda has a higher REL we expect the strategy of investing now to be more attractive. Figure 21 shows that K* is higher than actual investment cost K for both investment options. The call option is then "in the money", hence higher than zero. This is a result from the higher REL, which gives the vessel a longer period of acquiring revenue from the investment.
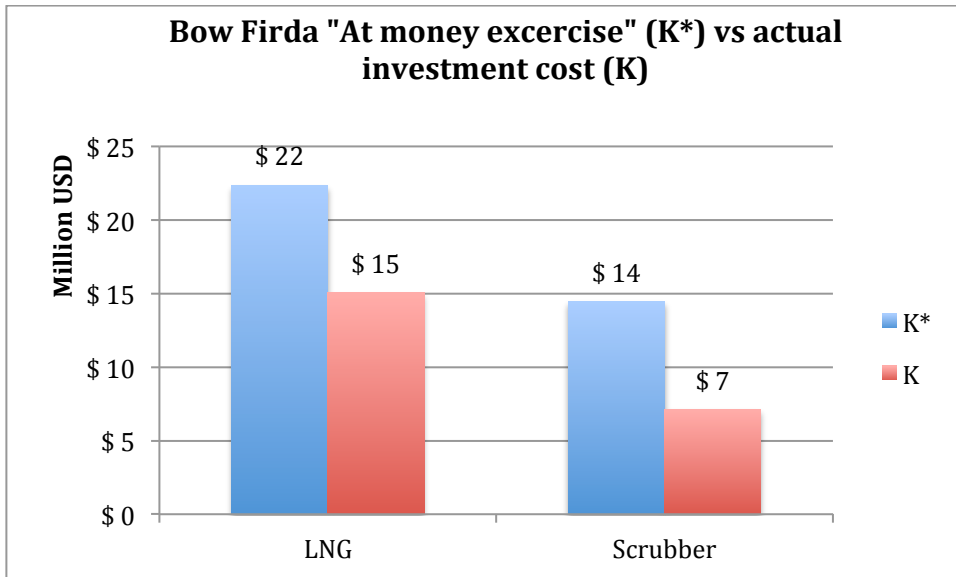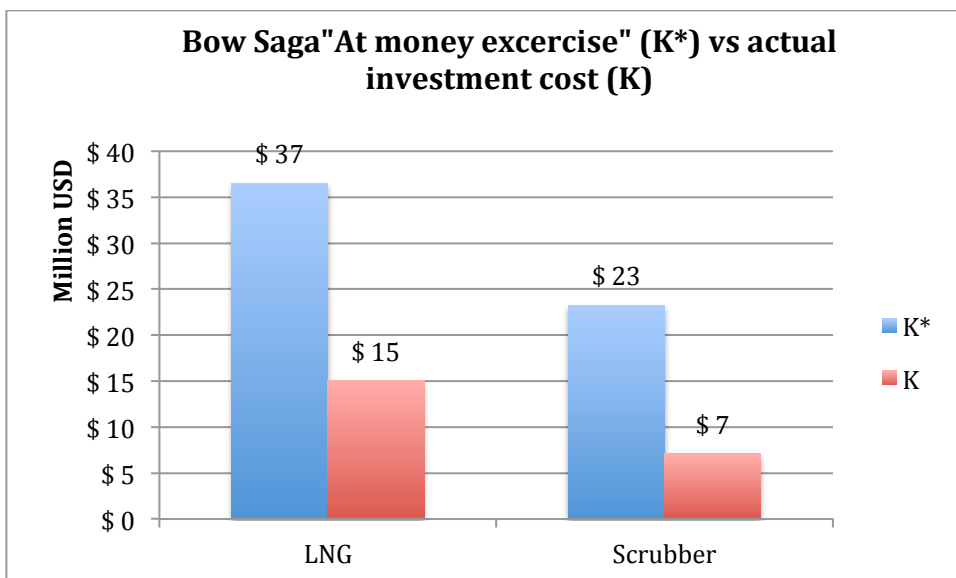
Figure 21: " At the money" K* vs. actual investment cost K for Bow Firda. Both investment alternatives, LNG and scrubber are represented.

Bow Saga is the vessel with highest REL and have a higher K* then Bow Firda. A longer lifetime for Firda and Saga neutralize some of the risk of not earning high enough revenues to justify the initial investment cost. The K* value for LNG is higher than the exercise price K, and is therefore "in the money". For the scrubber option it is the same conclusion.

Figure 22: " At the money" K* vs. actual investment cost K for Bow Saga. Both investment alternatives, LNG and scrubber are represented.

6.6.2 Call option values

LNG Call Option Values

We will first analyse the value of the call options without the deferral value. It is not possible to draw any conclusion from the call option values, but will give a wider comprehension of the option paths illustrated in Figure 23. For Bow Flower our analysis shows an increase in call option values for the LNG alternative throughout the lifetime. As the call option value increases, postponement gets more attractive. This is a result of acquired market information about future fuel prices and CapEx, which management obtains by waiting. Bow Flower is the vessel with lowest REL, and therefore has a higher risk for not recouping the investment cost of installing LNG. In Figure 23 we can see that the value of investing in LNG in 2020 is zero for Bow Flower, thus it is "out of the money". This means that there is no value of investing in LNG retrofit for this vessel in 2020.

The LNG call values for Bow Firda are more fluctuating in the analysed period, see Figure 23.The increase is a result of the acquired information; hence the value increases as the risk is reduced due to more information at hand. Periods with decrease are due to the fact that the value of not investing and sacrificing potential savings is valued higher than the value of gaining more information. In Figure 23 we see that the value of investing in LNG for 2020 have an "in the money" value at USD 7.3M. This means that there is a positive value for shipowners by investing in LNG retrofit in 2020.

Bow Saga has a USD 21.5M option value of investing in 2020 (See Figure 23). The value increases in 2021 as the management gain more information from the market. This information has a higher value than the cost of running on distillates for one more year. Between 2021 and 2025 the value is decreasing. This is due to the vessels high REL, with a coherent lower risk of not recouping the investment cost compared to the other vessels. With a lower risk, the value of further reduction of risk is worth less than the value of potential loss of savings. In other words, the postponement of the investment does not have as high neutralization effect on risk for this vessel as it has on Bow Flower and Bow Firda. To make any conclusion about optimal decision we first have to analyse the value of deferral. This will be done in section 6.6.3.
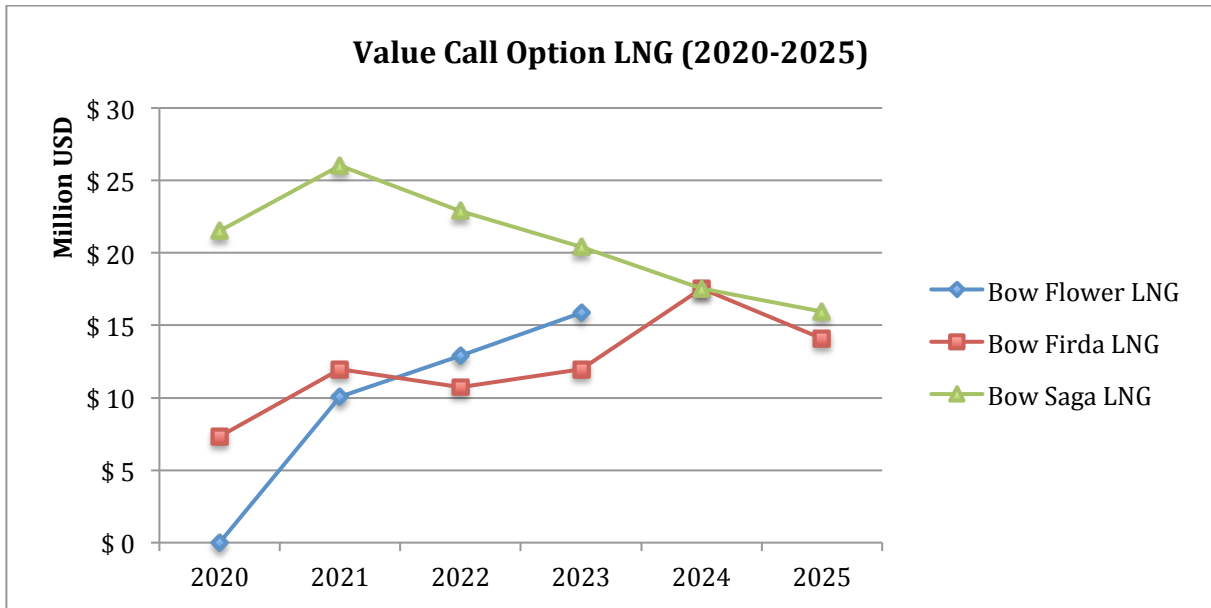
Figure 23: Call values for investment alternative LNG for all vessels

Scrubber Call Option Values

The alternative of retrofitting to scrubber has a lower risk than for LNG. This is due to the low CapEx and constant savings in fuel costs compared to propulsion on distillates, for all scenarios. There is risk in this alternative since the savings can fluctuate, but the total risk is lower than for LNG. For both the vessels with highest REL we have a close to constant decrease of the call option values, which implies that loss of potential savings is valued higher than additional market information. For Bow Flower we have a constant increase throughout the lifetime, implying that the value of more information is valued higher than investing in scrubber. We can see in Figure 24 that the call value for investing in 2020 is zero for Bow Flower, hence the option is "out of the money" and it does not bring any savings value to the shipowners.
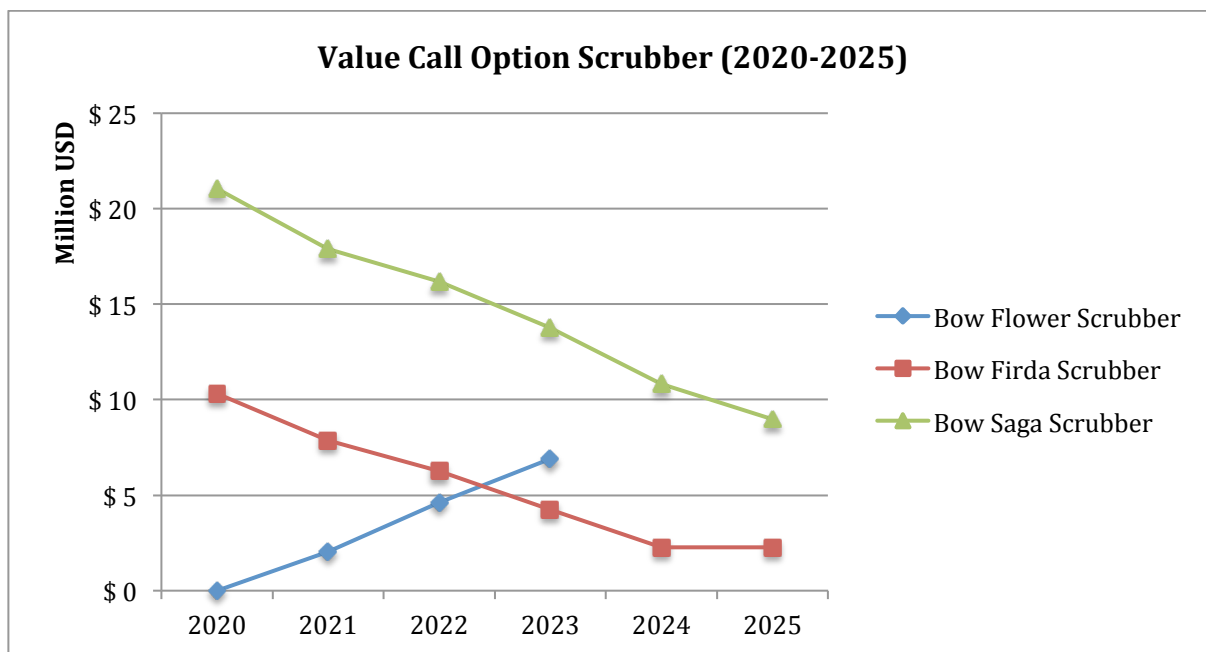
Figure 24: Call values for investment alternative scrubber for all vessels

6.7 Deferral option value

In order to obtain the call value of deferring, the exercise price (RF) must be deducted from the accompanying call option values. For a proper understanding of how to identify the optimal investment time, a recall from theory can be useful: Theory implies that it is optimal to invest when the call option value of investing in 2020 is higher than the deferral value (Brach, 2003). Since we use a Parisian barrier call option, the value of investing in 2020 has to stay higher for an extended period of time. This can be accomplished in two different ways; either by knocking the option "down and in" through the barrier[3]; which means that the optimal time for investing is when the deferral value decreases and intersect the value for the 2020 call option. If the call option value initially is higher than the deferral value it is optimal to invest. If management choose not to invest at this point, they bear a risk that the option can be knocked "up and out" through the barrier. This will be the case if the deferral value increases and intersect the barrier. Since we have two different investment alternatives, scrubber and LNG, we choose the one that provides shipowners the highest value.

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[3] The barrier is represented by the call value of investing in 2020. This is properly illustrated in Figure 26.

Bow Flower

For Bow Flower, the values of deferring increases continuously (Figure 25), which implies that investing later or never in LNG and scrubber is a better decision for a ship with short REL. Short REL implies poor revenues from investing in LNG or scrubber, thus recommending to keep running on distillates throughout the lifetime. We can see from Figure 25 that the 2020 call value of investing is never crossing the deferral option.
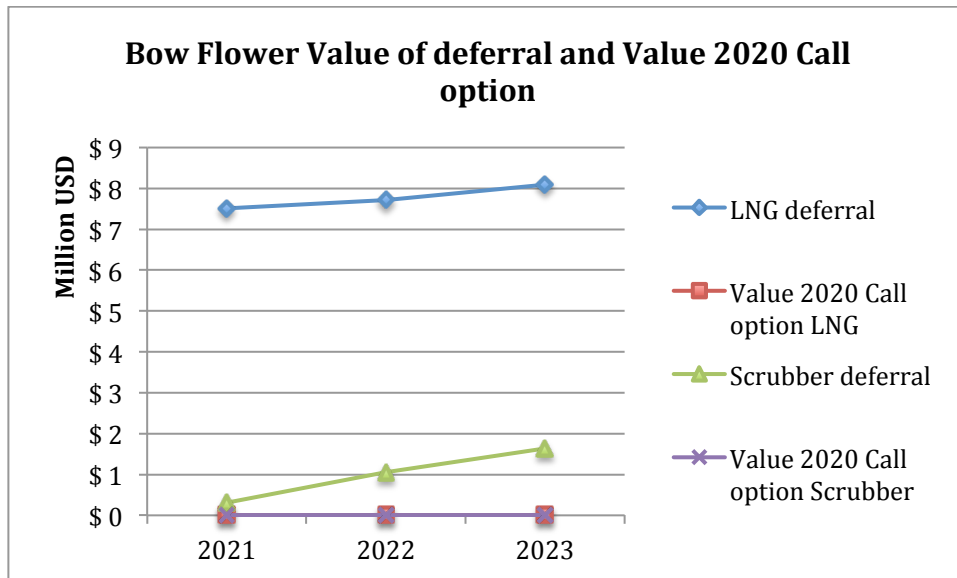

Figure 25: Bow Flower: Value of deferring and value of 2020 call option for LNG and scrubber. Value of the 2020 call option represents the barrier for the accompanying investment alternative.

Bow Firda

In the case of Bow Firda, the deferral value for LNG fluctuates throughout the period (Figure 26). In the start of 2022, the deferral value intersects the 2020 call option value, down and in. The intersection indicates the optimal time for investment. Since this is a Parisian barrier call option the value of deferral has to remain lower than the barrier for a persistent period of time. Our analysis indicates that the value remains lower than the barrier until 2024 when it gets knocked up and out. We recommend a one-year timeframe as long enough to determine if this is a short turn drop in LNG prices, or if it stabilizes at a low level. If the LNG market stabilizes in the low price segment, our analyses indicate investing in LNG retrofit in the end of 2022 for Bow Firda.

The value for scrubber deferral is below the 2020 call option value for the entire timeframe. It never gets knocked up and out since the deferral value has a constant decreasing value. Our

results for Bow Firda indicate scrubber as the optimal investment alternative, and should be implemented during the end of 2020. This is due to the fact that scrubber obtain a higher 2020 call option value then the scrubber deferral option value, LNG deferral option value and LNG 2020 call option value.
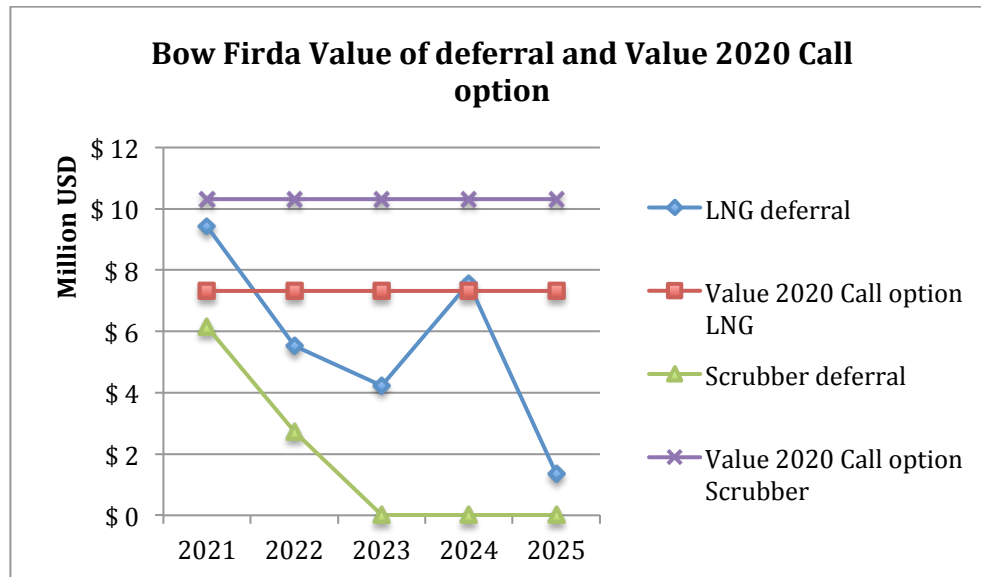

Figure 26: Bow Firda: Value of deferring and value of 2020 call option for LNG and scrubber. Value of the 2020 call option represents the barrier for the accompanying investment alternative.

Bow Saga

Bow Saga with the highest REL has a constant decreasing deferral value for both scrubber and LNG (see Figure 27). This implies that there is value by waiting, but if management wait for too long, the value will decrease. For LNG, the value of deferring is higher than the value of investing in 2020. The barrier crosses down and in during the year 2021. For this vessel we recommend a persistent six months time period as sufficient to see how the LNG prices evolve. The reason for the shorter time period is the longer REL of this vessel, which implies a lower risk for the investment. Thus, management will minimize the total loss of potential revenue. The 2020 call option value for scrubber is slightly below the 2020 call option value for LNG, thus the LNG alternative is favourable before scrubber. Further, we can see from Figure 27 that the deferral value for LNG intersect the LNG 2020 call option value in 2021, which indicates that the optimal time for investing in LNG for Bow Saga is in year 2022.

Our results for Bow Saga indicate LNG as the optimal investment alternative, and should be implemented in the beginning of 2022. This is due to the fact that LNG obtains a higher 2020

call option value than the scrubber deferral option value and scrubber 2020 call option value.
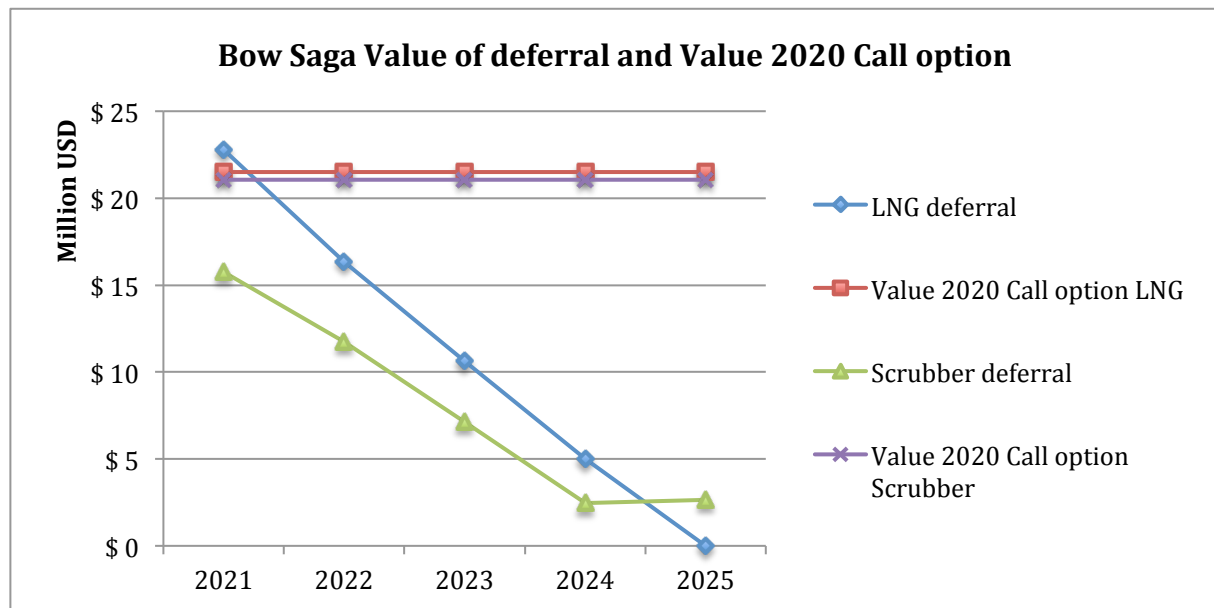

Figure 27: Bow Saga: Value of deferring and value of 2020 call option for LNG and scrubber. Value of the 2020 call option represents the barrier for the accompanying investment alternative.

Impacts of CapEx variations

The value of the real option for LNG depends on the spread between MDO-LNG and the evolvement of CapEx. The previously reviewed analysis incorporates the spread between the two fuel types by having three different price path scenarios on each alternative. To gain a wider perspective of the consequences of variations in CapEx for LNG, we have calculated the ROA with both low (USD 9.2M) and high (USD 20.8M) CapEx. If the investment cost drops to USD 9.2M in 2020, a LNG retrofit in 2021 would be optimal for Bow Firda and Bow Saga, which have the longest REL (Appendix G;Appendix H). For the youngest vessel, Bow Flower it is still optimal to keep running on distillates until obsolescence date (Appendix I). This is also confirmed previously in Figure 20 where the "at the money" investment cost is estimated to be maximum USD 8M (Appendix F).

If the LNG investment cost increases to USD 20.8M in 2020 it is advisable to rather invest in scrubber at the end of 2020 for the two vessels with the highest REL, Bow Firda and Bow Saga. For Bow Firda the value of the LNG 2020 call option never crosses the barrier line and indicates that investing in LNG for this vessel is not an alternative (Appendix J). This is in contrast to our results in the reference case. For Bow Saga, with the longest REL, the impact of variations in CapEx appears to be less significant. With high CapEx of USD 20.8M, the optimal time for investment only shifts with approximately six months, until the end of 2022 (Appendix K).

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7.0 Conclusion

In this thesis we have elaborated how the forthcoming new global regulations from IMO affect the stakeholders in the maritime sector. Increasingly stringent regulations enforce shipowners to make future investments that constitutes additional uncertainty and complexity to their business. The abatement solutions and accompanying technologies are currently available. Also, some of the solutions may also have beneficial effects, due to savings in fuel costs, decreased operational costs or higher energy efficiency. However, the cost aspect exceeds the revenues in all of the abatement solutions considered in this thesis. Regardless of the numerical results obtained in this paper, it is important to assess the inherent risk associated to technological viability, fuel availability and future fuel price development. LNG, scrubber and distillates are considered as commercially available technologies; nonetheless, limited experience with these technologies indicates potential for future improvements as well as failure. Development in infrastructure and bunker supply for distillates and LNG is uncertain. Conversely, the supply and infrastructure for traditional fuels are well established and may entail reluctance among shipowners in the choice of investing in e.g. LNG before scrubber. Furthermore, the current situation in the oil market is rather precarious and the directions for the future development are highly uncertain. In order to comply with the uncertainty, an adequate decision support tool that incorporates flexibility, and identifies the optimal time to invest is sought.

Our results indicate that a DCF model is a valuable decision support tool to assess the attractiveness of the investment alternatives considered in this thesis. However, the model only applies under the assumption that the input data is persistent for the total assessment period. Accordingly, we modified the traditional DCF model to incorporate three possible future scenarios based on weighted probabilities. From the DCF analysis it is evident that the optimal investment decision depends on expected remaining lifetime, and expected future development in fuel prices. As expected, the results indicate that propulsion on distillates is advisable for older vessels. The initial investment cost for LNG or scrubber exceeds the costs of running on distillates for a vessel with short remaining lifetime. The results also confirmed our perception that scrubber is favourable for medium aged vessels, while LNG only applies to vessels with high remaining lifetime. However, the DCF analysis also shed light on the inherent risk in these types of investments. A test for changes in LNG CapEx levels, revealed significant impact on the total LNG investment cost for medium aged vessels e.g. Bow Firda.

During the process of this dissertation, we have experienced the usefulness of managerial flexibility offered by ROA, and it has potential to be a valuable assistance tool in strategic investment planning. The approach provides shipowners the possibility to postpone an investment decision until more information is available, and thereby reduce the risk of making an irreversible investment. For comparison with the DCF analysis, the ROA reflects the characteristic findings that distillates are advisable for younger vessels while LNG is recommended for vessels with a longer remaining economic lifetime. However, for the medium aged vessel, scrubber appears to be the recommended investment alternative. This is due to the constant fuel cost savings in all three oil price scenarios, and a relatively low CapEx. The model also reveal that the vessels with longer remaining economic lifetime bears a lower investment risk, which implies that the value of deferring is lower for younger vessels. Accordingly, changes in CapEx have a minor impact on the strategic investment decision for the younger vessels, when compared to the older vessels. Although we have incorporated uncertainty in future fuel price development and CapEx, the input variables in our models are few. Nevertheless, it is possible to add complexity to the model in order to assess how variation in fuel consumption, operational and maintenance costs, technology development etc.

7.1 Directions for future research

The future worldwide emission regulation addressed in this paper, enters into force in 2020. This implies that our results are highly uncertain. An obligatory recommendation is to calculate the NPV and ROA closer to implementation date for the regulation. Within this timeframe shipowners will gain more recent information on fuel prices, cost of LNG retrofit, and development of global LNG bunker infrastructure. As this paper is highly dependent on future fuel prices over an extended period of time, a proper modelling of the relationship IFO/MDO/LNG is recommended. The commodity markets for energy are complex, and the market for oil and gas goes beyond the use of fuel for shipping and transportation. This implies that the consequences of substitution effects may be more prominent than considered in this thesis. This implies that the question of co-integration in one or several commodity markets should be proper analysed. Other aspects not considered in this thesis, are the effects of improved engine efficiency and reduction of fuel consumption when installing technology for compliance with other emission regulations e.g. NOx or EEDI. For this purpose, the real

option approach in this paper is applicable to add complexity. Our obtained results may be transferable for other similar vessels, or frequently traded route for a shipping company. However, it would be interesting to consider a strategic implementation of these results related to a fleet renewal process. This would combine using ROA for option to deferral, option to switch with the use of dual fuel, option to time charter more vessels (option to grow), or option to abandon markets/vessels. This would demand a closer contact and cooperation with the fleet owner.

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Appendix Collection
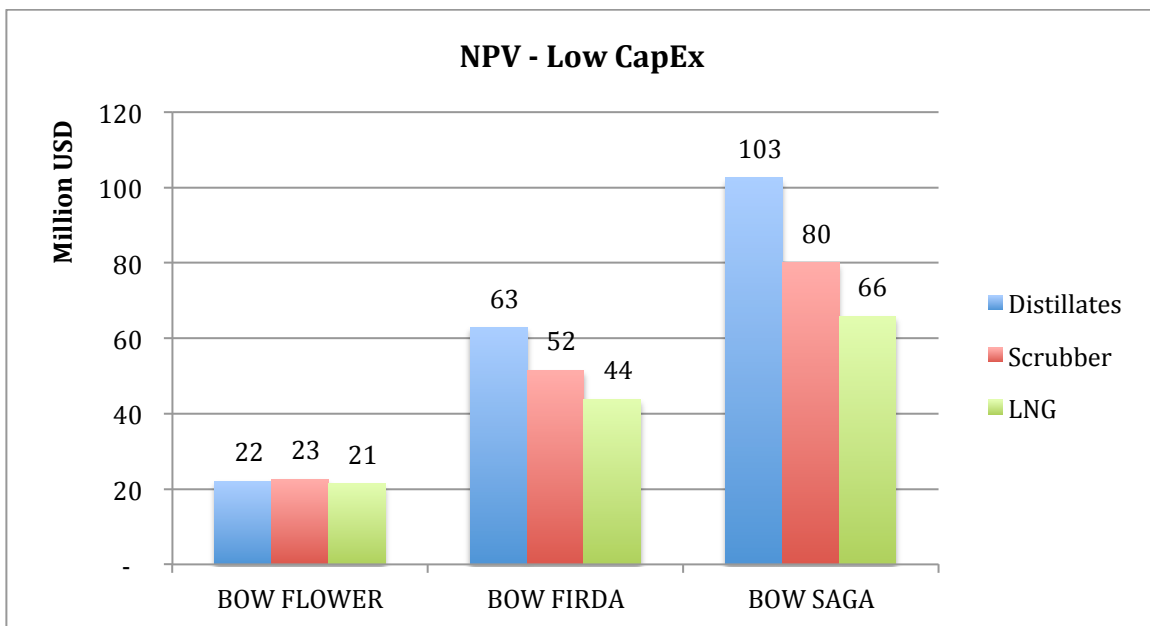
Appendix A

NPV - Low Oil Price Scenario
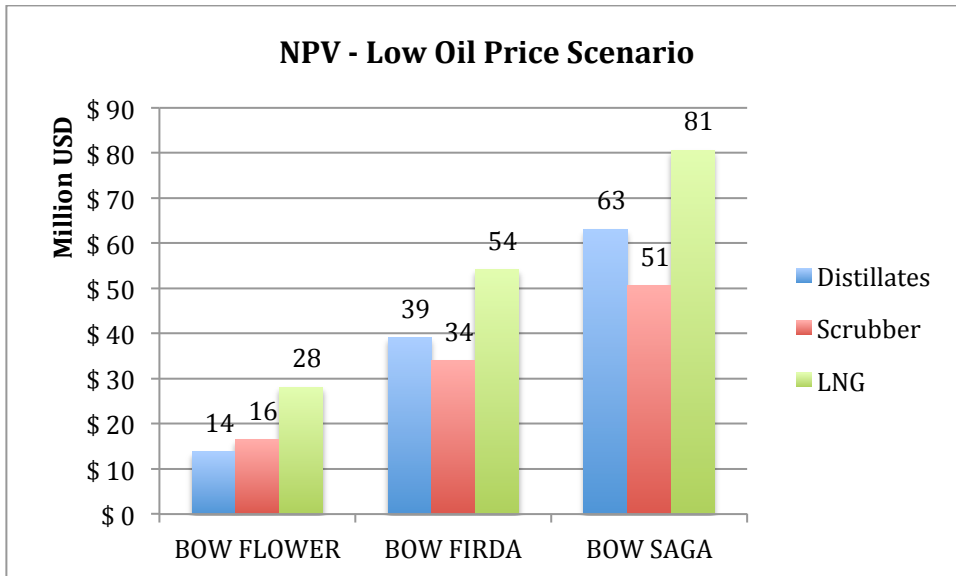
NPVs in the low oil price scenario

Appendix B

NPV - Neutral Oil Price Scenario
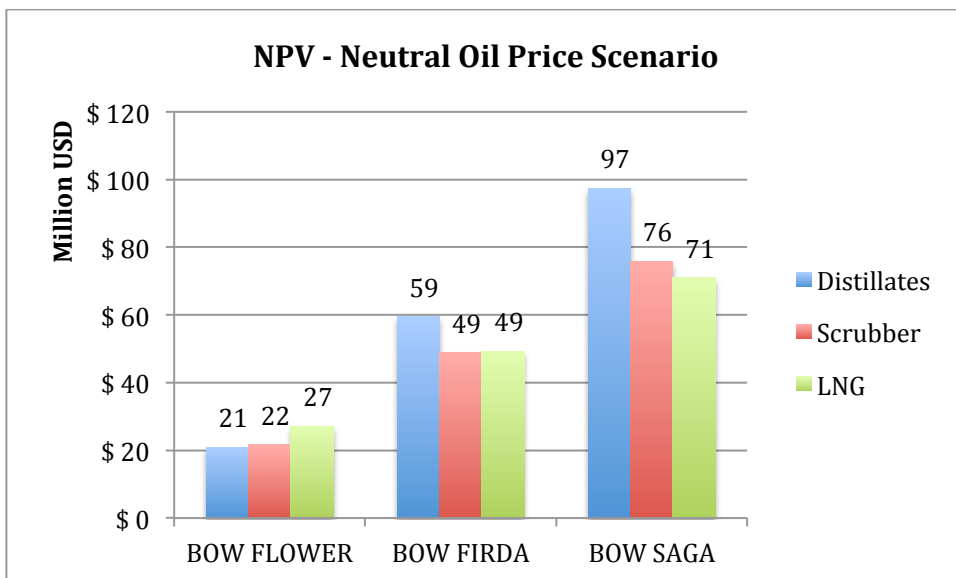
NPVs in the neutral oil price scenario

Appendix C

NPV - High Oil Price Scenario
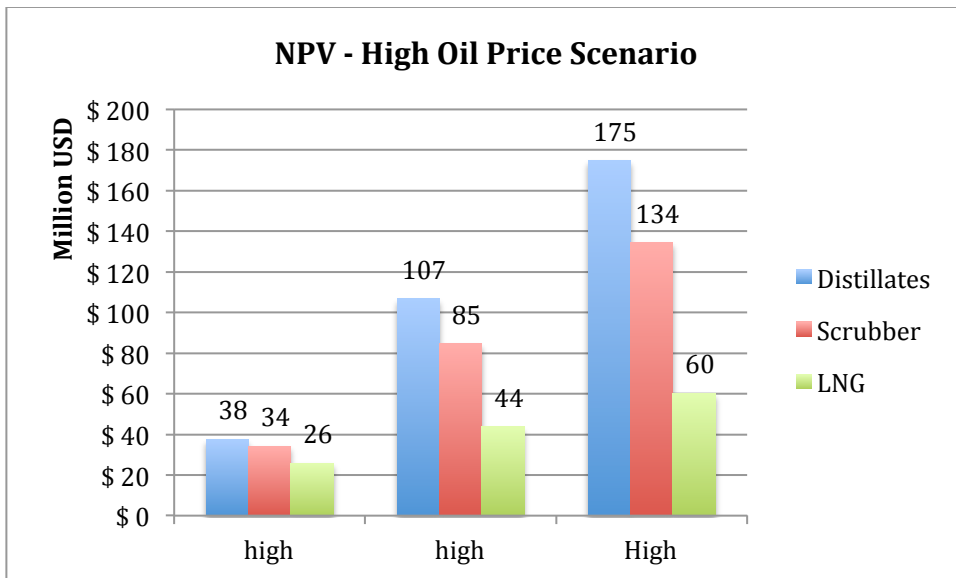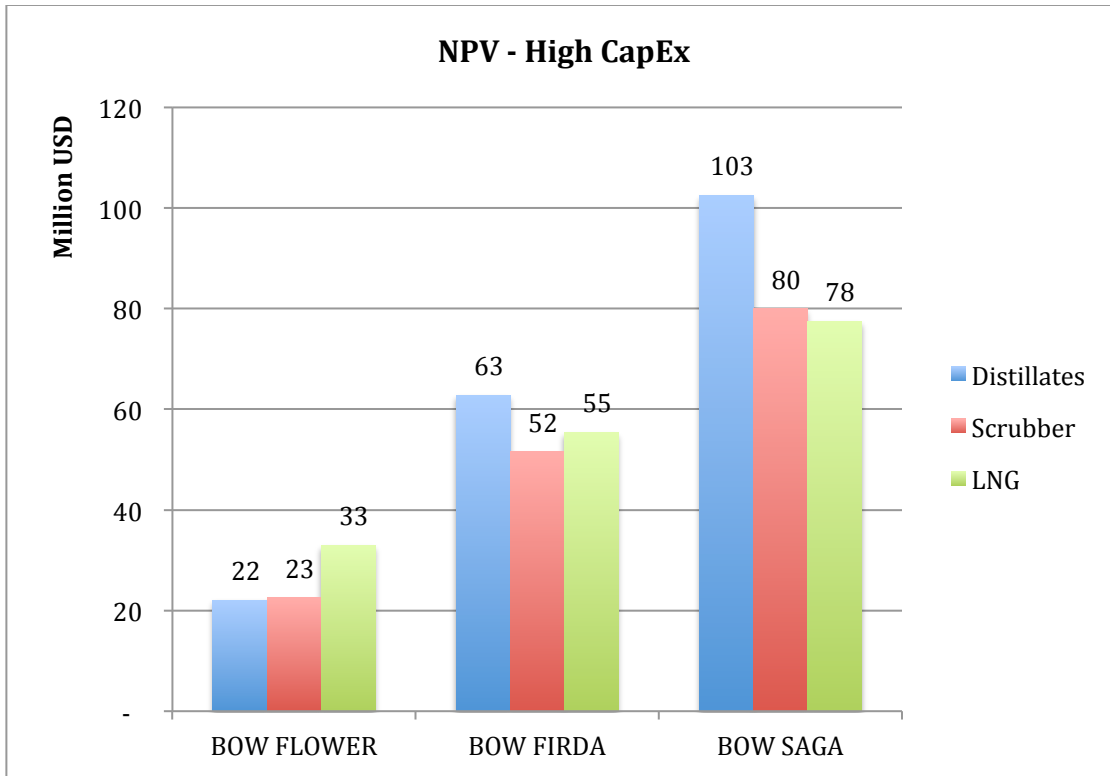
NPVs in the high oil price scenario (not referred to in the text, but is included as a basis for comparison)
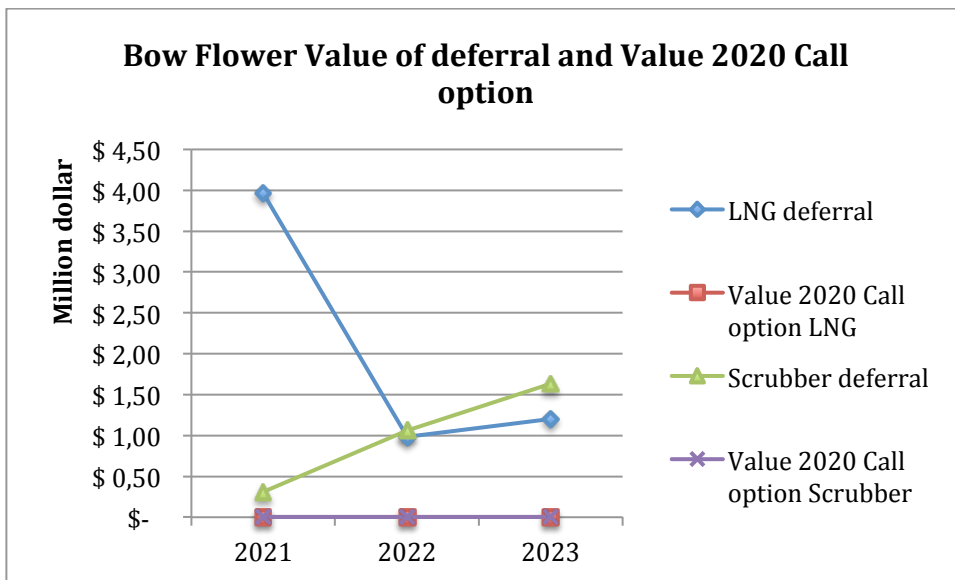
Appendix D

NPV - Low CapEx

NPVs with low CapEx of USD 10M (not referred to in the text, but is included as a basis for comparison)

NPV - High CapEx

NPVs with high CapEx of USD 20M
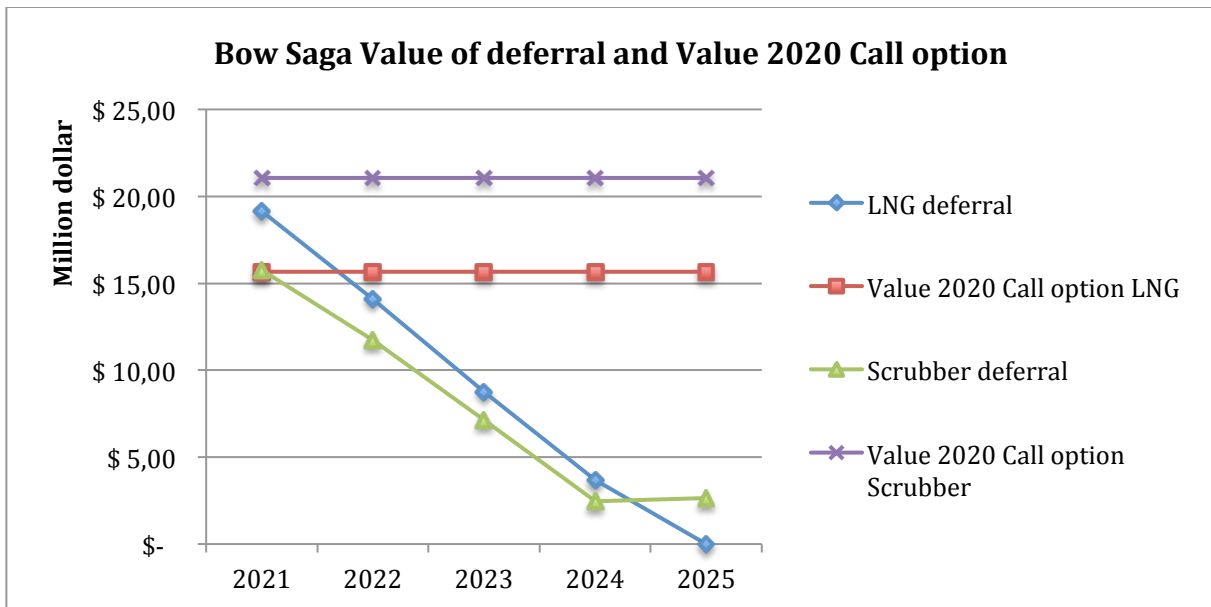
Bow Flower Value of deferral and Value 2020 Call option

Bow Flower Value of deferring and 2020 Call Option for LNG and Scrubber with exercise price for LNG $9.2M

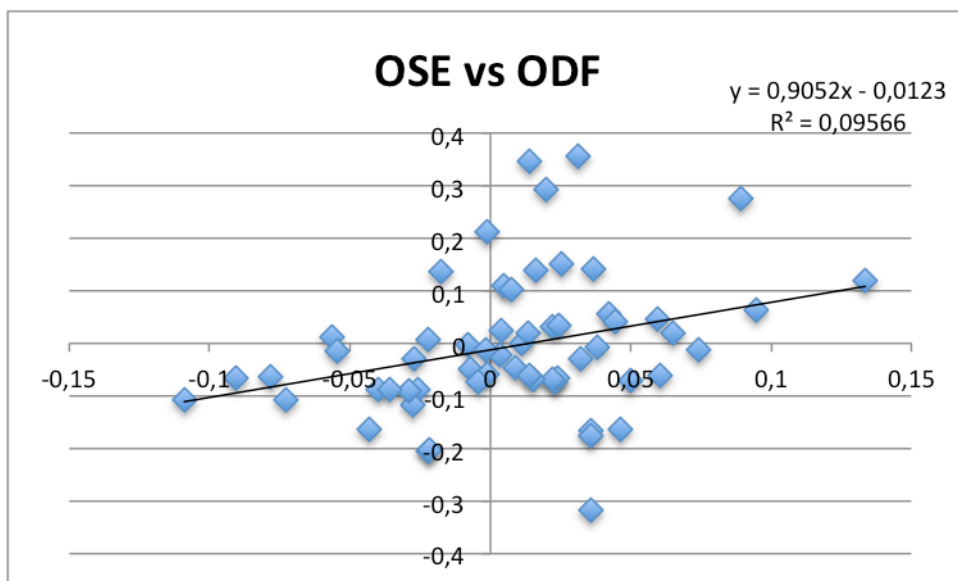**Bow Firda Value of deferring and 2020 Call Option for LNG and Scrubber with exercise price for LNG $9.2M**

Bow Saga Value of deferring and 2020 Call Option for LNG and Scrubber with exercise price for LNG $9.2M
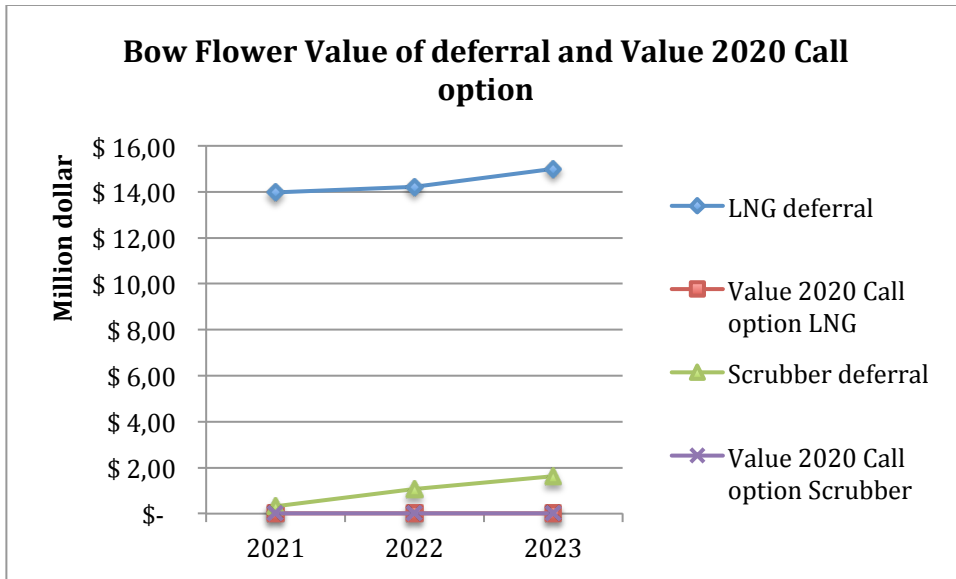
Bow Flower Value of deferring and 2020 Call Option for LNG and Scrubber with exercise price for LNG $20.8M

Bow Firda Value of deferring and 2020 Call Option for LNG and Scrubber with exercise price for LNG $20.8M

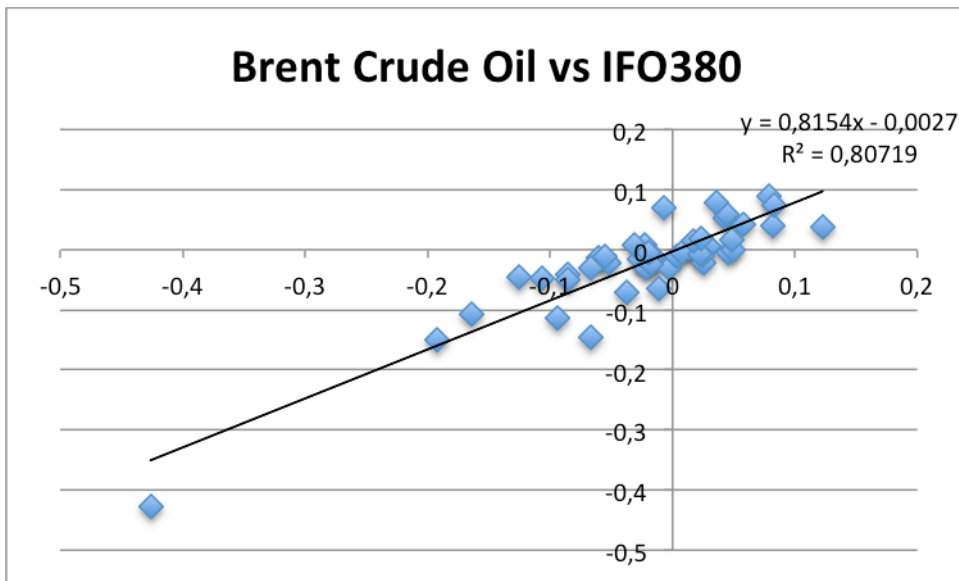**Bow Saga Value of deferring and 2020 Call Option for LNG and Scrubber with exercise price for LNG $20.8M**
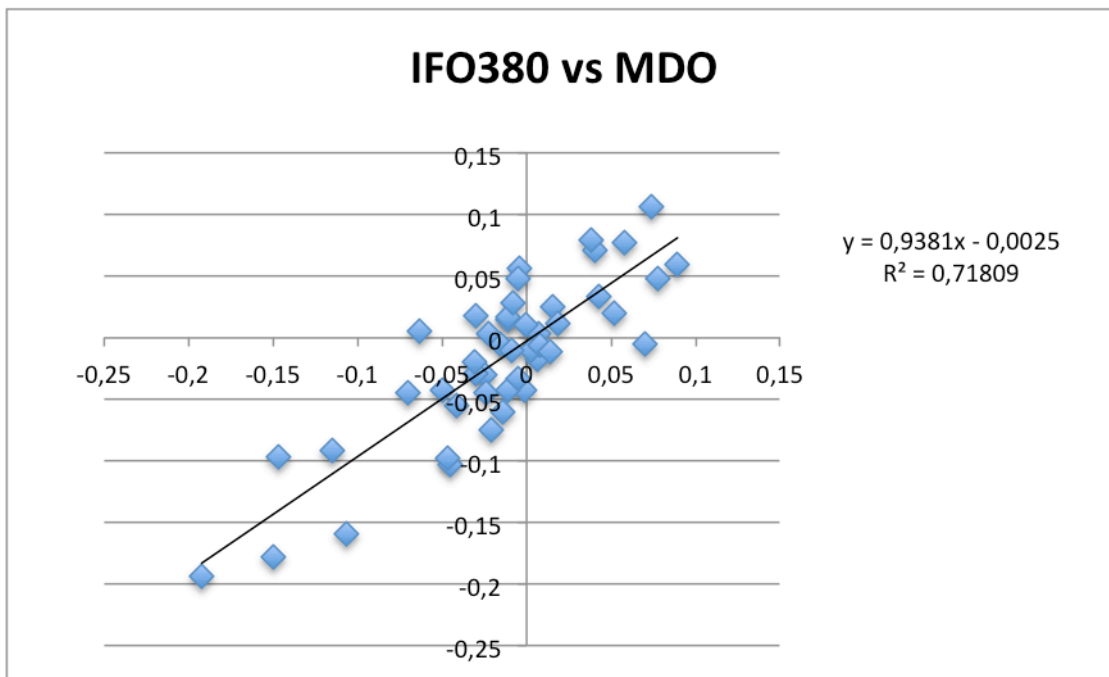
Beta Regression between OD Shipping and Oslo Stock Exchange, monthly data 01.04.2010-01.03.2015

Appendix M

Regression between Brent Crude Oil andIFO380, monthly data 01.04.2011-01.02.2015

Appendix N

Regression between IFO380 and MDO, monthly data 01.04.2011-01.02.2015

Appendix O

Prices	Correlation
Brent Crude Oil vs IFO 380	0.8984
IFO 380 vs MDO	0.8474
IFO 380 vs European Natural Gas (Zeebrugge)	0.2280

Correlation in fuel prices

Appendix P

Daily Average Trades	Total annual stocks traded			
2010-2015	2011	2012	2013	2014
17	4 642 206	11 256 034	13 221 555	10 751 231

Overview of the trading of OD stocks