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The potential of methanol as a competitive marine fuel

Diploma thesis in the Marine Engineering Programme

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Abstract

The environmental demands on the marine industry are getting tougher. At the start of the year 2015 the maximum permitted sulphur content in ships exhaust gas are lowered. Exhaust emissions from marine vessels are regulated by MARPOL. The regulation generally states that the maximum sulphur content in marine fuels will be lowered from 1,0 % to 0,1 %. This applies for vessels that operate within a Sulphur Emission Control Area.

The purpose of this study is to chart the potential of methanol as a marine fuel within the North European Sulphur Emission Control Area. To achieve this, a series of sub-questions has been constructed. The sub-questions are answered with a literature study, an electronic survey and by two interviews.

The results of this study indicate that the preconditions for the development of methanol propulsion are in progress. The engine-manufacturers can supply several different types of methanol powered engines. IMO (International Maritime Organization) is currently working on a regulatory framework which will cover the use of methanol aboard merchant vessels. According to the electronic survey and the two interviews there is a small certain interest to invest in methanol-propulsion. The current price of methanol is relatively high but according to the interviews this is expected to fall in a near future.

Keywords: Methanol, Marine fuel, Potential of methanol, SECA

Sammanfattning

Miljökraven på handelssjöfarten blir allt hårdare. Vid årsskiftet till 2015 så skärps kraven av svavelutsläpp i fartygs avgaser. Avgasutsläpp från fartyg regleras av MARPOL. Regelverket säger generellt att den högsta tillåtna svavelhalten i fartygsbränsle kommer att sänkas från 1,0 % till 0,1 %. Detta kommer att gälla fartyg som operarar inom svavelkontrollområden.

I denna studie undersökts vad metanol har för potential för att bli ett konkurrenskraftigt fartygsbränsle inom det Nordeuropeiska svavelkontrollområdet. För att undersöka detta har ett antal underfrågor formulerats. Dessa underfrågor besvaras med hjälp av en litteraturundersökning, en enkätundersökning och två intervjuer.

Resultaten i denna studie påvisar att de förutsättningar som krävs för att metanol ska etableras som fartygsbränsle är under utveckling. Motortillverkarna kan vid behov tillverka metanoldrivna fartygsmotorer. IMO (International Maritime Organization) håller på att utveckla ett internationellt regelverk för användning av metanol ombord handelsfartyg. Enkäten och intervjuerna i denna studie visar att det finns ett visst vagt intresse bland rederierna att investera i metanoldrivna fartyg. Metanolpriset är i dagsläget förhållandevis högt men enligt intervjuerna i studien så förväntas detta falla inom snar framtid.

Nyckelord: Metanol, Fartygsbränsle, Metanolens potential, SECA

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Table of Contents

List of Figures

List of Tables

Definitions

Flashpoint - The lowest temperature of a substance when it emits flammable vapours in a combustible concentration (Korver, 1996).

Low-speed diesel engine - Marine diesel engine with a working speed of maximum 240 RPM. (Rotations Per Minute)

Medium-speed diesel engine - Marine diesel engine with a working speed of between 240-960 RPM.

High-speed diesel engine - Marine diesel engine with a working speed above 960 RPM.

IMO - (International Maritime Organization) A United Nations agency responsible for marine activities.

SOLAS - *(Safety Of Life At Sea*) International regulatory framework developed by the IMO concerning safety issues on merchant ships.

MARPOL - International regulatory framework developed by the IMO. The purpose of MARPOL is to prevent pollution from marine vessels.

SECA - Sulphur Emission Controlled Area

1. Introduction

The demands on the marine industry regarding exhaust emissions are getting stricter. At the start of the year 2015 the maximum allowed sulphur content in marine fuels used by vessels operating within a SECA will be restricted from 1,0 % to 0,1 % (IMO, 2005). Vessels that normally run on heavy fuel oil will then either have to change to a low sulphur alternative or to install a scrubber unit to lower the sulphur content in the exhaust gas. This study is focused to examine the potential of methanol as a competitive sulphur free marine fuel within the North European SECA.

1.1. Purpose

The purpose of this study is to chart the potential of methanol as a marine fuel within the North European SECA after 1 January 2015. This will be performed by analysing the commercial interest of methanol for ship propulsion. Also the economical features of methanol will be compared with the recognized marine fuels.

1.2. Research questions

From the purpose of this study, the following main research question has been generated:
What potential does methanol has to be a competitive marine fuel within in the North European SECA after 1 Jan 2015?

To answer this question, six sub-questions had to be constructed:
1) Are ship owners willing to invest in methanol powered vessels?
2) How available is methanol for bunkering aboard marine vessels?
3) What is the attitude of the shipping industry towards the use of methanol as marine fuel?
4) Is there any engine manufacture making methanol compatible engines?
5) Are there any international guidelines or regulations concerning the use of methanol aboard marine vessels?
6) What are the costs for using methanol as a fuel for a vessel?

1.3. Delimitations

This study is limited and focused to the marine activities within the North European SECA after 1 January 2015 when stricter exhaust emission regulations takes effect (IMO, 2005). Within a SECA methanol has most likely better economic conditions than on the global seas where it has to compete with cheap residential marine fuels, such as Heavy Fuel Oil.

2. Background

This chapter covers information about the North European SECA and fundamental information about the recognized marine fuels. It also holds a deeper explanation about the basics of methanol and its various areas of use. This chapter will also explain the working principle of a two-stroke marine engine fuelled by methanol and an example of the price history of the fuels used in marine appliances.

2.1. Sulphur Emission Control Area

Worldwide there are two main types of ECA´s (Emission Control Area), within these areas the exhaust emissions from shipping are restricted (IMO, 2014). One type of ECA is covering the east coast of North America as well as the west side including the Hawaiian Islands. These zones extend 200 nautical miles from shore outwards to the ocean (United States Environmental Protection Agency, 2014). Within these areas the emissions to air regarding particles, NO_x (nitrous oxides) and SO_x (sulphur oxides) are restricted (IMO, 2014).

The other emission control area covers the Northern Sea and the Baltic Sea. Within this area the sulphur emissions are restricted (IMO, 2014).

Since these ECA´s restrict the emissions of sulphur, they are often referred to as SECA (Sulphur Emission Control Area).

The current global restriction for sulphur content in marine fuel is 3.50 %, after 2020 this will be restricted to 0.5 %. Within the SECA´s the current limit is 1.0 % and will be restricted to 0.1 % after 1 January 2015 (IMO, 2014).

2.2. Recognized marine fuels

In 2010 the total amount of marine fuel consumed within the SECA was estimated to 12 million tons. This includes both distillate marine fuels and residual marine fuels (Danish Maritime Authority, 2012).

Distillate fuels and residual fuels are specified by ISO 8217, this international standard describes the characteristics of various fuels and it also restricts the content of impurities (ISO, 2010).

2.2.1. Intermediate and residual fuel oil

The most common marine fuels used on marine vessels are various types of residual fuel oils (Kuiken, 2008). These fuel specifications are commonly called residual fuels, intermediate fuels, heavy fuel oils or bunker fuels. These fuels are made from residues from the oil refineries which are blended with a higher grade of fuel oil to give desired characteristics. A common grade is called IFO-380 or RMG 380, as it has a viscosity of 380 centistoke at 50°C.

Table 1, displaying the ISO 8217 specification for RMG 380 (ISO, 2010).

RMG 380	
Viscosity at 50°C	≤ 380 mm^2/s
Flashpoint	≥ 60°C
Pour point	≤ 30°C
Sulphur content, global limit	≤ 3.5 %
Density at 15°C	0.991 kg/dm^3
Carbon residue	≤ 18 %
Water content	≤ 0.5 %

In table 1 it is stated that this fuel has a minimum flashpoint of 60°C. This limit is governed by SOLAS, the regulation generally states that all marine fuel types must have a flashpoint that exceeds 60°C (IMO, 2002).

As can be seen in table 1 this fuel has a maximum carbon residue content of 18 %, the carbon residue is a measurement of the residues the fuel produce when combusted (Kuiken, 2008). A high number can cause pollution of internal engine parts as well as increased exhaust emissions.

The pour point is defined as the minimum temperature at which the fuel will be pourable. To give this fuel a viscosity low enough to make it pump able it should be kept at temperature of at least 10 degrees above the pour point (MAN Diesel & Turbo, 2008). As shown in table 1 the pour point for RMG 380 is around 30°C. This fuel will require heating before it can be transferred through various systems in the vessels (Kuiken, 2008). Before the fuel can be injected into the engine it is usually heated to about 120°C. The heating is commonly supplied by a steam system. If the heating is lost the fuel can solidify and clog critical machinery parts such as fuel pipes, high pressure pumps and fuel distributors.

Before Intermediate fuel oils can be used in a diesel engine it will need on-board treatment to remove impurities and water. This cleaning process is commonly performed by a centrifugal separator and various fuel filters (Kuiken, 2008). Because of the high residual content of this fuel it is mostly used by low-speed and medium-speed diesel engines. The specific heat value of IFO-380 is around 40.5 GJ/ton (Giga joule per ton).

In April 2014, the European spot-price for IFO-380 was around 580 USD/ton (MABUX, 2014). This is equivalent to 14,29 USD/GJ (Appendix 2) more about the price-history in chapter 2.5.

After the oil crisis in the 1970s more vessels were equipped to use residual fuels in order to lower the fuel costs (Reders & Mundt, 2005). Steam turbine propelled vessels were becoming too inefficient and they were gradually replaced by the more efficient 2-stroke diesel engines. Before the fuel crisis there were no diesel engines powerful enough to propel the biggest marine vessels. This oil crisis and a harsher economic environment boosted the development of large 2-stroke diesel engines.

2.2.2. Marine Gas oil (MGO)

DMA is a typical grade of MGO. (Bunkerworld, 2014)

Table 2, displaying the ISO 8217 specification for DMA (ISO, 2010).

DMA	
Viscosity at 40°C	≤ 6 mm^2/s
Flashpoint	≥ 60°C
Sulphur content, global limit	≤ 1.5 %
Density at 15°C	0.890 kg/dm^3
Carbon residue	---
Water content	---
Appearance	Clear & bright

Marine gas oil is a generic term for the highest grades of marine fuel. Some of the grades are very similar to fuels used ashore for road vehicles (Kuiken, 2008). As stated in table 2, this fuel has a zero limit for carbon residue content which makes this fuel combust more efficiently than IFO 380. MGO normally has a specific heat value of 43 GJ/ton. This fuel can be used for all types of diesel engines.

The current European spot-price for DMA is around 900 USD/ton (MABUX, 2014). This is equivalent to 20,86 USD/GJ (Appendix 2).

2.2.3. Marine Diesel oil (MDO)

DMB is a typical grade of MDO (Bunkerworld, 2014).

Table 3, displaying the ISO 8217 specification for DMB (ISO, 2010).

DMB	
Viscosity at 40°C	≤ 11 mm^2/s
Flashpoint	≥ 60°C
Sulphur content, global limit	≤ 2.0 %
Density at 15°C	0.900 kg/dm^3
Carbon residue	≤ 0.30 %
Water content	≤ 0.30 %
Appearance	----

Marine Diesel oil is made of a mixture of MGO and some lower grade fuel (Kuiken, 2008). Note that in table 3, MDO has a minor acceptance for carbon residue and water, which makes it slightly cheaper than MGO. This fuel can also be used by most types of marine diesel engines.

MDO normally has a specific heat value of 42.7 GJ/ton (Kuiken, 2008).

In April 2014, the European spot-price for MDO was around 880 USD/ton (MABUX, 2014).

2.2.4. Liquefied natural gas (LNG)

Liquefied natural gas is a fossil fuel that derives from oil fields, shale gas fields and other underground types of wells (White & McGuire, 2000). Before the gas is used as a fuel it is processed to remove impurities such as carbon dioxide, water and toxic compounds. LNG is a gas mixture with very high methane content which is usually around 70-99 %. The remaining compounds are mainly ethane, propane, carbon chains and nitrogen.

The heat value of LNG is around 13,7 kWh/kg (kilowatt hours/kilogram) which is equivalent of 49.320 GJ/ton$(13{,}7kWh * (3600sec/hour))$ (Jansson, 2011).

LNG is compressed and cooled to liquid-form which reduces its volume by 600 times (White & McGuire, 2000). To keep the methanol liquefied it is usually kept under high pressure or it is cooled below its boiling point of -161.5°C. LNG used for propulsion aboard ships is often stored in isolated and pressurized tanks. These tanks are complex structures and require much deck-space which instead could be used to store cargo.

Liquefied natural gas is becoming increasingly popular as a marine fuel. From the years 2014-2020 the global investments of LNG for the marine industry is expected to USD64.4 billion (Euromoney Trading Limited, 2014).

Methane is a greenhouse gas, when comparing methane to carbon dioxide regarding their global warming potential, methane is 21 times more powerful (United States Environmental Protection Agency, u.d.).

When using LNG as a fuel for an Otto-principle engine some of the fuel is not completely combusted, this is called methane slip (Haraldson, 2013). The engine manufacturers are working on reducing the amount of methane slip. Methane slip reduces the environmental advantages of using LNG. When running an auxiliary generator on LNG about 3 grams of methane will be emitted for every produced kilowatt-hour of work.

The price for LNG as a marine fuel is currently very hard to clarify. The price will vary depending on how complicated the logistic handling of the fuel is.

2.3. Methanol

Methanol has the most basic molecular structure of all the alcohols. It has four hydrogen atoms, one oxygen atom and one single carbon atom (MI, 2014). It is flammable at room temperature and burns with an almost invisible blue smokeless flame.

Table 4, displaying specifications for pure methanol (MI, 2014).

METHANOL	
Chemical structure	CH_3OH
Lower heating value	19.9 MJ/Kg
Flashpoint	12°C
Auto-Ignition Temperature	470°C
Sulphur content	0.5 PPM
Density at 15°C	0.796 Kg/dm^3

As shown in Table 3, methanol has a sulphur content of 0.5 PPM which is considerably lower than the requirements of fuels used within a SECA. The lower heating value of methanol is about half of the heating value of diesel oils and residual fuels, also the density of methanol is lower than for diesel oils and residual fuels.

"Auto-ignition temperature is the lowest temperature where a substance will auto-ignite and combust in normal atmospheric conditions without any external influences." (Helmenstine, 2014). As shown in table 3, the auto-Ignition Temperature for methanol is 470°C.
A fuel with a high Auto-ignition temperature can be difficult to ignite in an ordinary diesel principle engine. This is because a diesel engine ignites its fuel only with highly compressed, high temperature air (Kuiken, 2008).

2.3.1. Applications

Methanol is used in a vast range of different products such as plastics, synthetic materials, solvents, antifreeze liquids, petrol additives and refrigerants (Australian Govornment. Department of the Environment, u.d.).

Marine applications

Methanol has previously only had very limited use on marine applications, mostly as liquid fuel cells which are producing low outputs used as auxiliary power for private boats and yachts (Ynovex Energy, u.d.). The main advantages to use a fuel cell instead of a combustion engine are its low noise levels and its almost zero NO_x (nitrous oxides) and Particle emissions.

Wärtsilä is currently working on a methanol fuel-cell project (Pagni, 2008). The fuel cells developed by Wärtsilä are producing 1 kW, but when stacked together the power output can be increased up to 20 kW. These fuel cells, called SOFC (solid oxide fuel cells), has an electrical efficiency of more than 40 % and an overall efficiency of 80 %. The SOFC´s require high temperature to work which in return requires higher demands from materials in the components. On the positive side the SOFC´s will produce very low emissions.

2.3.2. Methanol production

Methanol is either produced from fossil fuels or biomass. The total global methanol production in 2011 was around 60 million tons and the consumption in Europe was about 7 million tons (Johnson, 2012).

Fossil-methanol

Fossil fuels are by far the most common source of raw-material for the production of methanol (MI, 2014). A benefit of methanol is that it can be manufactured from numerous different types of hydrocarbons. The most common source of raw material is methane found in natural gas. There are also several different methods of producing methanol from the natural gas. The most common procedure is called Steam reforming which is a two-step process:

Firstly steam and methane will react to create Synthesis Gas, which is a gas mixture:

$$2\,CH_4 + 3\,H_2O \rightarrow CO + CO_2 + 7\,H_2.$$

(Methane + water → Carbon monoxide + Carbon Dioxide + Hydrogen)

In the second step a catalyst is used to form methanol, hydrogen and water:

$$CO + CO_2 + 7\,H_2 \rightarrow 2\,CH_3OH + 2\,H_2 + H_2O$$

(Carbon monoxide + Carbon Dioxide + Hydrogen → Methanol + hydrogen + water)

The most common grade of methanol is chemical grade, this is the one mentioned in this study. When producing methanol, if the last refining step is skipped the product is called Raw-methanol. This grade contains some impurities and water, though it has about 10 % lower production costs than chemical grade methanol (Danbratt & Haraldson, 2013).

Bio-methanol

Methanol is commonly called “wood alcohol” this is because the first methanol that was produced was made from the distillation of wood (alcohol-encyclopedia.eu, u.d.).

Today methanol made from renewable hydrocarbons and carbohydrates is usually produced from the pyrolysis process (Yong Xu a, 2011). This process works by heating raw-material up to around 500°C in an oxygen free atmosphere. This will cause H_2, CO, CO_2, CH_4, N_2 and other hydrocarbons to vaporize into a sort of synthesis gas. This syngas usually have lower quality than one made from fossil fuels and will therefore need some treatment before it can be converted into pure methanol.

Methanol made from renewable hydrocarbons and carbohydrates are getting a lot of attention as an environmentally friendly fuel, especially in Europe. In Holland there is a plant which produces methanol from crude glycerine (a by-product from bio-diesel production). The plant opened in 2007 and has an annual capacity of 200 000 tones (CHEMREC, 2008). The production method in this facility is very similar to the steam reforming used when producing methanol from fossil fuels. This is because glycerol has similar properties compared to methane.

There is an ongoing project in Sweden with the goal to start a bio-methanol plant in Hagfors (VärmlandsMetanol AB , u.d.). If constructed the plant will produce methanol from wood residues, the annual production capacity will be 109 500 tons. The goal of this project is to supply methanol for the automobile fleet in Sweden.

2.3.3. Safety

There are safety concerns about the use of methanol in a marine environment. Methanol is flammable, has a low flashpoint and is considered toxic.

Health concerns

Methanol can enter the body through, inhalation, ingestion and through skin exposure (Methanol Institute, 2013). Since methanol is used in so many different everyday used items people are to a small extent exposed to methanol every day. For example, aspartame a sweetener commonly used in carbonated soda has a considerable content of methanol. If a person with a weight of 70 kg drinks 33 ml of aspartame sweetened soda it will give the same methanol content in the blood as bathing its hand in pure methanol for 2 minutes. Methanol is as most harmful if ingested. Drinking as little as 25 ml of pure methanol can be fatal, if not properly treated.

The main symptoms of methanol poisoning will appear 12-14 hours after exposure (Methanol Institute, 2013). The symptoms usually consist of, headaches, nausea, vomiting, abdominal pain, troubled breathing and loss of balance and impaired vision. High exposure can lead to coma and death. There is little known about the long term effects of methanol exposure but as far as known the long term symptoms are similar to the acute symptoms. Methanol is so far not classified as a carcinogen.

Fire safety

The methanol institute has released a Methanol Safe Handling Manual for methanol distributors and users (Methanol Institute, 2013). This manual covers firefighting procedures for handling and preventing a methanol fire.

Methanol will burn with a light blue flame which is almost impossible to detect in daylight (Methanol Institute, 2013). Methanol also often burns with a low flame temperature. These two factors can make a methanol fire hard to detect and it can also complicate the firefighting procedures used to extinguish it.

ScanTech Offshore has developed a system for fire detection and fire suppression that can be fitted to a methanol storage tank (Scantechoffshore, 2014). The system works automatically and will in case of fire instantly release a fire suppressing foam that will smother the fire.

When comparing methanol to gasoline for the interest of the automobile industry, methanol is considered safer (OFFICE OF MOBILE SOURCES, 1994). This is because methanol has a lower heat release rate than gasoline, it ejects less flammable fumes and methanol vapours are more easily dispersed to the atmosphere than gasoline.

2.3.4. Regulations

IMO is currently working on a regulatory framework that will cover the use of low flashpoint fuels on-board vessels (International Maritime Organization, 2013). The code will be called: The International Code of Safety for ships using gas or other low flash-point fuels (IGF Code). The code is planned to be released in the later part of 2014.

In 2013 the classification society Den Norske Veritas (DNV) released a new set of tentative regulations for marine vessels regarding low flashpoint fuels, which includes methanol (DNV, 2013). Usually all fuels used on merchant ships are required to have a flashpoint above 60°C due to the risk of fire. If a vessel fulfils these new sets of rules, the ship is allowed to use low flashpoint fuels. These regulations are quite similar to those applied on engines running on LNG.

2.3.5. Methanol Pricing

Methanex is a methanol producer and supplier and are operating on all continents. They hold about 15 % of the global methanol market. (Floren, 2012). Every month they post their current price for methanol on their website.

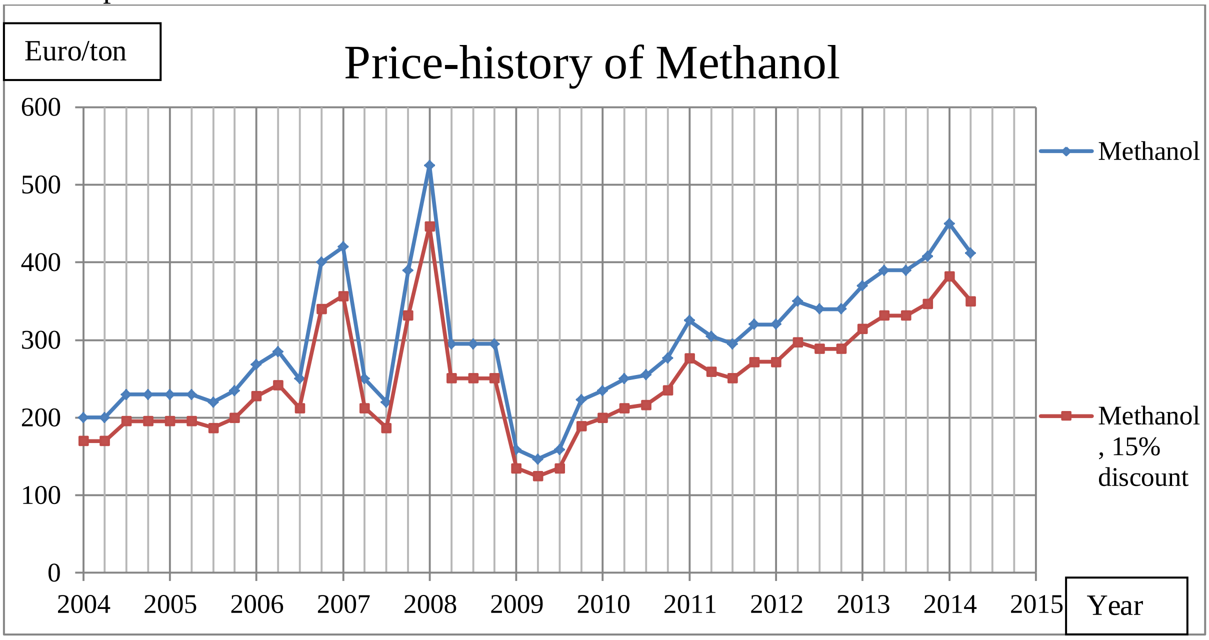

Figure 1, displaying price history of methanol (Methanex, 2014)

Figure 1 displays the posted price-history of methanol from Methanex. According to Methanol Market Services Asia the contracted price will be about 15 % lower than the posted price (Methanol Market Services Asia, 2013). More about the price-history of methanol in chapter 2.5.1.

2.4. Methanol Engines

As stated in chapter 2.3, methanol is difficult to ignite in an ordinary diesel engine. There are today two leading engine manufactures developing large marine engines compatible to run on methanol. The first one is Wärtsilä who are focused on developing four-stroke diesel cycle engines (Danbratt & Haraldson, 2013). The second company is MAN Diesel Turbo which is focused on remodelling their two-stroke diesel cycle engines to be methanol compatible (Laursen, 2014).

2.4.1. Basics of a diesel engine

Before the methanol engine is described the basics of a diesel engine must be known. The engine is working by compressing air to a high pressure and a high temperature which the fuel then is injected into (Kuiken, 2008). The high temperature within the cylinder will cause the fuel to ignite. This ignition process applies to both two-stroke and four-stroke engines.

Four-stroke diesel principle

The four-stroke engine works by having an intake-stroke, a compression-stroke, a power-stroke and an exhaust-stroke (Brain, 2013). The intake stroke takes place when air is sucked through the inlet valve as the piston moves downward. When the piston is at the bottom the inlet-valve closes and the piston changes direction to start compressing the air. Just before the piston reaches the top of the stroke the fuel is injected. The following step is the power-stroke which takes place as the fuel is combusted and the piston is moving downwards. Lastly is the exhaust-stroke which takes place as the exhaust gases are driven out from the cylinder through the exhaust valves.

Two-stroke diesel principle
The 2-stroke principle is similar to the four-stroke but it only uses one crank turn to execute the same work as a 4-stroke engine produces in two crank turns (Animated Engines, 2012). In the 2-stroke engine the compression-stroke and the power-stroke is performed same way as in the 4-stroke engine. The intake starts when the piston passes the intake holes in the cylinder wall on its way down and it stops when the piston passes the holes on the way upwards. The exhaust gases are driven out through the exhaust valve. The valve is opened just before the intake starts and is closed slightly before the intake stops. The reason for the exhaust valve to open before the inlet is to lower the cylinder pressure enough to ensure sufficient scavenging of the cylinder.

2.4.2. MAN Dual Fuel Engines
MAN Diesel & Turbo is an engine manufacturer which are producing large marine engines, both 4-stroke and 2-stroke (MAN, 2014). MAN has an engine concept called Dual Fuel. As the name suggest its working with two fuels, often with one that is hard to ignite such as methanol or LNG and one that is easier to ignite such as diesel oil. MAN has two types of Duel Fuel engines, GI-engine and LGI-engine. The GI-engine is a Gas Injection engine where one of the fuels is injected in gas-form and which then is ignited by the other liquid fuel. The LGI-engine is a Liquefied Gas Injection engine where both fuels are injected in liquid-form. Methanol can be used in the LGI-engine.

2.4.3. Differences towards regular marine diesel-engines
In comparison to a conventional marine-diesel engine the most considerable things that differ are:

- The cylinder head, where an extra injector is added.
- A Fuel Block, that accommodates fuel for injection
- The fuel delivery system, a part of the piping is double walled to detect any leakage.
- A special ventilation system for possible leakage.

(Laursen, 2014)

BFIV (Booster Fuel Injector Valve)
The BFIV is the second injector added to the cylinder head. The BFIV is a combination of an old conventional slide valve design and the newer booster design (Laursen, 2014). This design has been used for almost 10 years and is a proven successful for several different engine types. This valve is working by building up a pressure high enough to start the injection, this by using a hydraulic pressure of 300 Bar. When the injection pressure is sufficient the valve opens and the fuel is injected into the engine. The fuel is pumped from and stored inside a fuel block that is added beside each cylinder. Each fuel block contains enough fuel to accommodate for at least one injection.

Fuel Delivery System
The fuel delivery system for a methanol engine system follows the same concept as for a regular diesel engine. The fuel is taken from a service tank and is delivered to the engine via a booster pump that boost the fuel pressure to around 8-10 bar (Laursen, 2014). After that there is a circulation pump that circulates the fuel. The circulation of the fuel is to make sure the fuel stays in liquid form and to prevent cavitation of the fuel before entering the fuel block and the BFIV.

2.4.4. New Build or Retrofit

The procedure of installing a methanol engine can be made through either building a new ship with a clean installation or as a conversion of the old engine (Laursen, 2014). The conversion of the old engine is completed by replacing the cylinder head for a LGI type, adding the double walled piping, a new monitor system and installing a new ventilation system for the fuel pipes. This conversion is called retrofit and can be performed to all of the existing 2-stroke crosshead engines that MAN delivers. The retrofit will not affect the performance of the engine specification more than higher fuel consumption because of the lower heating value of methanol compared to diesel or HFO.

2.4.5. Low Flashpoint

Because methanol is a low flashpoint fuel there must be a ventilation system installed to prevent any leakage from entering the engine room atmosphere. This ventilation system is combined with double walled piping which is installed to all piping within the engine room (Laursen, 2014). If there is to be a leakage of the fuel from the primary pipe it will be leaking into the next pipe, the fuel fumes will be transported by the pipe ventilation to a gas detector. If any methanol fumes are detected the system will automatically shut of the methanol supply and switch over to full diesel operation. This switchover is performed without any notice in performance losses.

2.4.6. Price for installing or retrofitting a vessel

The price for constructing a new vessel with methanol fuelled engines is slightly higher than installing a regular diesel engine (Laursen, 2014). This is mainly due to the costs for the double walled piping, inert gas system for tanks and the fuel delivery system. To retrofit a diesel powered vessel to run on methanol the cost will be about the same as installing the systems for methanol power for a new constructed ship at the shipyard. When comparing investment costs for a methanol powered vessel and an LNG powered vessel the methanol vessel will be less expencive. This is beacuse a methanol vessel don’t need expencive high pressure fuel tanks and a very advanced fuel delivery sytem.

2.5. Fuel Price History

This chapter displays the price-history of marine fuels, crude oil and natural gas. The price for marine fuel or crude oil is often displayed in USD/ton. As this study will compare different fuels with different lower heating values, a more fitting price unit is established, USD/GJ.

2.5.1. Price History of marine fuels

The market price of MGO-DMA, IFO380 and methanol has been converted into USD/GJ. This data have formed figure 2.

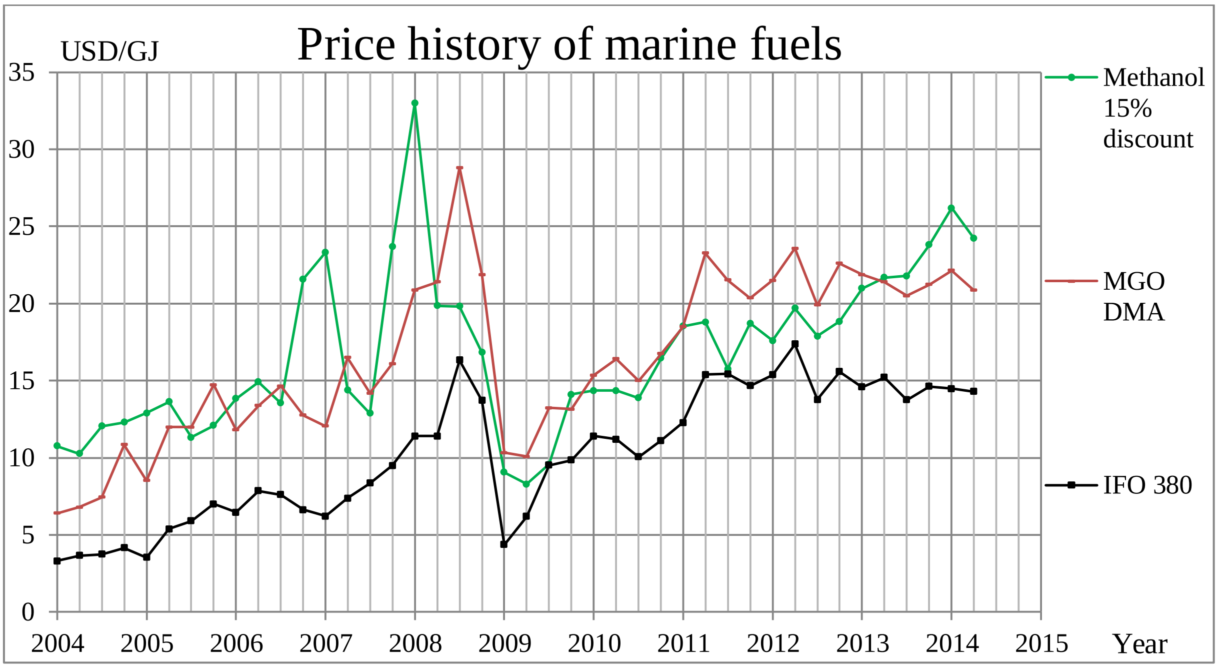

Figure 2, displaying price history of Methanol, MGO and IFO 380

As shown in figure 2 and mentioned earlier in chapter 2.3.5., the methanol price is based on a 15 % discount.

Sources and calculations for figure 2 are found in the Appendix 2.

2.5.2. Price History of Natural Gas and Crude Oil

The crude oil price and natural gas price has been converted to USD/GJ to form figure 3.

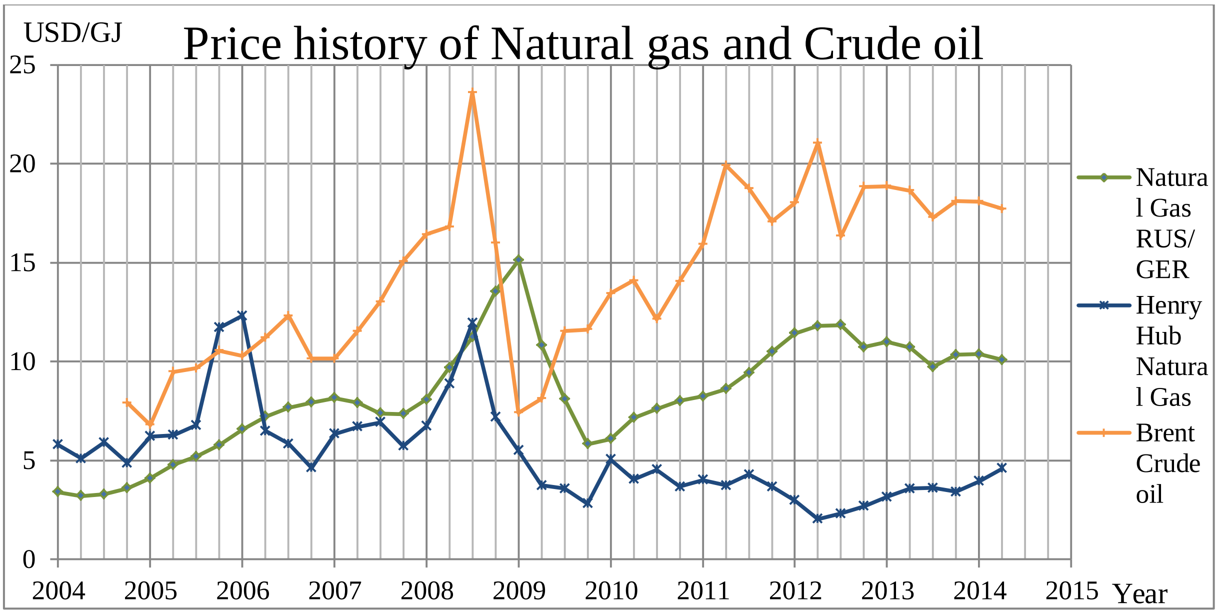

Figure 3, displaying price history of Natural Gas and Crude Oil

Sources and calculations for figure 3 are found in the Appendix 2.

3. Method
The main study is made as a literature survey which is supplemented with a questionnaire answered by ship-owners. The purpose of the literature survey was to get background knowledge about marine fuels in general and to get a deeper knowledge about methanol. The result from this literature survey has contributed to answer sub-question 2, 4, 5 and 6.

The questionnaire is used to quantify the ship-owners attitude towards methanol as a marine fuel in general. It will also answer to how willing they are to invest in new methanol vessels and how willing they are to retrofit their current vessels to run on methanol. The result from this questionnaire has mainly contributed to answer sub-question 1 and 3.

This study has also included interviews with ship-owners which have invested in methanol powered vessels. The interviews have given a deeper understanding of the ship-owners attitude of methanol and their willingness of investing in methanol-powered vessels.

3.1. Literature survey
The data and information used in the background has been taken from numerous different sources. Because of the lack of previous research very few scientific articles has been referred to. A great part of the data and information has been taken from commercial companies. Such as engine manufactures and fuel suppliers. Another large part of the data used has been found at governmental webpages, IMO and classification societies.

3.2. Electronic survey
The electronic survey was sent to ship-owning companies within Sweden, Denmark, Norway and Finland. This survey was sent to the ship-owners by e-mail. Their addresses were found in the webpage of each given country's ship owners 'association. The authors have chosen not to send the survey to management companies as they don´t answer to the operation of the ship. The companies that the survey was sent to were believed to be able and responsible to answer the questions given in the survey to indicate their interest of investing in methanol. The questions which were asked in the survey were given in such effort that it should be possible to determine any connection between investment of methanol, ship types and size of the actual fleet. All answers have been handled anonymously.

3.3. Interviews
The two interviews with representatives from Marinvest and Stena Teknik was conducted at their offices in Gothenburg, both meetings lasted for about 50 minutes. The interviews were semi-structured, the interviewers had prepared questions that would answer why the companies are investing in methanol and what they believe will be the benefits of using methanol. The interviews were not sound-recorded, the interviewers only took notes.

After the interviews the data was analysed and a two summaries was written. The summaries were sent to the interviewees by e-mail for approval before they were posted in chapter 4.2.

The reason for interviewing Stena Teknik and Marinvest was because of their known investments in methanol propulsion.

4. Results

This first part of this chapter includes the result from the electronic survey. The second part includes summaries from the interviews. In the last part the sub-questions is answered.

4.1. Results from the electronic survey

The survey was e-mailed to 121 ship-owning companies in the countries of Norway, Sweden, Finland and Denmark. The results presented below shows what the ship owning companies thinks of methanol as a future marine fuel for marine vessels operating inside the SECA-area of Europe. It also shows roughly how big fleet each company have and how often the ships operate inside this SECA-area. It also shows if the companies have an interest to invest in methanol-powered vessels.

19 answers have been received from 2014-03-26 to 2014-04-08. This corresponds to a response rate of roughly 16 %.

These are the questions and answers given from the survey:

1) How many vessels are operating within your fleet?

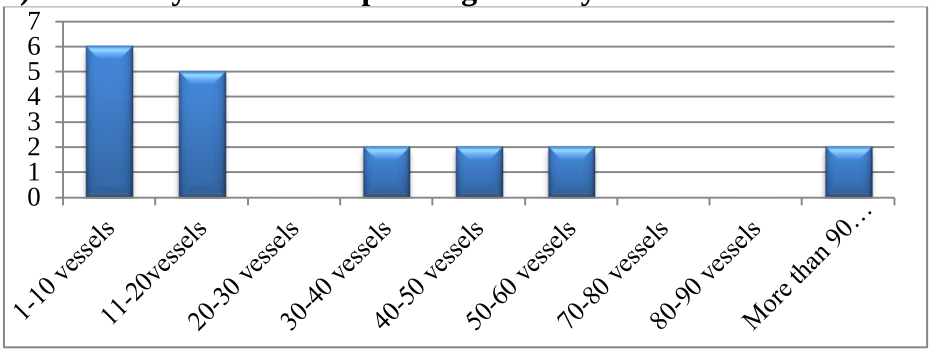

Figure 4, displaying answers from survey question 1

This graph shows that most of the answered shipping companies in this survey have a fleet in the range of 1-10 and 11-20 vessels.

2) What kind of vessels does your company operate?

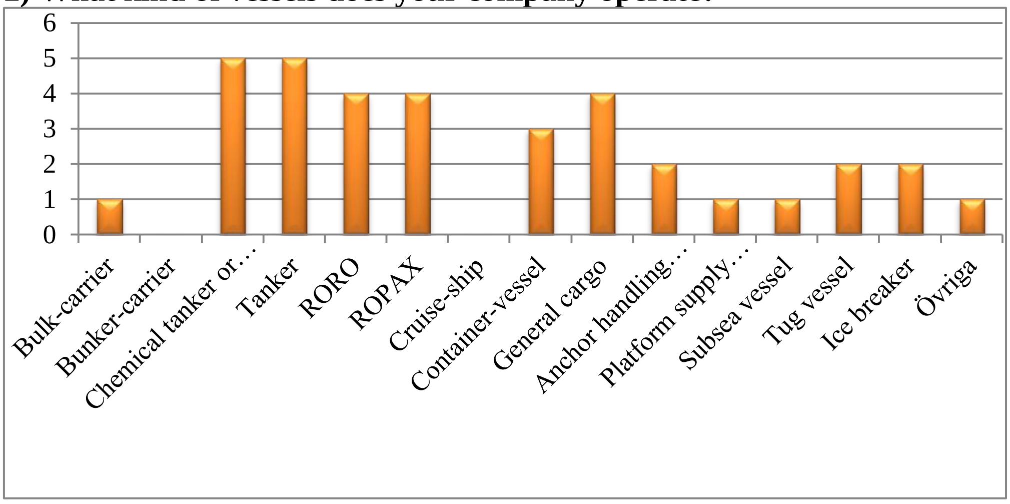

Figure 5, displaying answers from survey question 2

Multiple answers were possible.

3) Does your company have vessels that operate within the North European SECA?

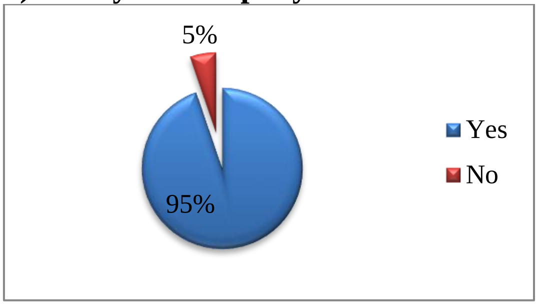

Figure 6, displaying answers from survey question 3

This graph explains how many of the answered ship-owners that have ships within the North European SECA. 19 answers total on this question.

4) How often are your vessels operating within the SECA-area?

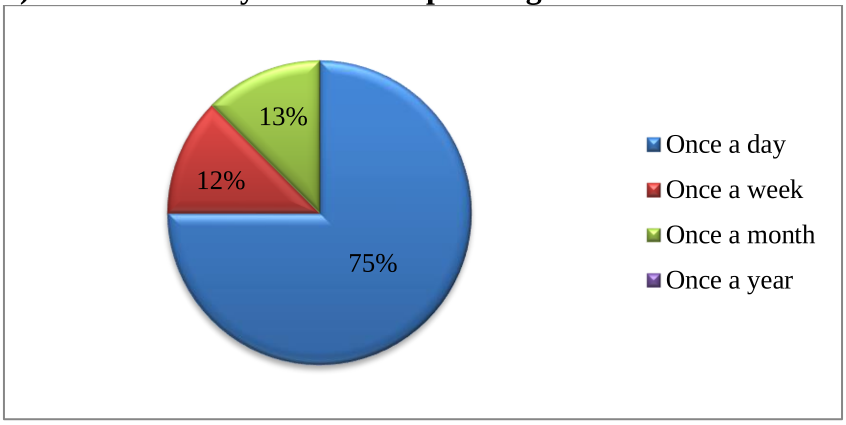

Figure 7, displaying answers from survey question 4

This graph shows how often the vessels of the shipping companies are operating within the North European SECA.14 answers total on this question.

5) How many of your vessels are operating within the SECA-area in Europe?

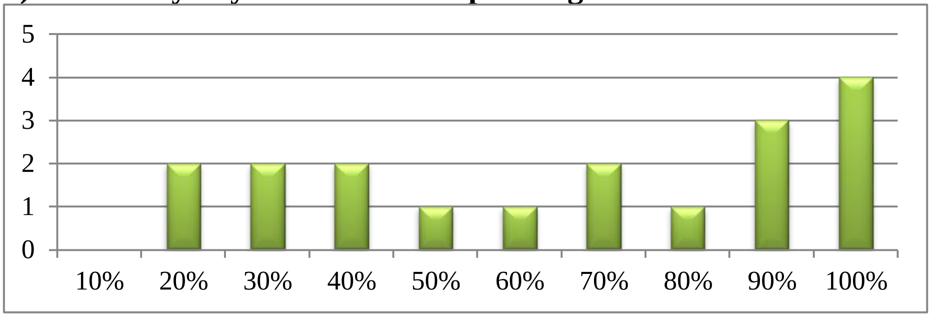

Figure 8, displaying answers from survey question 5

This graph displays the percentage of a ship-owners fleet that is operating within the SECA-area.

Example: Two ship-owners stat that 20 % of their fleet are operating within the SECA, four ship-owners state that 100 % of their fleet operate within the SECA. 18 answers total on this question.

6) What is the general opinion in your company about methanol as a marine fuel within the SECA-area in Europe?

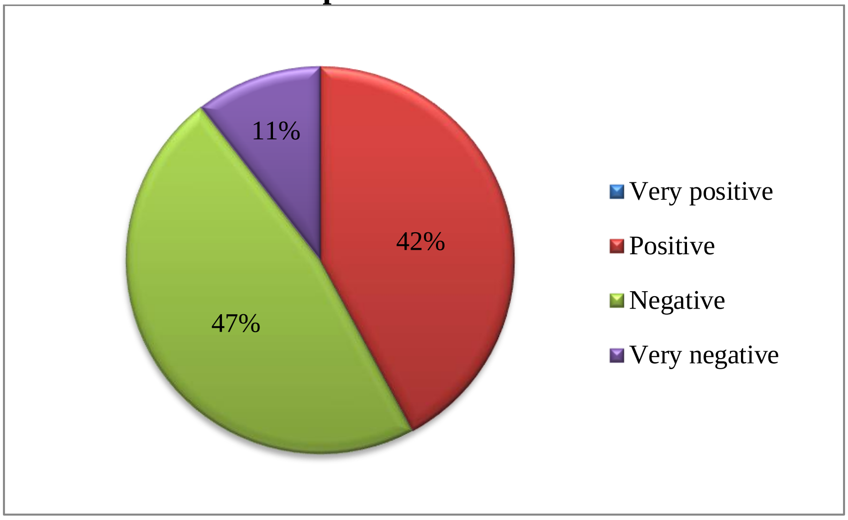

Figure 9, displaying answers from survey question 6

According to this survey the interest from the answered shipping companies is 42 % positive to methanol and 58 % is negative or very negative. 19 answers total on this question.

7) Is your company willing to invest in methanol as a future fuel?

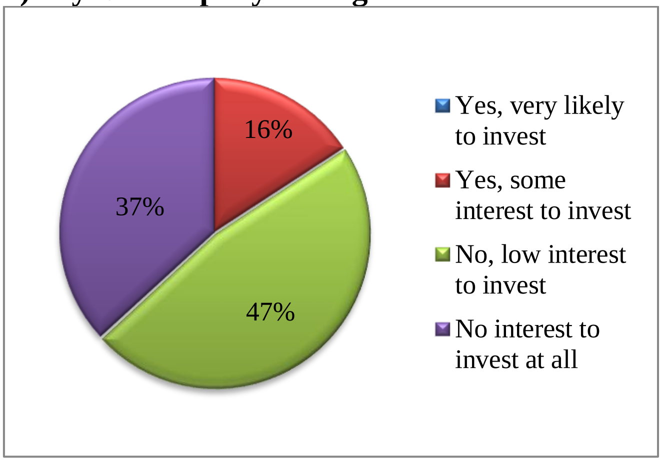

Figure 10, displaying answers from survey question 7

This shows if the answered shipping companies are likely to invest in methanol powered vessels. 16 % of the answered shipping companies show "some interest to invest" in methanol powered vessels.19 answers total on this question.

Table 5, displaying answers from survey question 8

8) How is your company planning to invest in methanol as a fuel?

By retrofitting exiting vessels	1 Answer
By building new vessels	1 Answer
By both retrofit and new build vessels	0 Answers
Other	1 Answer

Of those three shipping companies that are interested in investment of methanol powered vessel this table how they would invest in methanol.

9) What is the reason for your company to invest in methanol?
If answered yes to the question "Is your company willing to invest in methanol as a future fuel?

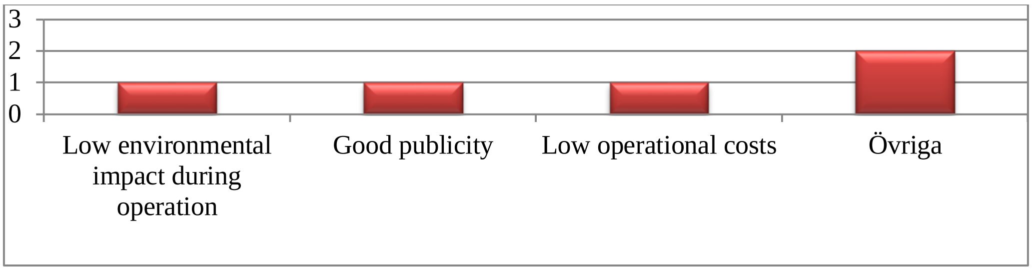

Figure 11, displaying answers from survey question 9

This shows why they would invest in methanol (multiple answers were possible).

10) What is the reason for not investing in methanol?
If answered no to the question "Is your company willing to invest in methanol as a future fuel? "

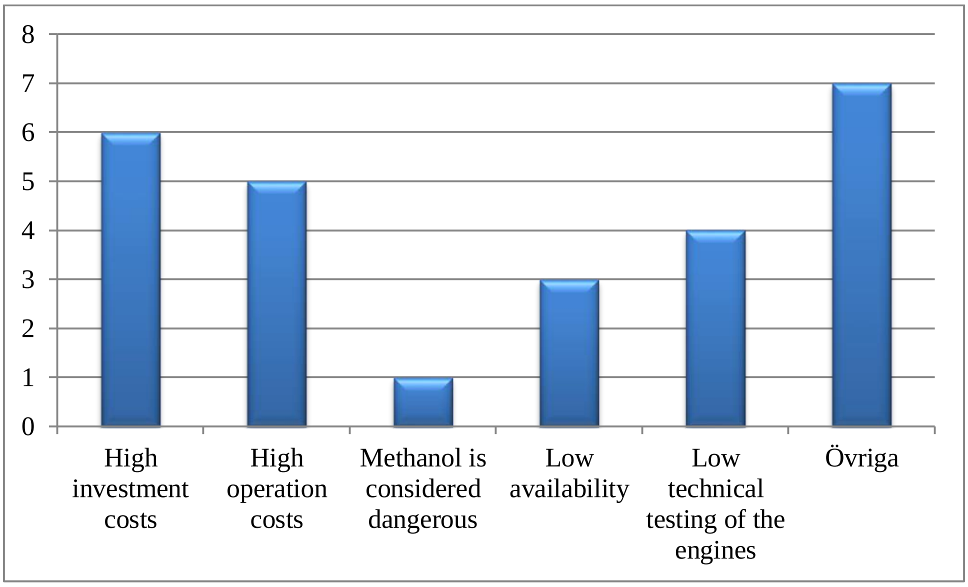

Figure 12, displaying answers from survey question 10

This shows the reason why the answered shipping companies don't want to invest in methanol (multiple answers were possible).

4.2. Results from interviews

This study includes interviews with representatives from two ship-owners.
The first interview was with Lars Mossberg, CEO of Marinvest. Marinvest is a ship-operator which mainly operates Bulk-carriers. The second interview was with two representatives from Stena Teknik, Per Stefensson (Marine Standards Advisor) and Lillie Marlén Lock (Project Engineer).

4.2.1. Interview with Marinvest

After an interview with Lars Mossberg (CEO of Marinvest) the following has been concluded:

Waterfront Shipping is together with Marinvest, Mitsui O.S.K. Lines and Westfal-Larsen investing in six chemical tankers of 50.000 DWT, they will be equipped with MAN ME-LGI engines compatible with running on methanol (MOSSBERG, 2014). Their auxiliary generators will run on MGO. Marinvest will manage two of these vessels.

The vessels will be delivered in 2016 and will be operating from methanol plants or storage facilities located world-wide (MOSSBERG, 2014). The main reason for investing in methanol compatible machinery is because the vessels main cargo will be methanol and it seemed suitable to use as fuel. Using methanol as fuel will give the vessels possibility to enter SECA areas after 2015 without first having to perform any measures.

Mossberg says that the investment has been considerable but it will be less expensive than to build a vessel powered by LNG (MOSSBERG, 2014). Running the vessels on methanol will cost about the same as running on diesel-oil. Marinvest is cooperating with DNV and MAN to develop the regulations for using methanol aboard marine vessels. There are yet no methanol-bunker vessels available and this bunker problematic is solved by using a part of the vessels cargo as fuel.

Marinvest is more positive towards using methanol than ethanol (MOSSBERG, 2014). Ethanol is often made from crops which instead could be used for producing food. Mossberg-[1] states that “Food shouldn’t be used as fuel”.

Using methanol as fuel will also likely produce less harmful particle emissions than using highly refined marine diesel. Methanol is not considered to be especially harmful compared with other substances transported by chemical tankers. The vessels and the company already have procedures for handling methanol in a safe manner. (MOSSBERG, 2014)

1. Lars Mossberg (Chief executive officer, Marinvest) interviewed by the authors of this study. 2 April 2014.

4.2.2. Interview with Stena Teknik

After an interview with Per Stefenson and Lillie Marlén Lock from Stena Technical Division, the following has been concluded:

Stena Line is very interested in new solutions to overcome the new coming SECA restrictions (Stefenson & Lock, 2014). One of these solutions is to retrofit vessels to run on methanol. According to Stena, Methanol is a very interesting fuel alternative because of its very low sulphur content. The engines will also have the same low NO_x, SO_x and Particle emission levels as an LNG-engine. Methanol also has big potential for lowering the CO_2 emissions because the fuel can be mixed with bio-methanol. They believe that methanol can help them towards reaching their zero-vision on environmental impact.

Stena has a done project aboard their vessel Scanrail. The purpose of the project was to convert methanol to DME (dimethyl ether) aboard and use it to fuel the vessel (Stefenson & Lock, 2014). The conclusion of this project was that converting Methanol to DME aboard was complicated and it would be better to do it ashore.

Another project within Stena is to convert Stena Germanica to run its main engines on methanol (Stefenson & Lock, 2014). This project is driven together with their engine manufacturer Wärtsilä. The project is to be started in January 2015 when the ship is dry-docked. To begin with one or two of Germanicas main engines are supposed to be retrofitted and if proven successful the remaining engines are also to be converted. If the Germanica project is successful and the price for methanol is considered economical they will most likely convert more vessels for methanol propulsion.

Stena has together with the Swedish Transport Agency given proposals to IMO according the coming IGF-code (Stefenson & Lock, 2014). The IGF-code will likely be released to first regulate LNG-vessels. Later when the code is completed methanol vessels will also be included. Stena´s proposal is that parts of the IGF-code concerning methanol should follow offshore standards as they are higher than the regulations for chemical-tankers.

Stefenson states that the wide flammability limit and the low flashpoint of methanol is a safety issue (Stefenson & Lock, 2014). The IGF-code and regulations from the classifications society will cover the safety aspects regarding the use of methanol. He also says that safety will be maintained by implementing effective routines and by having a good safety culture aboard the vessels.

Stena is researching many capabilities to reach SECA regulations (Stefenson & Lock, 2014). They are not looking for one solution on all vessels. They are more interested in finding an optimal solution for each single vessel. An example of this is that Scrubbers might be an alternative on some vessels, on other vessels scrubbers cannot be installed because of stability issues.

During the development of Stena’s project they have gained many followers who are interested in their project about methanol (Stefenson & Lock, 2014). Stena is also following other ship-owners projects on overcoming the stricter SECA-regulations.

When Stena Germanica is converted for methanol propulsion the plan is to bunker the vessel with tanker-trucks (Stefenson & Lock, 2014). If more vessels are converted it might be attractive for Stena to retrofit one of their bunker vessels and use it to fuel their methanol powered vessels. It is also stated that there are several methanol suppliers who are interested in delivering methanol for Stena lines vessels.

4.3. Answers to sub-questions

The data taken from the literature survey, the results from the interviews and the survey can answer the following sub-questions.

1) Are ship-owners willing to invest in methanol powered vessels?

According to the survey used in this study, 16 % of the correspondent stated that they have "some interest to invest". Also when adding the interest from Stena and Marinvest it is apparent that there are ship-owners willing to invest in methanol powered vessels.

2) How available is methanol for bunkering aboard marine vessels?

From the data gathered for this study, there are no bunker vessels available for handling methanol. This statement is supported from the data gathered in the interviews. According to the interview with Stena Teknik the most attractive way of bunkering at this moment is from tanker-trucks (Stefenson & Lock, 2014).

3) Is there any engine manufactures making methanol compatible engines?

Yes, in chapter 2.4. it is shown that "MAN Diesel & Turbo" can construct methanol engines in almost all ranges on the 2-stroke side. They can also retrofit most of their elder 2-stroke engines for methanol propulsion. Wärtsilä is working on the development of 4-stroke methanol engines (Danbratt & Haraldson, 2013).

4) Are there any international guidelines or regulations concerning the use of methanol aboard marine vessels?

Yes, as stated in chapter 2.3.4. IMO is going to release a regulatory framework covering the use of low flashpoint fuels aboard marine vessels. Also the classification society DNV has released a set of tentative regulations concerning the use of methanol on marine vessels.

5) What is the attitude of the shipping industry towards the use of methanol as marine fuel?

In the survey 42 % of correspondent stated that they are positive towards the use of methanol as a marine fuel within the North European SECA. From the interview with Stena Teknik they mention that they have many followers for the methanol project. The attitude of IMO concerning the use of methanol on marine vessels appears to be positive. Because they are as mentioned in chapter 2.3.4., working on regulations covering methanol as a marine fuel.

6) What are the costs for using methanol as a fuel for a vessel?

As mentioned in chapter 2.4.4. the marine diesel engines from MAN have the same specified power-output as their methanol alternative. The same is stated about the engines from Wärtsilä (Danbratt & Haraldson, 2013). If assumed that these engines will work with constant efficiency regardless of the fuel-type used, the specified fuel consumption in GJ/nautical mile will stay constant.

This means that the most substantial factors for determine the cost of using methanol on a vessel will be the fuel-cost and the investment-costs for the engine.

The costs for retrofitting or upgrading an engine to be able to run on methanol are hard to clarify. This is due to costs for adapting the fuel systems to fit the various engine-room layouts.

As an example of retrofitting the MAN 6G50ME-C engine to LGI-specifications it will be about 33 % more expensive to rebuild the engine for LNG/LPG-specifications than for an engine with methanol-specifications (Laursen, 2014). The costs to retrofit will most likely be even higher when considering more and bigger cylinders.

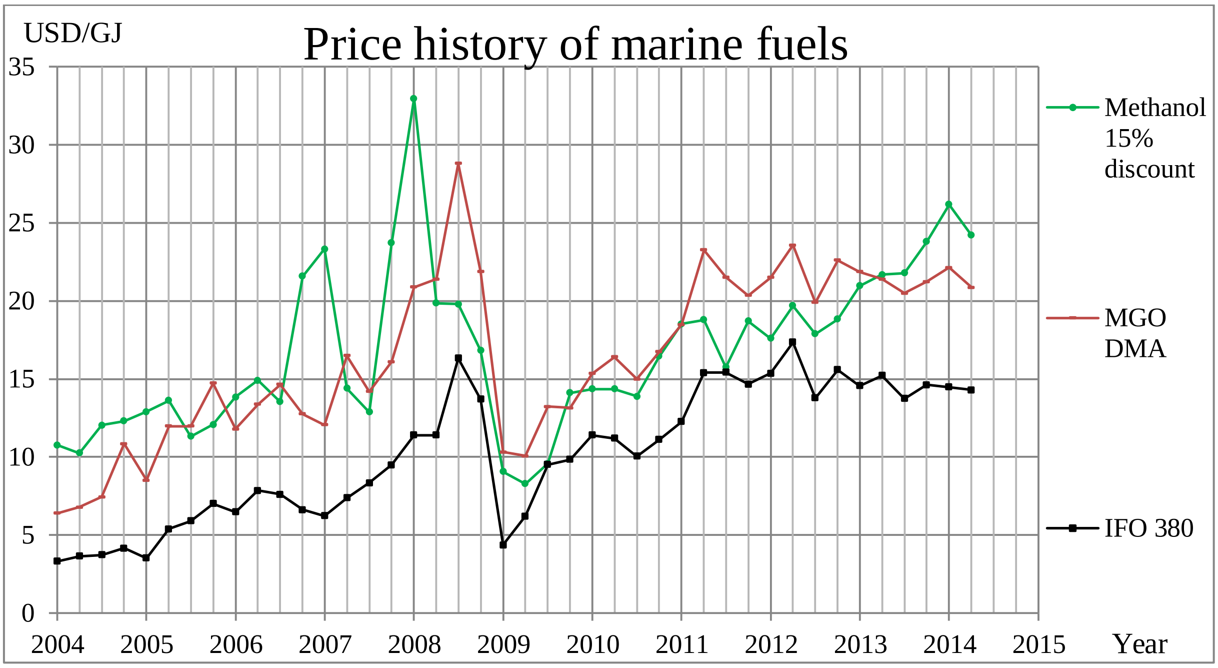

Figure 213, displaying price history of Methanol, MGO and IFO 380

Sources and calculations for figure 13 are found in the Appendix 2.

Example: If a vessel using MGO is retrofitted to run on methanol the fuel-cost will change proportionally to the difference in the USD/GJ-price. If using the prices from 1 April 2014 with a 15 % discount on methanol, the price on methanol will be 16 % more expensive than using MGO and 69 % more expensive than IFO 380.

5. Discussion

This chapter contains a discussion of the method used for this study and a discussion of the results.

5.1. Discussion of Method

The electric survey did result in an answer rate of about 16 % which is considered to be very low. The low answer rate isn't high enough to base any conclusions on, but assumptions can be made according to it. The low rate received can be explained from of not preparing the companies for the survey, for example calling the companies in advance to see if they want to participate in the survey. On the other hand, calling 121 ship-owning companies and contact the correct representatives would take a considerable amount of time which has been spent on researching for information for the background chapter. The interviews which were performed with Marinvest and Stena Teknik could have been anonymous to furthermore give information from the interviewed company. But on the other hand that wouldn't give the relevance and the information needed to strengthen this thesis.

A great part of the data and information has been taken from commercial companies. The validity of these sources can be questioned. Commercial companies are likely to overstate or understate information about their products or services to give them good publicity.

This study both use a literature survey, an electronic survey and two interviews to answer the research question. Because of that these three methods comes up with the same results, the reliability of this study is strengthened. As an example, both of the interviews, the literature survey and the interview states that the current operational costs (fuel costs) of using methanol is relatively high.

The sources from the governmental webpages, IMO and classification societies are considered to have a greater validity.

5.2. Discussion of Results

The authors state that most important factor on predicting the potential of methanol as marine fuel is the price. The survey show that a major reason for not investing in methanol is because of economic aspects such as investment costs and operational costs. In chapter 4.3 the costs for using methanol are described. The price for using methanol is currently 16 % higher than for using MGO and 69 % higher than for IFO-380, see Figure 213, displaying price history of Methanol, MGO and IFO 380.

According to figure 2 it is shown that the methanol price has been rather varied over the years and since the beginning of 2013 it has been priced above the MGO.

In chapter 2.3.2. it is stated that methanol is mainly produced from natural gas. The common marine fuels, IFO and MGO are produced from Crude Oil. The authors believe that this disparity can have a positive impact on the future price of methanol compared to the common marine fuels.

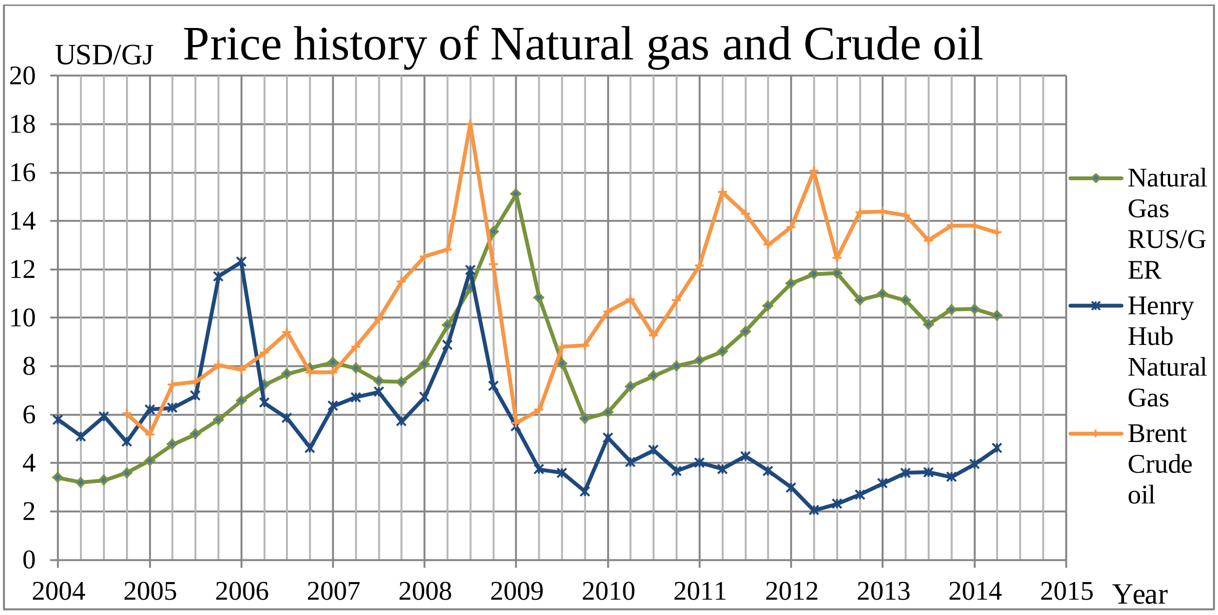

Figure 3, displaying price history of Natural Gas and Crude Oil

Sources and calculations for figure 14 are found in the Appendix 2.

As shown in figure 14, the crude oil price is rising steadely and the european natural gas price is slightly lower priced. The American Natural gas price is even lower, because the tremendous expansion of shale gas exploitation. In the future, if the gas imports from US to Europe increases the euoropean price of natural gas might be reduced which could lower the production price of methanol. From the interviews it is shown that the shipowners expect the price of methanol to fall considerable in the near future.

The results the survey also states that a reason for not investing in methanol propulsion is because the technology is not yet tested and validified (Chapter 4.1.). Though as shown in chapter 2.4. the only parts that seperate a methanol engine from a regulular marine diesel engine are the fuel system and the cylinder heads. Are the ship owners ready to invest in new technology?

In the end of chapter 2.2.1. it is described how the oil crisis in the 1970´s affected the marine industry to invest and develop engines which could combust heavy fuel oil, because of the high fuel prices. Tougher economical demands on the marine industry forced the ship-owners to invest in new technology. A parable to this can be that the stricter emission regulations might force the ship-owners to invest in new technology to meet the new demands.

If methanol is produced efficiently from biomaterial as described in chapter 2.3.2. it can form an almost CO_2 neutral fuel. If the flagstates, IMO, shipowners and other operators within the energy sector will invest in infrasturucture and production-facilites for bio-methanol, the shipping industry can eventually have an even smaller environmental impact and be almost CO_2 netural, far better than any other form of transportation.

The annual european consumption of methanol is around 7 million tons (Chapter 2.3.2.).The annual consumption of marine fuel within the north European SECA is about 12 million tons (Chapter 2.2.1.). When comparing these figures it can be assumed that the production of methanol should have capacity to satisfy a small demand of methanol for marine applications. Though for an extensive use of methanol for marine vessels, the production of methanol will have to increase.

The engine manufactures claims that their engines can run on raw-methanol which contains some impurities which would lower the fuel cost by about 10 % (Danbratt & Haraldson, 2013). The availability of raw-methanol has not been investigated in this study but the authors believe that the availability of raw-methanol should be higher than for chemical grade because of its less complicated production procedure.

The safety-concerns of methanol are often discussed. As displayed in chapter 2.3.3. Methanol is often considered toxic and flammable. Methanol has a flashpoint of 12°C while MGO has a flashpoint of about 60°C. This gives a negative impact for the fire-safety of methanol compared to MGO. The auto-ignition temperature of Methanol is 470°C, which is considerably higher than for MGO. For example if methanol is spilt onto a hot exhaust pipe, the high auto-ignition temperature will make it less flammable than MGO.

Toxicity of methanol:
* Methanol is not classified as a carcinogen while several of the substances in MGO, MDO and IFO are classified as carcinogens.
* Methanol is as most dangerous if ingested, it can cause blindness and death. Drinking 25 ml of methanol can be fatal. What will be the health-effects of drinking 25 ml MGO?
*There is not much known about the long term effect of methanol exposure, but they are believed to be similar to the short-term effects.

When taking all the factors into consideration, including the ones mentioned in chapter 2.3.3., the authors cannot prove that methanol should more dangerous than the common marine fuels.

6. Conclusions

The main research-question is: What potential does methanol has to be a competitive marine fuel within in the North European SECA after 1 Jan 2015?

From the results gathered in this study and from the results of the discussion, the authors believe that methanol does have a certain potential to become a competitive marine fuel, even though the current interest to invest in methanol propulsion is vague. The engine manufactures can supply several different types of methanol powered engines. IMO are working on guidelines and regulations concerning methanol vessels. With these upcoming regulations methanol is not considered to be more dangerous than the common marine fuels. The future price development of methanol is considered to be favourable compared to established marine fuels. The main bottleneck for restricting the use of methanol aboard vessels is the limited established logistics for supplying the vessels with fuel.

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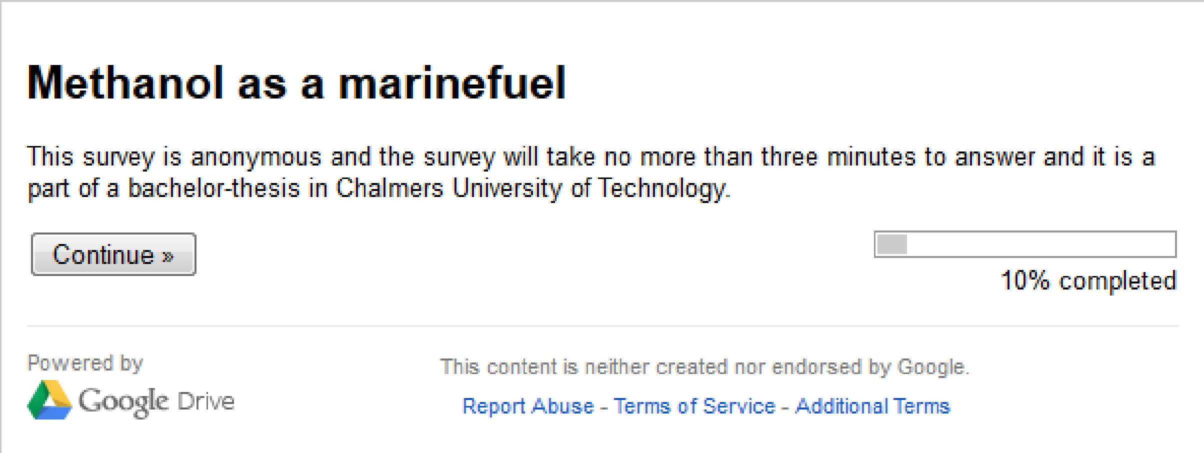
Appendix 1

This Appendix includes the response-form which was sent to the responding ship owners.

Electronic survey



Methanol as a marinefuel

This survey is anonymous and the survey will take no more than three minutes to answer and it is a part of a bachelor-thesis in Chalmers University of Technology.

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Page 1

Methanol as a marinefuel

* Required

How many vessels are operating within your fleet? *

- ◯ 1-10 vessels
- ◯ 11-20vessels
- ◯ 20-30 vessels
- ◯ 30-40 vessels
- ◯ 40-50 vessels
- ◯ 50-60 vessels
- ◯ 70-80 vessels
- ◯ 80-90 vessels
- ◯ More than 90 vessels

What kind of vessels does your company operate? *

It is possible to give multiple answers.

- ☐ Bulk-carrier
- ☐ Bunker-carrier
- ☐ Chemical tanker or product tanker
- ☐ Tanker
- ☐ RORO
- ☐ ROPAX
- ☐ Cruise-ship
- ☐ Container-vessel
- ☐ General cargo
- ☐ Anchor handling vessel
- ☐ Platform supply vessel
- ☐ Subsea vessel
- ☐ Tug vessel
- ☐ Ice breaker
- ☐ Other: ______

« Back | Continue »

20% completed

Page 2

Methanol as a marinefuel

* Required

Do your company have vessels that operate within the SECA-area in Europe? *

- ( ) Yes
- ( ) No

How often are your vessels operating within the SECA-area?
Select the most suitable alternative.

- Once a day
- Once a week
- Once a month
- Once a year

[...inue »]

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Page 3

Methanol as a marinefuel

How many of your vessels are operating within the SECA-area in Europe?
The anwser is given in percentage.

	1	2	3	4	5	6	7	8	9	10	
0%	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	100%

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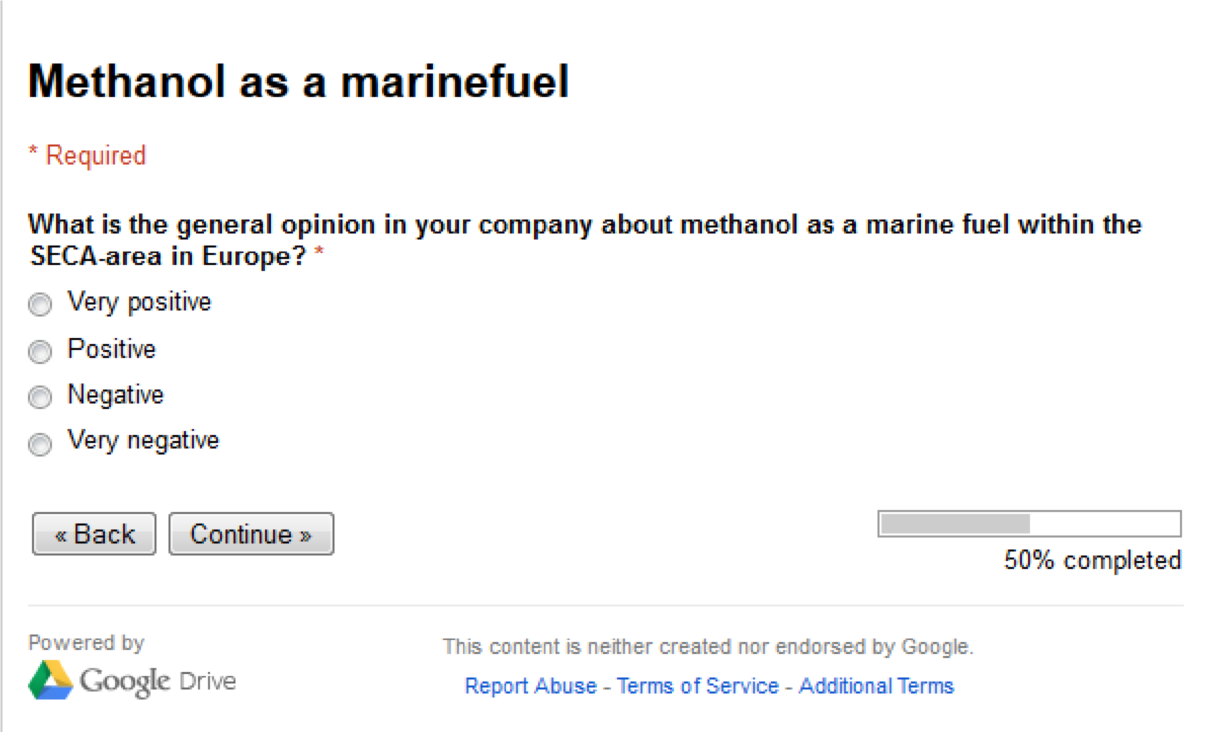
Page 4



Methanol as a marinefuel

* Required

What is the general opinion in your company about methanol as a marine fuel within the SECA-area in Europe? *

- Very positive
- Positive
- Negative
- Very negative

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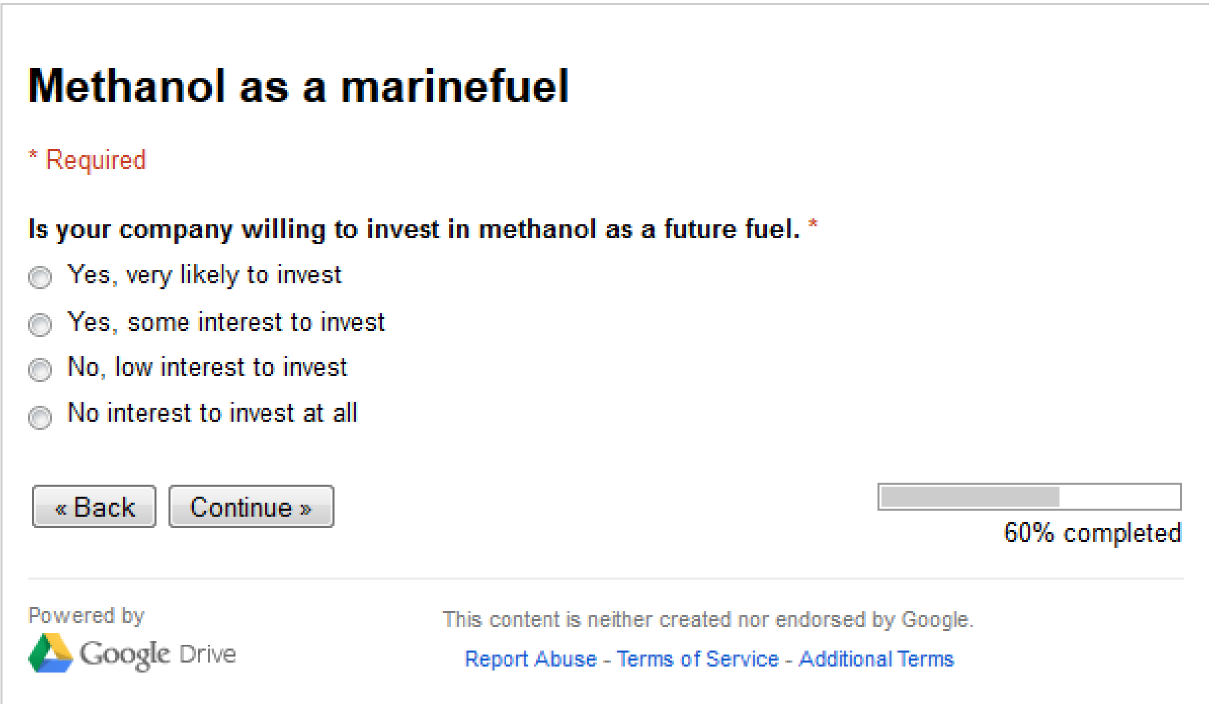
Page 5



Methanol as a marinefuel

* Required

Is your company willing to invest in methanol as a future fuel. *

- Yes, very likely to invest
- Yes, some interest to invest
- No, low interest to invest
- No interest to invest at all

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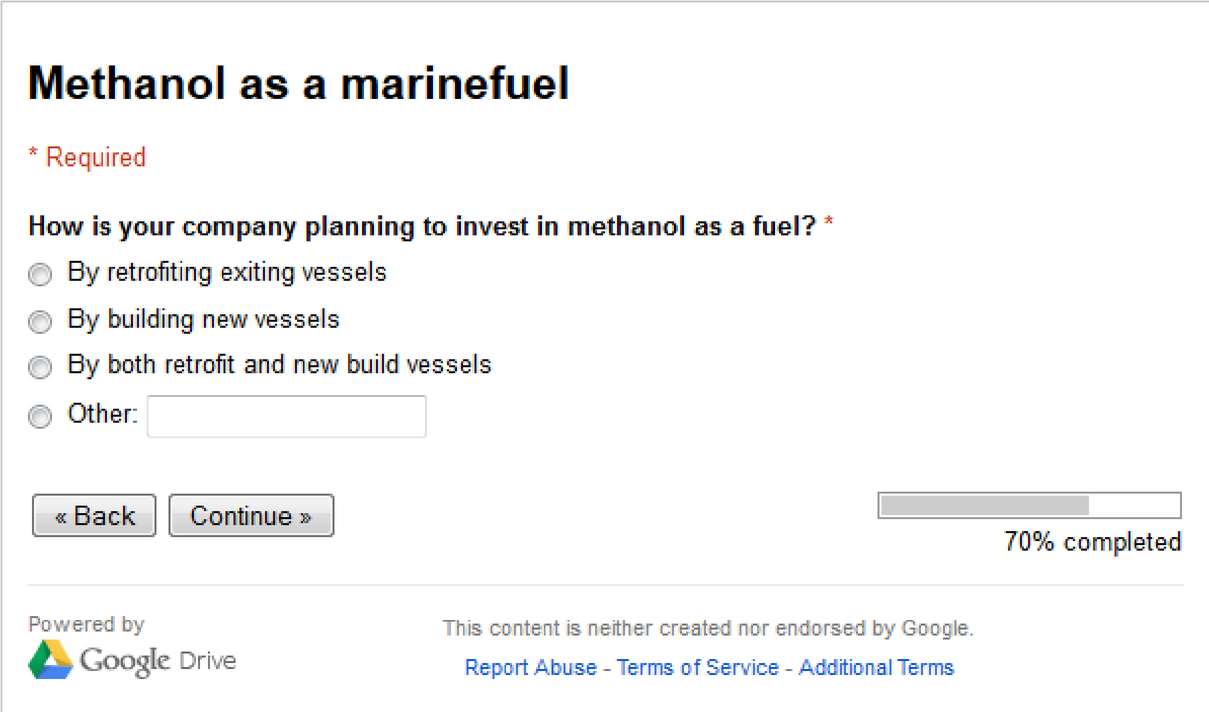
Page 6. If answered yes on this question the questionnaire will be sent to page 7.1, 8.1 and 9. If answered no the questionnaire will be sent to page 7.2 and 9.



Methanol as a marinefuel

* Required

How is your company planning to invest in methanol as a fuel? *

- By retrofiting exiting vessels
- By building new vessels
- By both retrofit and new build vessels
- Other:

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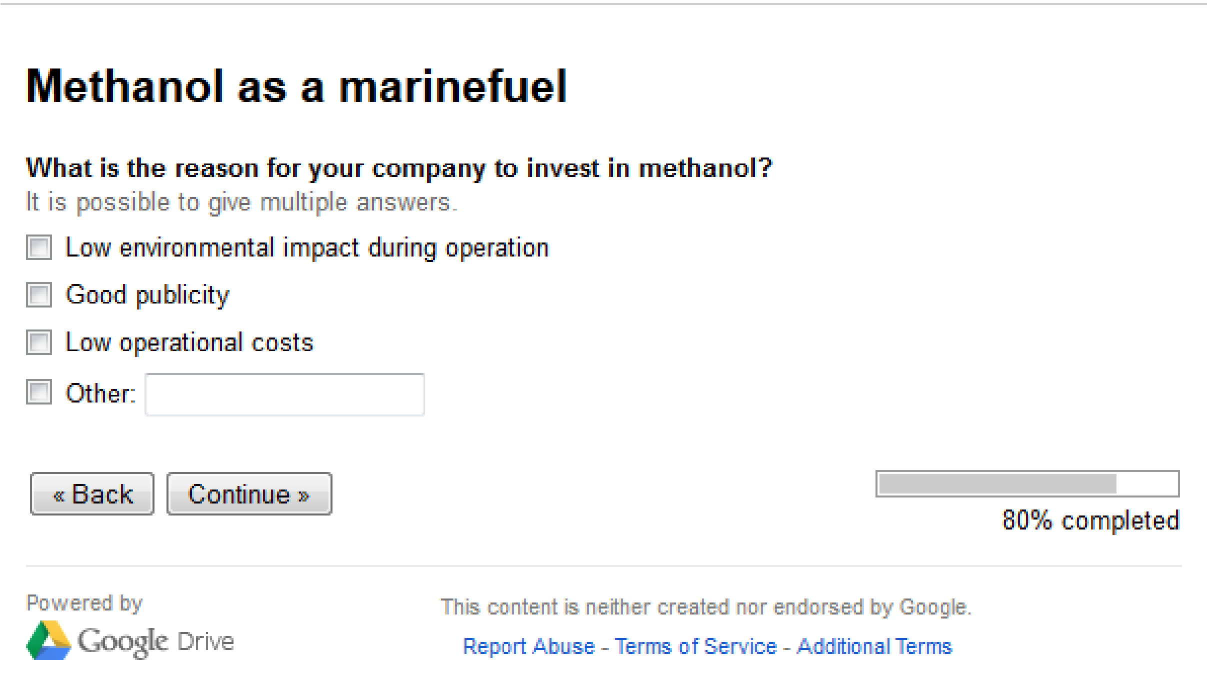
Page 7.1



Methanol as a marinefuel

What is the reason for your company to invest in methanol?

It is possible to give multiple answers.

- Low environmental impact during operation
- Good publicity
- Low operational costs
- Other:

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Page 8.1

Methanol as a marinefuel

If answered no to last question, what is the reason for not investing in methanol?

It is possible to give multiple answers.

- [ ] High investment costs
- [ ] High operation costs
- [ ] Methanol is considered dangerous
- [ ] Low availability
- [ ] Low technical testing of the engines
- [ ] Other:

« Back Continue »

90% completed

Page 7.2

Methanol as a marinefuel

Thank you for your time

The result of this survey will be used in our bachelor-thesis. The thesis will be complete in June and if you want to see the result of this survey or if you want a complete copy of the study, please contact us on

warvid@student.chalmers.se or antlund@student.chalmers.se

Thank you for your help in this matter.

Best Regards,
Arvid Wachsman and Anton Lundgren.

« Back Submit

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100%: You made it.

Page 9

Appendix 2

This chapter includes explanation of how the calculations of various fuel-prices are performed. The resulting USD/GJ-prices of these calculations are used in various diagrams within this study.

Methanol price

The main source for the price-history of methanol states the price in Euro/ton (Methanex, 2014).

These price-figures have been multiplied with the corresponding exchange-rate of the date the price was specified, to convert the price figure into USD/ton. These figures have then been divided by the specific heating-value of methanol, converting the price into USD/GJ. Lastly, the 15 % discount has been removed.

Source for Methanol Price: (Methanex, 2014)
Source for Exchange rate: (OANDA, 2014)
The lower-heating value of methanol is 19.9 GJ/ton (MI, 2014).

IFO-380 and MGO

The fuel price of IFO and MGO from the main source (MABUX, 2014) are stated in USD/ton. These figures have been divided by the lower heating value of each fuel to form the price in USD/GJ.

The lower heating-value for IFO is 40.5 GJ/ton (Kuiken, 2008).
The lower heating-value for MGO is 43 GJ/ton (Kuiken, 2008).
Source for the Fuel-prices: (MABUX, 2014)

Natural gas

The main source used for natural gas states the price in USD/MMBTU (Million British Thermal Unit), this price has then been divided by 1,06 to form the price in USD/GJ.

Source for Price of Russian-German natural gas: (QUANDL, 2014)
Source for the US Henry Hub natural Gas: (QUANDL, 2014)

Brent crude oil

The price for crude oil is normally displayed in USD/barrel. This has been divided by 0,159 to form the price in USD/m^3. Dividing these figures with the density of crude oil has converted the price into USD/ton. Lastly, the USD/ton price has been divided by the heating value to form the price in USD/GJ.

The lower heating value of crude oil is: 43.5 GJ/ton (JATRO, 2014).
The density of crude oil is 0,862 ton/m^3 (Engineeringtoolbox, 2014).
Source for the Price-history of Brent crude oil: (MABUX, 2014)