YRKESHÖGSKOLAN
NOVIA

Sales Opportunities for Machinery Design in Shipbuilding

Potential machinery system retrofits due to future legislation and environmental requirements

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Abstract

This thesis was executed on behalf of Foreship, which is a naval architect and marine engineering company with customers all over the world. The work was about investigating upcoming requirements and legislation regarding discharges from ships. Based on this, potential sales opportunities for machinery system retrofits that these upcoming requirements and legislation can give the machinery department at Foreship are being analyzed.

The work begins with background information whereupon the theory part containing existing as well as upcoming requirements and legislation is presented. The theory part is followed by an explanation of the implementation and used methods. Lastly, the results as well as a critical oversight and a discussion are presented. The results are a combination of the accomplished investigation and interviews with experts within the field. The achieved results show that new sales opportunities are upcoming for the machinery department at Foreship. These sales opportunities are based mostly on more stringent requirements for the discharge of exhaust gases, but also on changes of requirements regarding ballast water and sewage.

The short-term sales opportunities mean more planning regarding installations of exhaust gas cleaning systems, more LNG-related projects, more dual-fuel projects, small updates of machinery systems and to some extent more planning of ballast water systems. The long-term sales opportunities consist of more projects regarding hybrid ships as well as electric driven ships, and eventually projects regarding nuclear powered ships.

Language: English Key words: ship, environmental requirement, sales opportunity

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EXAMENSARBETE

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Inriktningsalternativ:	Maskinkonstruktion
Handledare:	Ehrström Kenneth & Laaksonen Jaakko

Titel: Försäljningsmöjligheter för maskinplanering inom fartygsindustrin

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Datum 26.3.2020 Sidantal 54 Bilagor 2

Abstrakt

Detta examensarbete utfördes på uppdrag av Foreship. Foreship är ett konsult- och planeringsföretag inom fartygsbranschen med kunder över hela världen. Arbetet handlar om att undersöka kommande restriktioner och lagstiftning gällande utsläpp från fartyg. Utifrån det analyseras sedan eventuella försäljningsmöjligheter för eftermonteringar av maskinutrustning på fartyg, vilka de nya restriktionerna och lagarna kan ge maskinavdelningen på Foreship.

Arbetet inleds med bakgrundsfakta varefter teoridelen innehållande befintliga samt kommande restriktioner och lagstiftning presenteras. Efter teoridelen följer en förklaring av utförande samt använda metoder. Slutligen presenteras resultatet samt en kritisk granskning och diskussion om arbetet. Resultatet är en kombination av den utförda undersökningen samt intervjuer med experter inom ämnet. Det erhållna resultatet visar att nya försäljningsmöjligheter är på kommande för Foreships maskinavdelning. Dessa försäljningsmöjligheter grundar sig till största delen på striktare avgasutsläppskrav, men även på ändringar av kraven gällande utsläpp av ballastvatten och avloppsvatten.

De framtagna kortsiktiga försäljningsmöjligheterna innebär mera planering gällande installationer av avgasrengöringsutrustning, flera LNG-relaterade projekt, flera dual-fuel-projekt, små uppdateringar av maskinsystem samt i någon mån mera planering av ballastvattensystem. De mera långsiktiga försäljningsmöjligheterna består av flera planeringsprojekt gällande hybridfarkoster och eldrivna fartyg, samt eventuellt projekt gällande kärnkraftsdrivning.

Språk: engelska Nyckelord: fartyg, miljökrav, försäljningsmöjlighet

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OPINNÄYTETYÖ

Tekijä:	Willberg, Pontus
Koulutus ja paikkakunta:	Kone- ja tuotantotekniikka, Vaasa
Suuntautumisvaihtoehto:	Koneensuunnittelu
Ohjaajat:	Ehrström Kenneth & Laaksonen Jaakko

Nimike: Konesuunnittelun myynnin mahdollisuuksia laivanrakennusalalla

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Päivämäärä 26.3.2020 Sivumäärä 54 Liitteet 2

Tiivistelmä

Tämä opinnäytetyö suoritettiin Foreshipin toimeksiantojen mukaisesti. Foreship on laiva-alalla toimiva konsultointi- ja suunnitteluyritys, jolla on asiakkaita ympäri maailmaa. Opinnäytetyön ensimmäinen tavoite oli selvittää tulevia lainsäädännön muutoksia sekä rajoituksia koskien laivapäästöjä. Toinen tavoite oli analysoida muutosten ja rajoitusten aikaansaamia liiketoimintamahdollisuuksia Foreshipin koneosastolla, koskien jälkiasenteisten konelaitteiden markkinointia ja myyntiä.

Työ alkaa taustatiedoilla, jonka jälkeen esitetään teoriaosa. Teoriaosa sisältää nykyiset sekä tulevat rajoitukset ja lainsäädännöt. Teoriaosan jälkeen käydään lävitse opinnäytetyön suoritustapa. Lopuksi esitetään tulokset, kriittinen arviointi ja pohdinta. Tulokset koostuvat tutkimuksesta sekä haastatteluista asiantuntijoiden kanssa. Tulosten perusteella tiukentuvat päästörajoitukset tarjoavat Foreship Oy:n koneosastolle uusia liiketoimintamahdollisuuksia jälkiasenteisten konelaitteiden markkinoinnissa ja myynnissä. Uudet liiketoimintamahdollisuudet perustuvat pääasiassa tiukentuviin pakokaasupäästörajoituksiin. Muutokset painolastivesipäästörajoituksissa sekä jätevesipäästörajoituksissa tuovat myös uusia liiketoimintamahdollisuuksia.

Lyhytaikaiset liiketoimintamahdollisuudet koostuvat pakokaasunpuhdistuslaitteistojen asennusten suunnittelusta, LNG- ja dual-fuel -projekteista, pienistä konejärjestelmäpäivityksistä, sekä jossain määrin painolastivesijärjestelmien suunnittelusta. Pitkäaikaisemmat liiketoimintamahdollisuudet koostuvat useammista suunnitteluprojekteista koskien hybridialuksia ja sähköaluksia, sekä myöhemmin myös ydinkäyttöisiä aluksia.

Kieli: englanti Avainsanat: laiva, ympäristörajoitus, myyntimahdollisuus

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Abbreviations

IMO – International Maritime Organization

MARPOL – The International Convention for the Prevention of Pollution from Ships

SOLAS – International Convention for the Safety of Life at Sea

NO_x – Nitrous Oxides

SO_x – Sulphur Oxides

CO_2 – Carbon Oxides

GHG – Greenhouse Gas

BWM – Ballast Water Management

PPM – Part Per Million

ECA – Emission Control Areas

LNG – Liquid Natural Gas

DF – Dual-fuel

SCR – Selective Catalytic Reduction

EGR – Exhaust Gas Recirculation

PM – Particulate Matter

EEDI – Energy Efficiency Design Index

EEXI – Energy Efficiency Existing Ship Index

1 INTRODUCTION

I started working as a summer trainee for the machinery department at Foreship in May 2019, and after the summer I continued working part-time for the same department. I have worked mostly with scrubber systems for cargo ships, but I have also become acquainted with ballast water treatment systems and other machinery systems.

In August 2019 I was given the opportunity of executing my thesis work for Foreship and together with the department head and colleges we came up with title of the thesis. This chapter consists of a short company introduction, purpose, problem area, delimitation and disposition.

1.1 Company introduction

Foreship Ltd. is an in August 2002 established naval architect and marine engineering company that designs machinery systems, electrical systems, pipe systems, steel constructions and interior solutions for ships. At the moment Foreship has over 100 employees in eight different cities in four different countries. The head office is stationed in Helsinki, Finland, and then there is an office in Turku, Rauma and Maariahamina. Except for the Finnish offices, one office is stationed in Tallinn, Estonia, one in Hamburg, Germany, one in Miami, USA and one in Seattle, USA. (Foreship, n.d.)

1.2 Problem area

Regarding the machinery design in ship building retrofit projects, ballast water systems and scrubber systems together with emission abatement technologies are some of the core competences. The industry, as well as the shipowners, are aware that future legislation and environmental requirements will come into force sooner or later and that they will affect the planning and designing of machinery systems for ships. Today, there are many requirements for how much emissions the ships can have and within what emission limits they must adhere to. The problem is that without an investigation it is difficult to know exactly what new requirements are coming and at what stage they become active. Not being prepared for these new requirements and legislation, enhances the risk of not being able to the update the strategy and expertise within the branch. So, shortly the two questions are:

1. What environmental requirements and future legislation are upcoming?

2. What opportunities do these eventual upcoming restrictions give Foreship?

1.3 Purpose

The main purpose of this work is to investigate what environmental requirements and legislation are forthcoming, and thus to investigate the future possibilities for Foreship's machinery department. For example, if a new law or rule comes into force that says open-loop scrubber systems are no longer acceptable, Foreship is likely to receive several design projects of closed-loop scrubber systems instead. Another example is if there will be a new requirement that says ships with a certain kind of engine or a certain size of the engine(s) will be forced to install SCR-systems for exhaust gas cleaning to be enough, the machinery department at Foreship will get the opportunity to take several new jobs and possibly be able to expand their area of knowledge. An investigation of this type is very useful for Foreship. Environmental pollution, environmental requirements and exhaust emissions are very relevant in these days, therefore an investigation and research within this is even more appropriate.

1.4 Delimitation

This topic is quite broad, and it would be possible to investigate many different outcomes, problems and aspects related to this. I have nevertheless set the main aim of investigating upcoming requirements and legislation for exhaust gas cleaning, and thus sales opportunities for these. I have also investigated possibilities for other relevant systems. Planning exhaust gas cleaning systems is however currently one of the main works for the machinery department and therefore it is advisable to focus on examining upcoming requirements that have an impact on sales and designing of these.

It would be possible to do a comprehensive investigation within this topic, but it would be very wide and time-consuming. For this reason, I have chosen not to dig too deep into the respective subsectors in this work, hence I have made a preparatory study to show what is to come and what is eventually forthcoming. If Foreship find a specific thing in this work they would like to further investigate, it is easier for them to begin.

1.5 Disposition

Below follows a description of what the work contains and how the different parts are arranged. This is to give the reader an overview of the content and of the work as a wholeness.

Theory: This part consists of compiling existing and future environmental requirements and legislation. It also explains how different systems work, together with IMO (International Maritime Organization) and other organizations that set requirements and regulations are presented.

Method: This chapter describes the procedures used to obtain the necessary information and data.

Results: Here are the theory and sales opportunities analyzed.

Result discussion: In this chapter the result is being discussed and analyzed.

Discussion: This part consists of a summary and discussion of the work and the result obtained. This also includes suggestions for improvements and further research.

2 THEORY

The theory in this thesis consists mainly of a compilation of existing environmental requirements and legislation, as well of a listing of upcoming environmental requirements and legislation. Since the IMO is the organization that mainly sets all global emissions requirements within the marine industry, the theory part is mostly based on their conventions and paragraphs. To get a good start on the work and get an idea of what is most relevant in for this thesis, I and my supervisor, found out who would be the right expert person to discuss with. I contacted a specialist in environmental certification for the marine sector at the Finnish Transport and Communications Agency (Traficom), Ville-Veikko Intovuori, I told him about my thesis and its purpose, and asked what he thought was important to include in a work like this. According to Intovuori, Annex 6 of the MARPOL convention is the part that is most useful and would give the work a good content. He also told about the different parts in the Annex 6 and what parts I should give attention to. We discussed this with my supervisor and concluded that I should investigate all parts of the MARPOL convention but invest most in Annex 6 as that part will probably yield the best results.

The reason why Annex 6 is the most relevant is that it deals with regulations for air pollution, and today, air pollution is considered a very big threat to the environment. (worldwildlife, n.d.)

The information in the theory part is compiled from IMO's own material and from sources that explains IMO's material. In order to gain a broader understanding and explanation of the different parts of the emission convention, the Finnish and Swedish national legislations as well as the Finnish Traficom and other similar sources have been helpful. But first, some background information about environmental history and impacts of emissions is presented.

2.1 Background

The environmental threat has not always been known to mankind, but during the 20th century the knowledge of environmental threats and climate change were increased considerably. During the early 1900s, strange fogs were noticed above certain cities, first in America but then also in Europe and other parts of the world. At first it was thought that the problems were small and temporary, but it was later realized that they were bigger than people thought, and they did not disappear. Nowadays, problems caused by pollution of the environment have become global, and discussions about how to reduce emissions and pollution are held daily all over the world. (Huges, 2008)

The impacts of environmental pollution are many, and some are bigger than the other. For the human health and for vegetation on the planet there are short-term and long-term impacts. Examples of these are getting toxic heave metals into your body, and for vegetation photochemical air pollution. There are also globally big impacts, for example some compounds can stay in the atmosphere for up to centuries. They will spread evenly throughout the atmosphere. This has happened with CFCs (chlorofluorocarbons) which have penetrated the ozone layer and with CO_2 (carbon dioxide) which is the most important human greenhouse gas. Because of this, prevention of environmental pollution is very relevant. (Fenger & Tjell, 2009)

2.2 IMO International Maritime Organization

IMO is a global standardized agency that sets rules and regulations regarding safety, construction, operation, environmental friendliness, energy efficiency in the marine sector. IMO is to be a fair organization and is thus universally accepted and implemented. IMO's strategy is to strive for an efficient and innovative spirit. Because shipping is at a very international level, an authority is needed to provide all parties with the same information, and this is an important task for IMO. (IMO, 2019)

The Marine Environment Protection Committee, MEPC, is a committee whose task is to address environmental issues, which in practice means that they control and prevent emissions and pollution produced by a ship. Also, they deal with issues relating to ship recycling, identification of special areas and similar issues. MEPC works under IMO's remit. (IMO, 2019)

2.3 MARPOL Convention

MARPOL is the main international convention of IMO whose purpose is to prevent ship emissions that are harmful for the marine environment. MARPOL was adopted in 1973 at IMO but a definitive convention (MARPOL 73/78) came into force in 1983. The convention includes six practical annexes and all these six annexes include regulations that tell more specific about preventing and minimizing pollution from ships. (IMO, 2019)

These six annexes are:

Annex 1 Regulations for the Prevention of Pollution by Oil

Annex 2 Regulations for the Control of Pollution by Noxious Liquid Substances in Bulk

Annex 3 Prevention of Pollution by Harmful Substances Carried by Sea in Packaged Form

Annex 4 Prevention of Pollution by Sewage from Ships

Annex 5 Prevention of Pollution by Garbage from Ships

Annex 6 Prevention of Air Pollution from Ships (IMO, 2019)

According to MARPOL, some sea areas are "special areas" with a higher level of protection than other sea areas, which means that for technical reasons related to their oceanographic and ecological conditions as well as their sea traffic, special methods are required to prevent discharges into these. (IMO, 2019) These areas are presented in each annex.

2.4 Annex 1 Regulations for the Prevention of Pollution by Oil

Each year, oil ships transport around 2900 million tonnes of crude oil as well as oil products worldwide. In order to ensure that these oil ships are safely built, operated correctly and are designed to reduce the oil leaks in the event of an accident, IMO has introduced various controls and requirements. (IMO, 2019)

Oil includes liquids containing petroleum, such as crude oil, sludge, heavy fuel oil, and oil waste. This annex also includes regulations for all ballast water and washing residues from the washing of cargo tanks in tankers. (Kaushik, 2019) (lagboken.se, u.d.)

The list below presents the equipment every ship should have. The equipment should not only be in good condition, it also must be calibrated, maintained and spare parts must be onboard all the time.

1. Approved equipment for oil filtering
2. Equipment for 15 PPM bilge alarm
3. Connections for the discharge that meets the standards (Kaushik, 2019)

The list below presents the tanker specific must have equipment

1. Equipment for detecting the boundary between oil and water, interface detector
2. Washing system for the crude oil is necessary if the specific tanker is in contact with this type of oil
3. ODMCS (Oil discharge monitoring and control system)

4. Arrangements and equipment regarding pumping, piping and discharge for the ship

5. Bilge holding tank, collecting oily bilge water (Kaushik, 2019)

2.4.1 Special areas

In the table below the dates for when this annex was adopted, when it entered into force and from which day it has been in effect is being presented for each special area. **Date of entry into force** means that from this date the regulation has the legal right to exist. **In effect from** means that from this day the regulation becomes applicable.

Table 1. Special areas for Annex 1 (IMO, 2019)

Special Areas	Adopted #	Date of Entry into Force	In Effect From
Annex I: Oil			
Mediterranean Sea	2 Nov 1973	2 Oct 1983	2 Oct 1983
Baltic Sea	2 Nov 1973	2 Oct 1983	2 Oct 1983
Black Sea	2 Nov 1973	2 Oct 1983	2 Oct 1983
Red Sea	2 Nov 1973	2 Oct 1983	*
"Gulfs" area	2 Nov 1973	2 Oct 1983	1 Aug 2008
Gulf of Aden	1 Dec 1987	1 Apr 1989	*
Antarctic area	16 Nov 1990	17 Mar 1992	17 Mar 1992
North West European Waters	25 Sept 1997	1 Feb 1999	1 Aug 1999
Oman area of the Arabian Sea	15 Oct 2004	1 Jan 2007	*
Southern South African waters	13 Oct 2006	1 Mar 2008	1 Aug 2008

"*The Special Area requirements for these areas have not yet taken effect because of lack of notifications from MARPOL Parties whose coastlines border the relevant special areas on the existence of adequate reception facilities (regulations 38.6 of MARPOL Annex I and 5(4) of MARPOL Annex V)." (IMO, 2019)

2.4.2 Discharge of oil

In general, it is prohibited for ships to discharge oil or oily mixture at all, but if all these criterions below are filled it is allowed. The exceptions to the prohibition of oil spills from ships other than oil tankers in special areas (except the Antarctic area) are listed below:

1. Oily mixture from engine rooms on a ship with a gross tonnage of at least 400 may be discharged outside the special areas, provided that:
    a. The ship is moving
    b. The ship is equipped with an approved oil filtering equipment in accordance to the requirements
    c. The maximum concentration of oil in the effluent is not over 15 PPM
    d. The oily mixture does not come from the cargo pumps or cargo holds, it comes only from the engine room
    e. The oil-containing mixture, for oil tankers, is not mixed with oil residues
    f. The ships distance to the nearest land is at least 12 nautical miles. (lagboken.se, u.d.) (Kaushik, 2019)
2. Oily mixture from engine rooms on a ship with a gross tonnage of at least 400 may be discharged in the special areas, provided that:
    a. The ship is moving
    b. The ship is equipped with an approved oil filtering equipment in accordance to the requirements
    c. The maximum concentration of oil-mixture in the effluent is not over 15 PPM
    d. Discharge of oil or oil mixtures into the sea within the special area of Antarctic is forbidden. (Kaushik, 2019) (lagboken.se, u.d.)
3. Oil-containing mixture from an oil tanker cargo tank space may be discharged outside special areas, provided that:
    a. The ship is more than 50 nautical miles from the nearest land

b. The ship is moving

c. The instantaneous oil spill rate does not exceed 30 liters per nautical mile at any point

d. The total quantity of oil-mixture contained in the discharge shall not exceed 1/15 000 of the cargo contained in the oil for of oil tankers delivered by 31 December 1979 or, for oil tankers delivered after 31 December 1979, the total quantity of oil contained in the discharge shall not exceed 1/30 000 of the cargo contained in the oil

e. The ship has a monitoring and control system for oil discharge and a slop tank arrangement in accordance to the requirements. (lagboken.se, u.d.) (Kaushik, 2019)

2.4.3 Upcoming regulations

For this annex, no new regulations or legislation is upcoming.

2.5 Annex 2 Regulations for the Control of Pollution by Noxious Liquid Substances in Bulk

Requirements for transport of chemicals in bulk are determined according to MARPOL ANNEX 2 and SOLAS Chapter 7 - Carriage of dangerous goods. Bulk is a load that is unpacked, with other words it is in lose form and it can be in both dry and wet form (Wikipedia, 2019). Examples of typical dry bulk are lime, coal, salt manure or grain and examples of wet bulk are oil, various chemicals and gas (Wikipedia, 2019).

Some of the substances classified as either dry or wet bulk can be directly harmful to the environment, and therefore standards must be followed when designing ships to carry these types of goods. (IMO, 2019)

2.5.1 International Bulk Chemical Code (IBC code)

The IBC code is a prescription that sets the international standards for transport of chemicals, but also sets construction and design standards for ships. Different chemicals affect the environment in different ways, and some are more harmful than others. The IBC Code lists

all chemicals and the risks for each of them, and the list also contains requirements for ships for each type of chemical transport in bulk. (IMO, 2019)

MARPOL Annex 2 consists of a pollution categorization system for noxious liquid substances in bulk which are harmful to the environment. The system puts the substances in different categories depending on their environmental impact if they are discharged into the sea, starting from the most hazard.

Category X: Major hazard

Category Y: Hazard

Category Z: Minor hazard

Other: No harm (IMO, 2019)

2.5.2 Discharge requirements

Discharge of noxious liquid substances in bulk that fall into categories x, y or z are prohibited unless they are made in accordance with the regulations that apply to these types of discharges. Before discharge is made, the relevant tank must be emptied to the maximum according to existing regulations. (MARPOL Training Institute, n.d.)

The regulations below must be followed:

1. Self-propelled ships are moving at a speed of at least 7 knots. Non-self-propelled ships must move at a speed of at least 4 knots

2. Discharges must be made via the underwater discharge outlet that is below the water surface, and they cannot exceed the maximum flow for which the underwater outlet is designed for

3. Discharges must be made at least 12 nautical miles from land and at least 25 meters below the surface of the water. (MARPOL Training Institute, n.d.)

The following individual restrictions must also be followed for the different categories:

Category X:

1. If discharge has occurred, prewash must be done before the ship leaves the unloading port. The resulting residues of the prewash must be released to a reception facility

intended for these substances. When the content of the substance reaches a level of maximum 0.1% of the weight, the tank must be completely emptied.

2. If the tank is then filled with water, it may be discharged into the sea as long as the discharge follows the regulations above

3. If the government does not consider it possible to measure the content of the substance in the water without delaying the ship, other similar measures can be taken. This requires that the tank is prewashed according to the regulations, and that the Cargo Record Book is filled in correctly and approved by the intended surveyor.

Category Y and Z:

Emissions of these substances shall be discharged in accordance with the general emission regulations for this annex. If emissions are discharged in accordance with the instructions in the manual, a prewash shall be made before the ship leaves the unloading port. If a tank wash is done, the resulting residues of this must be released to an approved and accessible reception facility intended for this substance. Additional rules apply to substances with high viscosity or solidifying substances in category Y. These rules are as follows:

1. Prewash procedure shall be discharged in accordance with existing regulations

2. Resulting residues of prewash shall be discharged to a receiving facility intended for these substances

3. If the tank is then filled with water, it may be discharged into the sea as long as the discharge complies with the general emission regulations in this Annex. (MARPOL Training Institute, n.d.)

2.5.3 Special Areas

In the table below the dates for when this annex was adopted, when it entered into force and from which day it has been in effect is being presented for each special area.

Table 2. Special areas for Annex 2 (IMO, 2019)

Special Areas	Adopted #	Date of Entry into Force	In Effect From
Annex II: Noxious Liquid Substances			
Antarctic area	30 Oct 1992	1 Jul 1994	1 Jul 1994

2.5.4 Upcoming regulations

For this annex, no new regulations or legislation is upcoming.

2.6 Annex 3 Prevention of Pollution by Harmful Substances Carried by Sea in Packaged Form

Requirements for transport of chemicals in packaged form or in solid form are determined according to MARPOL Annex 3 and SOLAS Chapter 7 - Carriage of dangerous goods. SOLAS and MARPOL together adopt these regulations regarding pollution, standards for packaging, labeling, documentation and more. Both MARPOL and SOLAS base their regulations and requirements on the International Maritime Dangerous Goods code IMDG, developed by IMO. (IMO, 2019) No concrete regulations regarding discharge exist, because discharge of or leaks from substances in packaged form are not made.

2.6.1 Upcoming regulations

For this annex, no new regulations or legislation is upcoming.

2.7 Annex 4 Prevention of Pollution by Sewage from Ships

Sewage is a type of wastewater that has been produced due to human activity on a ship, and it can be divided into two categories, Blackwater and Greywater. Blackwater is wastewater from toilets, urinals, wash tubs, medical dispensary and scuppers located in connection with these systems and greywater is wastewater from drainage of dishwasher, cabin showers and baths, drainage of laundry, interior deck drains and from air conditioner condensate. Sewage often contains physical, chemical and biological pollutants, which can be harmful to the environment, and therefore IMO has set regulations for how ships should treat their wastewater. (Wankhede, 2019)

2.7.1 Discharge requirements

According to Annex 4, ships must comply with various regulations regarding the discharge of wastewater to protect the environment from harmful substances. These rules deal with the ship's equipment, such as cleaning systems, control systems, certification and examination, as well as the provision of port reception facilities. (IMO, 2019)

The regulations are following:

1. Annex 4 says that ships traveling internationally, with a weight over 400 gross tonnage and carrying more than 15 persons must be equipped with an approved sewage water treatment system, a sewage holding tank, or both

2. Each country's government has a duty to ensure that at each port and terminal on which ships enter ashore, enough wastewater reception facilities must be provided so that no delays to ships occur

3. Discharge of wastewater into the sea within a certain distance from land is prohibited unless otherwise stated. Discharge is however allowed if the ship is equipped with an approved sewage treatment system or the emissions are comminuted and disinfected using an approved system and the ship is more than three nautical miles from the nearest land.

If the discharges are not treated at all, the ship must be at least 12 nautical miles from the nearest land, the operating speed must be at least 4 knots and the discharge rate of the discharge must comply with regulations approved by the administration. (IMO, 2019) (Wankhede, 2019)

4. The discharge rate shall not exceed 1/200000 of swept volume as follows:

DR_{max} = 0,00926 * V * D * B **(1)**

Where:

DR_{max} = Maximum permissible discharge rate (m^3/h)

V = Ship's average speed (knots) over the period

D = Draft (m)

B = Breadth (m) (IMO, n.d.)

2.7.2 Special Areas

In the table below the dates for when this annex was adopted, when it entered into force and from which day it has been in effect is being presented for each special area.

Table 3. Special areas for Annex 4 (IMO, 2019)

Special Areas	Adopted #	Date of Entry into Force	In Effect From
Annex IV: Sewage			
Baltic Sea	15 Jul 2011	1 Jan 2013	**

"** The discharge requirements for the Special Area shall take effect:

1. For new passenger ships:
   On 1st June 2019
2. For existing passenger ships:
   On 1st June 2021
3. For existing passenger ships with a two-year extension period:
   On 1st June 2023
   "For existing passenger ships en route directly to or from a port located outside the special area and to or from a port located east of longitude 28˚10' E within the special area that do not make any other port calls within the special area."" (IMO, 2019)

2.7.3 Upcoming regulations

Wastewater discharge

The discharge of wastewater within the Baltic Sea will be prohibited by 2021 for existing cruise ships. To meet this regulation the ships must discharge their sewage at receiving facilities or install more effective treatment equipment. (WaterWorld, 2016)

2.8 Annex 5 Prevention of Pollution by Garbage from Ships

Garbage is any kind of waste that does not fall under the categories in the other annexes in MARPOL. Garbage can be food waste, cargo residues, operational waste, plastic, ash, cooking oil, and the like. (IMO, n.d.)

2.8.1 Discharge requirements

Generally, discharges of all garbage into the sea is prohibited, but if the rules are followed, it is permissible in certain circumstances. IMO has compiled an overview of the discharge requirements which is presented below.

Table 4. Simplified overview of the valid discharge requirements (IMO, 2019)

<table>
<tr><th rowspan="2">Garbage type[1]</th><th colspan="2">All ships except platforms[4]</th><th rowspan="2">Regulation 5
Offshore platforms located more than 12 nm from nearest land and ships when alongside or within 500 metres of such platforms[4]</th></tr>
<tr><th>Regulation 4
Outside special areas and Arctic waters
(Distances are from the nearest land)</th><th>Regulation 6
Within special areas and Arctic waters
(Distances are from nearest land, nearest ice-shelf or nearest fast ice)</th></tr>
<tr><td>Food waste comminuted or ground[2]</td><td>≥3 nm, en route and as far as practicable</td><td>≥12 nm, en route and as far as practicable[3]</td><td>Discharge permitted</td></tr>
<tr><td>Food waste not comminuted or ground</td><td>≥12 nm, en route and as far as practicable</td><td>Discharge prohibited</td><td>Discharge prohibited</td></tr>
<tr><td>Cargo residues[5, 6] not contained in washwater</td><td rowspan="2">≥ 12 nm, en route and as far as practicable</td><td>Discharge prohibited</td><td rowspan="2">Discharge prohibited</td></tr>
<tr><td>Cargo residues[5, 6] contained in washwater</td><td>> 12 nm, en route and as far as practicable (subject to conditions in regulation 6.1.2 and paragraph 5.2.1.5 of part II-A of the Polar Code)</td></tr>
<tr><td>Cleaning agents and additives[6] contained in cargo hold washwater</td><td rowspan="2">Discharge permitted</td><td>≥ 12 nm, en route and as far as practicable (subject to conditions in regulation 6.1.2 and paragraph 5.2.1.5 of part II-A of the Polar Code)</td><td rowspan="2">Discharge prohibited</td></tr>
<tr><td>Cleaning agents and additives[6] in deck and external surfaces washwater</td><td>Discharge permitted</td></tr>
<tr><td>Animal Carcasses (should be split or otherwise treated to ensure the carcasses will sink immediately)</td><td>Must be en route and as far from the nearest land as possible. Should be >100 nm and maximum water depth</td><td>Discharge prohibited</td><td>Discharge prohibited</td></tr>
<tr><td>All other garbage including plastics, synthetic ropes, fishing gear, plastic garbage bags, incinerator ashes, clinkers, cooking oil, floating dunnage, lining and packing materials, paper, rags, glass, metal, bottles, crockery and similar refuse</td><td>Discharge prohibited</td><td>Discharge prohibited</td><td>Discharge prohibited</td></tr>
</table>

"1 When garbage is mixed with or contaminated by other harmful substances prohibited from discharge or having different discharge requirements, the more stringent requirements shall apply.
2 Comminuted or ground food wastes must be able to pass through a screen with mesh no larger than 25 mm.
3 The discharge of introduced avian products in the Antarctic area is not permitted unless incinerated, autoclaved or otherwise treated to be made sterile. In polar waters, discharge shall be made as far as practicable from areas of ice concentration exceeding 1/10; in any case food wastes shall not be discharged onto the ice.
3 Offshore platforms located 12 nautical miles from nearest land and associated ships include all fixed or floating platforms engaged in exploration or exploitation or associated processing of seabed mineral resources, and all ships alongside or within 500 m of such platforms.
5 Cargo residues means only those cargo residues that cannot be recovered using commonly available methods for unloading.
6 These substances must not be harmful to the marine environment. " (IMO, 2019)

2.8.2 Special areas

In the table below the dates for when this annex was adopted, when it entered into force and from which day it has been in effect is being presented for each special area.

Table 5. Special areas for Annex 5 (IMO, 2019)

Special Areas	Adopted #	Date of Entry into Force	In Effect From
Annex V: Garbage			
Mediterranean Sea	2 Nov 1973	31 Dec 1988	1 May 2009
Baltic Sea	2 Nov 1973	31 Dec 1988	1 Oct 1989
Black Sea	2 Nov 1973	31 Dec 1988	*
Red Sea	2 Nov 1973	31 Dec 1988	*
"Gulfs" area	2 Nov 1973	31 Dec 1988	1 Aug 2008
North Sea	17 Oct 1989	18 Feb 1991	18 Feb 1991
Antarctic area (south of latitude 60 degrees south)	16 Nov 1990	17 Mar 1992	17 Mar 1992
Wider Caribbean region including the Gulf of Mexico and the Caribbean Sea	4 Jul 1991	4 Apr 1993	1 May 2011

"* The Special Area requirements for these areas have not yet taken effect because of lack of notifications from MARPOL Parties whose coastlines border the relevant special areas on the existence of adequate reception facilities (regulations 38.6 of MARPOL Annex I and 5(4) of MARPOL Annex V)." (IMO, 2019)

2.8.3 Upcoming requirements

Marine litter

Today, marine litter in the seas is a major problem, which is why IMO has issued requirements regarding discharge of these. Plastics of all forms, including microplastics, cause damage to the sea and organisms in the sea and therefore changes are needed. The IMO Action Plan for discharge of plastic litter was adopted in 2018 and is planned to be completed by 2025. This plan includes various intended measures to achieve the desired goal. These measures include, for example, better marking of fishing gear, improved deliveries to shore facilities, teaching the effects of marine litters to seafarers, investigating the emissions and availability of receiving facilities at ports. (IMO, 2019)

2.9 Annex 6 Prevention of Air Pollution from Ships

Annex 6 of MARPOL was adopted in 1997 but entered into force in 19 May 2005. Five years later, a revised version of Annex 6 was entered into force. This annex sets the limits for exhaust gas emissions and other air pollution, like greenhouse gases, from ships. The main limitations in the prevention of emissions are limitation of sulphur oxides SO_x and nitrous oxides NO_x as well as GHG emissions. These restrictions became even more stringent after the revised version of this annex came into force and have also become much stricter over the years. (IMO, 2019)

2.9.1 NO_x Nitrous Oxides

The emission requirements for NO_x are determined according to a three-level system called Tier and apply to marine engines with an output power of more than 130 kW and installed after January 1, 2000 or undergoes a bigger conversion after January 1, 2000. (IMO, 2019)

Table 6. Tier levels (IMO, 2019)

Tier	Ship construction date on or after	Total weighted cycle emission limit (g/kWh) n = engine's rated speed (rpm)		
		n < 130	n = 130 - 1999	n ≥ 2000
I	1 January 2000	17.0	$45 \cdot n^{(-0.2)}$ e.g., 720 rpm – 12.1	9.8
II	1 January 2011	14.4	$44 \cdot n^{(-0.23)}$ e.g., 720 rpm – 9.7	7.7
III	1 January 2016	3.4	$9 \cdot n^{(-0.2)}$ e.g., 720 rpm – 2.4	2.0

2.9.2 SO_x Sulphur Oxides and PM Particulate Matter

Sulphur oxide emissions are caused by the combustion of fuels, and especially low-grade fuel such as heavy oil or diesel with high Sulphur content. (Wankhede, 2019) Particulate matter emissions are a biproduct from diesel combustion. They are defined as very small soot particles in the exhaust gases. (Majewski & Jääskeläinen, 2019)

The table below shows the earlier and current sulphur and particulate matter limits outside as well as inside an ECA. ECAs are presented in Chapter 2, section 9.6. The unit m/m stands for mass by mass.

Table 7. Sulphur and particulate matter limits in fuels (IMO, 2019)

Outside an ECA established to limit SOx and particulate matter emissions	Inside an ECA established to limit SOx and particulate matter emissions
4.50% m/m prior to 1 January 2012	1.50% m/m prior to 1 July 2010
3.50% m/m on and after 1 January 2012	1.00% m/m on and after 1 July 2010
0.50% m/m on and after 1 January 2020*	0.10% m/m on and after 1 January 2015

"* as required under regulation 14, a review as to the availability of the required fuel oil was undertaken. MEPC 70 (October 2016) considered an assessment of fuel oil availability and it was decided that the fuel oil standard (0.50% m/m) shall become effective on 1 January 2020 (resolution MEPC.280(70))." (IMO, 2019)

2.9.3 CO_2 Carbon Oxides/GHG Green House Gases

In 2012 about 2,3 % of the global anthropogenic CO_2 emissions came from international shipping. The current requirements regarding GHG emissions consist of control and optimization of ships energy efficiency. These requirements are as follows:

1. Energy Efficiency Existing Ship Index. EEXI is an index that requires ships to follow the energy efficiency performance levels that exist, and it also has to change when the performance levels change. For new ships it is called Energy Efficiency Design Index, EEDI.

2. Ship Energy Efficiency Plan. SEEMP is a plan that consists of an improvement system of a ship's efficiency, by optimizing equipment, trimming, speeds and more. This applies to both new and existing ships.

These requirements apply to ships with a weight of minimum 400 tonnage and ownership as well as flag is irrelevant. (IMO, 2019)

2.9.4 ODS Ozone Depleting Substances

There are three different emissions of ODS from ships. Chlorofluorocarbons (CFC), halons and hydrochlorofluorocarbons (HCFC). These emissions/discharges come mostly from refrigeration and firefighting systems.

Below are the current relevant restrictions listed:

1. Ships constructed on or after 19 May 2005: New installations as well as retrofits of CFC or halon containing systems are prohibited

2. Ship constructed on or after 1 January 2020: New installation as well as retrofits of HCFC containing systems are prohibited

3. Existing systems may continue to be used and refilled if necessary

4. Intentional emissions of ODS to the atmosphere are not allowed. (IMO, 2019)

2.9.5 VOC Volatile Organic Compounds

Requirements regarding emissions of VOC applies only for tankers as well as for gas carriers who have the right systems for loading and storage of non-methane VOC or allow safe return ashore. VOC emissions must be measured in certain ports, and then measuring equipment - vapor emission control system (VECS) - must be used in accordance with standards. A party may choose to introduce measures of these kinds only for certain ports or for certain types of ships. (IMO, 2019)

2.9.6 Special Areas

In the table below the dates for when this annex was adopted, when it entered into force and from which day it has been in effect is being presented for each special area.

Table 8. Special areas for Annex 6 (IMO, 2019)

Special Areas	Adopted #	Date of Entry into Force	In Effect From
Annex VI: Prevention of air pollution by ships (Emission Control Areas)			
Baltic Sea (SO_x) (NO_x)	26 Sept 1997 7 July 2017	19 May 2005 1 Jan 2019	19 May 2006 1 Jan 2021****
North Sea (SO_x) (NO_x)	22 Jul 2005 7 July 2017	22 Nov 2006 1 Jan 2019	22 Nov 2007 1 Jan 2021****
North American ECA (SO_x and PM) (NO_x)	26 Mar 2010	1 Aug 2011	1 Aug 2012 1 Jan 2016***
United States Caribbean Sea ECA (SO_x and PM) (NOx)	26 Jul 2011	1 Jan 2013	1 Jan 2014 1 Jan 2016***

"*** A ship constructed on or after 1 January 2016 and is operating in these emission control areas shall comply with NOx Tier III standards set forth in regulation 13.5 of MARPOL Annex VI.

**** A ship constructed on or after 1 January 2021 and is operating in these emission control areas shall comply with NOX Tier III standards set forth in regulation 13.5 of MARPOL Annex VI." (IMO, 2019)

2.9.7 Upcoming regulations

1. Sulphur 2020

As mentioned earlier, year 2020 new sulphur limits are coming into force. More specific, after 1 January 2020 the maximum amount of sulphur in ships fuel oil must be maximum 0,50 % m/m outside the ECA area and 0,10 % m/m inside the ECA area. This means that use of and carriage of fuel oil that not fulfil the new requirements is prohibited from 1 January 2020, unless the ship has a scrubber installed and the emissions are under the limit. (IMO, 2019)

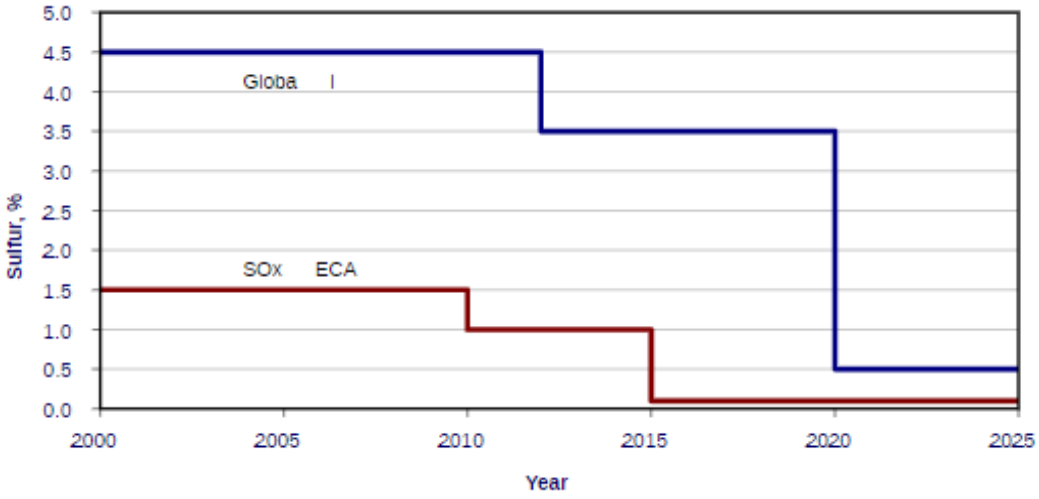

Figure 1. Annex 6 Sulphur limits (DieselNet, 2018)

2. NO_x Tier 3

For ships operating in North American ECA and the United States Caribbean Sea ECA the latest Tier level, Tier 3, came into force 1 January 2016, and for ships operating in the Baltic Sea ECA or the North Sea it came into force 1 January 2020. Every ship built after these dates must comply with this standard. This also means that if a ship undergoes a larger conversion, the same standards must be followed. A larger conversion is a modification on a ship when for example the main engines are replaced or undergoes a larger upgrade. (IMO, 2019)

3. GHG emissions

In 2018, IMO published an initial strategy containing a vision for how greenhouse gas emission reductions should be reduced. The IMO's plan is to totally reduce greenhouse gas emissions during this century, which is why this strategy is seen as very important and significant. (IMO, 2019)

The strategy for reducing GHG emissions from international shipping is defined by three levels of ambition as follows:

1. Implementation of EEDI for new ships. The purpose of this system should be reviewed and eventually stricter requirements for energy efficiency should be introduced.

2. Compared to 2008, a reduction in carbon intensity from international shipping by at least 40 % by 2030 and a desired reduction by 70 % by 2050.

3. The peak of GHG emissions should be reached as soon as possible and then a reduction of emissions by at least 50 % by 2050 compared to 2008 will occur. The Paris Agreement's temperature targets nshould also be followed in view of CO_2 emissions. (Greenhouse Gas Emissions, u.d.)

2.9.8 DNV GL Det Norske Veritas & Germanischer Lloyd

DNV GL is a classification society in the maritime industry and their role is to enhance the standard regarding safety, energy efficiency and environmental emission within the shipping industry in the world. DNV GL does a great amount of research development to improve things that have been outdated or are in need of a change. DNV GL has made a maritime forecast to 2050, which is a study of how emissions from shipping should be reduced and the GHG targets should be met. A pathway model has been made to evaluate different reduction measures for both existing ships and new ships. (Longva, 2019)

Presented below is DNV GL's pathway model:

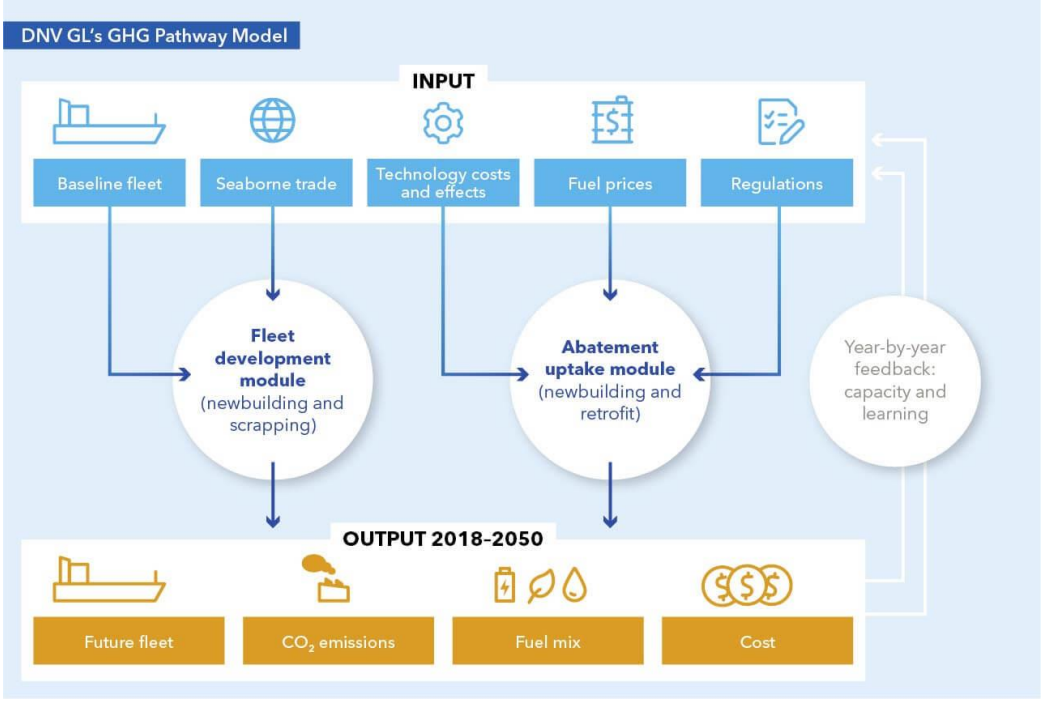

Figure 2. DNV GL´s GHG Pathway Model (Longva, 2019)

DNV GL has modeled three different paths that will possibly be taken when the GHG targets are to be achieved. The first two paths focus on new design requirements and operational requirements, while the third path describes what happens if no new requirements are introduced. (Longva, 2019) The three paths are presented below in a table made by DNV GL.

Table 9. DNV GL's three pathways' assumptions (Longva, 2019)

Description of DNV GL's three pathways' assumptions on regulations for reducing GHG emissions

	Two pathways to achieve IMO ambitions		A third pathway
	Focus on design requirements[1)] (DR)	Focus on operational requirements[1)] (OR)	Keep current policies (CP)
Design requirements for new-buildings	■ Currently adopted EEDI requirements until 2035 ■ From 2035: 60% reduction ■ From 2040: 90% reduction, starting with short-sea, then deep-sea vessels.	■ Currently adopted EEDI requirements	■ Currently adopted EEDI requirements
Operational requirements for all ships	■ Gradually increasing to 45% reduction in 2040	■ Gradually increasing to 60% reduction in 2050	■ No requirements

[1)]The design and operational requirements are carbon-intensity requirements set relative to an average ship in 2015, which is close to the reference lines used in the Energy Efficiency Design Index (EEDI) framework.

2.10 NRMM Non-Road mobile machinery emissions

This requirement applies to several sorts of vehicles, but for ships, it applies only to inland water vessels. This means it affects mostly smaller ships. The emissions this requirement wants to reduce is carbon oxides, hydrocarbons and nitrogen oxides and particulate matter. (NRMM, 2017) The first stage of this regulation came into force in October 2016, and the last stage (Stage 5) came into force in January 2019. Inland water vessels should have complied with this last stage before January 2020. In the transitional provisions figure shown below, it is also shown that type approval of Stage 5 is happening in the coming years. (European Comission, n.d.)

The emission standards (Stage 5) for inland water vessels are presented below:

Table 10. Stage 5 emission standards (DieselNet, 2016)

Category	Net Power	Date	CO	HC[a]	NOx	PM	PN
	kW		*g/kWh*				*1/kWh*
IWP/IWA-v/c-1	19 ≤ P < 75	2019	5.00	4.70[b]		0.30	-
IWP/IWA-v/c-2	75 ≤ P < 130	2019	5.00	5.40[b]		0.14	-
IWP/IWA-v/c-3	130 ≤ P < 300	2019	3.50	1.00	2.10	0.10	-
IWP/IWA-v/c-4	P ≥ 300	2020	3.50	0.19	1.80	0.015	1×10^{12}

[a] A = 6.00 for gas engines
[b] HC + NOx

In the figure below, transitional provisions are presented for the stages of the regulation:

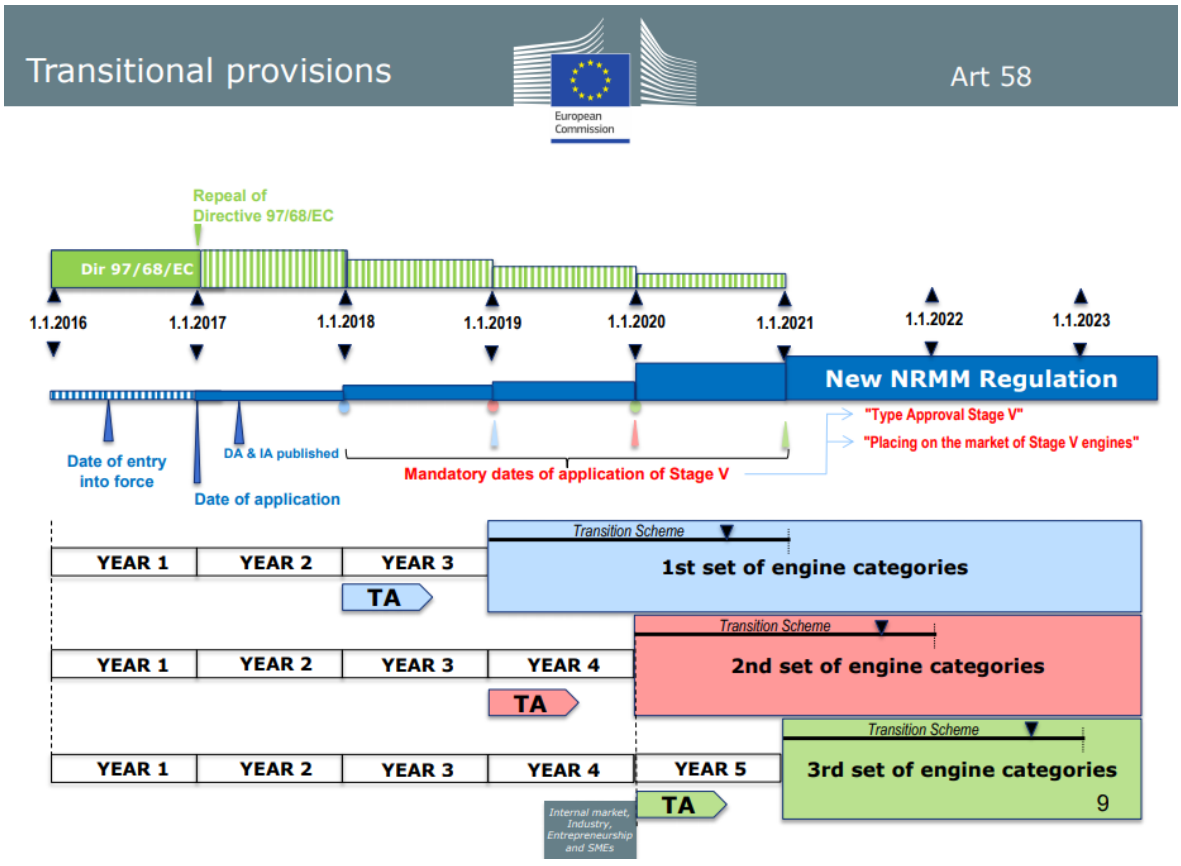

Figure 3. Transitional provisions (European Comission, n.d.)

2.11 Ballast Water Management Convention

When ballast water is moved between two different seas, besides water, different organisms and insect and animal species can also be moved. This is a problem because wrong species in wrong water are harmful for the ecosystem, which is not good considering the environment. In 2004, IMO introduced a BWM Convention whose purpose is to prevent the spread and movement of species and organisms. The convention came into force 2017 and it consists of different standards and regulations for how the ballast water process is to be done. (IMO, 2019)

The BWM consists of three standards, which are presented below:

The D-1 standard requires the ship to perform ballast water replacement at a distance of at least 200 nautical miles from the nearest land with a depth of at least 200 meters. The exchange of the ballast water must also be such that at least 95 % of the water volume is exchanged at these distances.

The D-2 standard specifies how much viable microbes and organisms can be contained in the discharges to the maximum. These criteria are:

1. Less than 10 viable organisms/m^3 which have a minimum dimension of 50 micrometer

2. Less than 10 viable organisms/ml which have a minimum dimension between 10 micrometers and 50 micrometers

3. Less than 1 cfu/100 ml of Toxicogenic Vibrio cholerae

4. Less than 250 cfu 100 ml of Escherichia coli

5. Less than 100 cfu/100 ml of Intestinal Enterococci. (IMO, 2019)

The D-3 standard requires that the equipment used for the ballast water exchange must be approved by the administration and comply with the rules of the convention. The equipment cannot be a risk to the environment, human health or property. (IMO, 2019)

2.11.1 Upcoming regulations

The D-1 and D-2 standards have been adopted at various stages and there are different stages for when they are obligatory for existing and for new ships. Up to 2024, existing ships have time to adopt standard D-2. (safety4sea, 2019) Thus, this is not an upcoming regulation, but a regulation to count on considering installation of BWM equipment in the nearest years. In the clipping of the Ballast Water Management Convention timeline figure IMO has made, the relevant dates are presented.

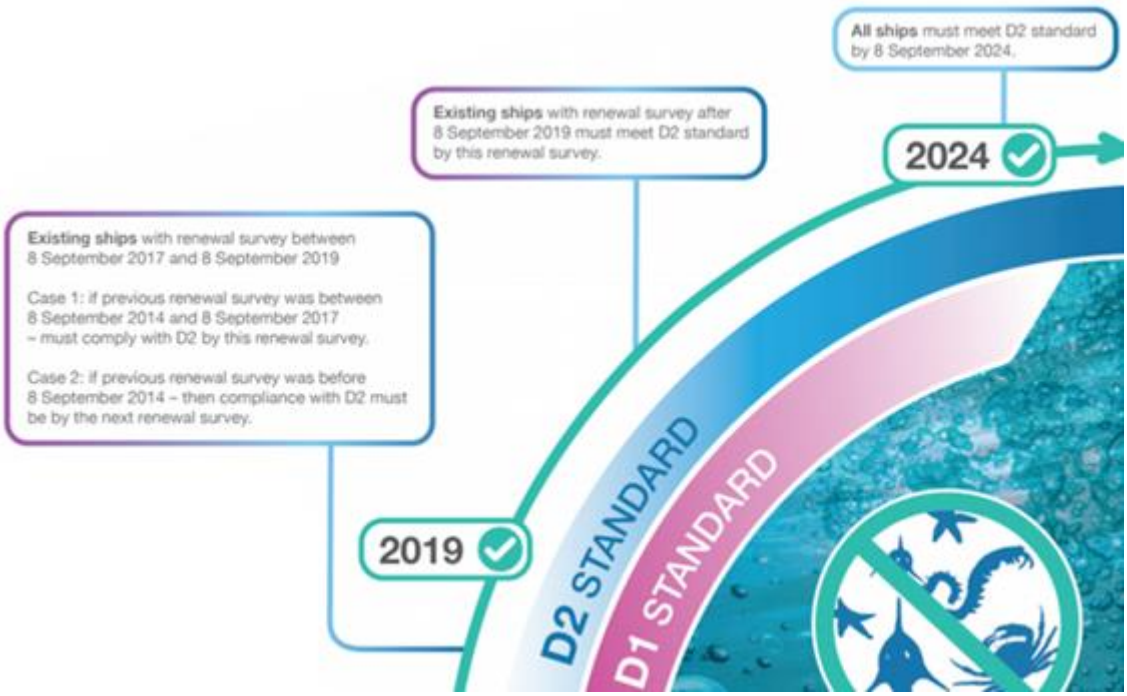

Figure 4. Clipping of BWM Convention timeline (safety4sea, 2019)

3 METHOD

The methods used to obtain information in this thesis are presented in this chapter. There are many ways to obtain information. Especially if the study concerns very current topics that are updated frequently, like this thesis, it is important to think about where to take information and which sources to use.

3.1 The text

The text in this work is written in English, because it is the language that reaches most people at Foreship, since an important working language within Foreship is English. English is also a language I master good enough to write a work of this kind in.

The text has been written in accordance with general writing principles and rules. According to A. Lewin Beverly, it is important to be consistent throughout the work regarding the layout and the writing of the text. It is also important to keep the sections and sentences short enough, and to avoid a sentence containing too much information, as this can be difficult for the reader to take in, Beverly says. (Beverly, 2010)

3.2 The communication between me and my supervisors

I strived to have regular communication to my supervisors during the work. This to get constantly feedback for my hitherto written text and to be led in the right direction. This communication was mostly verbal, but also dialogs via email and Skype were used. The communication between me and my supervisor was about the content, the layout, the time schedule, different methods to use and personal support through the whole work.

3.3 Investigation of existing and upcoming requirements

In order to obtain information on discharge and emission requirements, information was taken from websites. It was considered necessary to use websites and documents from websites to ensure that the newest information was used. IMO's own website was used extensively because the work was heavily based on their information. Articles contributed with good information, because they presented several upcoming requirements, experts' opinions and forecasts. To get more information, opinions and aspects also from people in the branch were included. This in the form of two interviews.

3.4 Interviews

According to Patel and Davidson, interviewing is a good method for getting questions answered and information obtained. A traditional interview where the questioner holds a dialogue with the respondent is a good way for the respondent to understand the questions correctly and to be able to ask up if ambiguities occur. (Patel & Davidson, 2019)

Patel and Davidson emphasize that the preparation and the layout of interviews are important to think about, also what questions you intend to ask, and in what order you ask them. Asking background questions first is a common way to start interviewing, after which you ask the essential questions. These things have been kept in mind during the planning of the interviews as well as during the interviews. Patel and Davidson also explain that the "funnel technology" can be used in interviews. This means that you first ask more general questions about the topic, then ask more specific questions. This is a technique that is considered motivating and activates the respondent, since it is easier for the respondent to express himself at the beginning of the interview. (Patel & Davidson, 2019) This technique has been used at some level for the interviews in this work.

For this thesis two interviews were held. One with Kristoffer Sandelin and one with Ville-Veikko Intovuori. In the Result section Sandelin is named as Respondent 1 and Intovuori as Respondent 2. The interview questions can be found in Appendix 1 for Sandelin and Appendix 2 for Intovuori.

3.5 From new requirements to sales opportunities

When I had the necessary information about existing and upcoming requirements and legislation obtained, the next step was to figure out how Foreship could get sales opportunities out of this. I got many aspects and information from the interviews, that helped me search the right information from the internet. Every upcoming requirement did not offer Foreship any sales opportunities, which also got clear during the process. I listed the opportunities I found and described how they could bring more (or different) new opportunities in the future.

3.6 Reliability

According to Patel and Davidson, it can be tricky to determine whether the reliability of the chosen methods is high enough to be used for research purposes. They believe that traditional interviews often hold a high level of reliability, especially if both the questioner and the respondent are trained for interviews. (Patel & Davidson, 2019)

Generally, a source-critical view of the sources to be used is required. There are essentially three types of sources; primary source, secondary source and third-party source. The primary source is the most credible and the one that should be used the most. The secondary source reproduces what is presented in a primary source. These are not always as credible as the primary sources, which requires that you as a user must analyze them thoroughly. The third-party source is a source that reproduces what is presented in the secondary source. (Björkstrand, 2016)

Some important things to have in mind when choosing sources:

1. Is the content in the source true?
2. Who is the actor behind the source? Is it in their interest to write about this topic?
3. When has the source been written and presented? Is it still relevant?
4. Does the content in the source match with other similar sources? (Björkstrand, 2016)

In this work I have followed these rules to get as reliable information as possible. As earlier mentioned, because this work is about requirements and legislation, it has been very important to use the correct data to get the newest information.

4 RESULTS

4.1 Interview results

The interview results are presented below.

Interview 1 – Respondent 1

This interview was held with a salesman of emission abatement technologies at the company HugEngineering in Switzerland. HugEngineering is a company that sells exhaust gas cleaning systems for both diesel and gas engines for ships, power plants and other facilities with engines of this type. The Respondents' education is Doctor of Technology and he has a long work experience in the development and sale of emission abatement technologies and has thus become familiar with various technologies and emission requirements, both international and national. His work experience in the area consists of having worked at the Wärtsilä engine factory for about nine years, with exhaust cleaning, ships, power plants and engines, and besides this he has also worked at several other exhaust gas cleaning companies with similar tasks, but most with the development of exhaust gas cleaning equipment. In recent years, the Respondent 1 has nevertheless been mostly involved in the sales of such systems.

When asked if Respondent 1 believes that new emission requirements for exhaust gases besides those we already know are coming, he states that it is difficult to predict what the future will entail, but what he is almost sure about is that various existing emission abatement technologies need to be updated and renewed to meet the new requirements that are forthcoming.

Many of the new requirements that apply to upcoming exhaust emissions apply only to new builds, which leads us to the question if the new requirements apply also to existing ships. According to Respondent 1, shipowners will try to avoid unnecessary costs such as retrofitting or additional assembly of exhaust cleaning equipment, and thus, if possible, not retrofitting any of these systems, if not required.

As is already known, there are some special areas around the world that have stricter emission requirements than other more common areas. In addition to these special cases, countries and cities can also set their own requirements for emissions, for example at major ports in France and Germany, according to Respondent 1, there will probably be very strict

requirements regarding exhaust emissions from ships. On the Norwegian fjords too, it has imposed strict restrictions on the amount of exhaust gases that may be emitted.

Respondent 1 means that shipowners must comply with these requirements in order to visit these areas. The requirements for cargo ships compared with cruise ships are going to have different character, since the areas they are operating in often are different. For cargo ships, it is often a must to reach a certain port with strict restrictions, and thus must have the technology required or use the fuel required to keep emissions below the limits. For cruise ships, the situation is a little different, as they do not run commercial traffic and can therefore adapt to the requirements that apply in certain areas and run other routes than before. This means that cargo ships need to retrofit exhaust cleaning equipment in accordance to the feasibility of their routes but of course, also the cargo ship owners want to adapt to the requirements and try to adjust their ships and the ship's routes.

Respondent 1 believes that the use of different fuels will become more common in the future due to new requirements coming up and different solutions to how emissions can be reduced. LNG has become increasingly common as emissions of nitrogen oxides and sulphur oxides are much lower compared to oil fuels. However, greenhouse gas emissions are relatively high by LNG combustion, and in today's situation, active discussions are held about how harmful they really are. The greenhouse gas emissions can be viewed in different ways, which means that there are many different views as to whether the use of LNG is better for the environment than the use of oil fuels. When using LNG, the same particles and nitrogen oxides do not occur, however, greenhouse gas emissions can be considered dangerous in different ways, and Respondent 1 believes that because of this, it can change the view of LNG and people may change their mind along time.

Respondent 1 believes that the use of dual fuel engines will become more common in the future. Dual fuel engine means that the ships can run on different fuels. Since the emission requirements apply regardless of the type of fuel used, emission abatement technologies for the various fuels will be needed if the ship is to operate in the areas with strict requirements.

Today, environmental friendliness is an important issue for many organizations and companies, and many facilities and projects are marketed as environmentally friendly and green. Such projects include installation of wind turbines, dredging and fairway work. In these types of projects, ships are often used for installation, transport of components or other support, and it is then not appropriate that the ships that have this task in these projects are highly polluting and emit environmentally harmful substances. Because of this, emissions

cleaning becomes even more important, even for smaller ships and ships operating in local areas. According to Respondent 1, this can also contribute to several installations of exhaust gas cleaning systems, even for existing ships.

As mentioned before, many installations of new cleaning equipment only apply to new builds, but some also apply to retrofits. Respondent 1 talked about a device called standby filter used for hoteling mainly, "hotel filter", which has become more and more common, and which has been installed on smaller cruise ships lately. A standby filter is a filter that is active only when the ship is in a port where the emission requirements are particularly high. When the ship has leaved the port area, the filter is deactivated. The reason why it is not used constantly is a cost and space issue.

It is still difficult at this stage to know and be able to say what kind of equipment will be used more, and when it comes to the question of whether open-loop scrubbers[1] will be played out by closed-loop scrubbers or other cleaning options, there are several theories. The idea that Respondent 1 had about this was that there is a risk that a so-called "scrubber gate" becomes relevant, which means that if it is considered that the open loop scrubber does not clean the exhaust emissions sufficiently, after which the method is totally banned, or at least with great probability in Europe. However, using open-loop scrubber is a popular option for ship companies, as it is a money maker for them. If all users of open-loop scrubbers take care and it is considered to be a sufficient cleaning method, this option may still be used and be on the market for a few years.

The biggest change that has taken place and continues to take place in exhaust emissions for ships is the amount of new alternative fuels to the traditional heavy crude oil. With several different fuel options also comes several different cleaning methods. Respondent 1 believes that now and in the future, it becomes more important to know the whole when purchasing engines. By this he means that you should know what fuels to use and the kind of engine that should be procured for that purpose, and what auxiliary equipment is necessary. Then it is also important to think about which exhaust cleaning technology must be installed for the requirements to be met. This applies to both new builds, retrofits and conversions.

[1] Open-loop scrubber is an exhaust gas cleaning system where seawater is used as the scrubbing medium. When the water has gone through the system it goes overboard. Closed-loop scrubber is similar to the open-loop scrubber, but instead of seawater as the scrubbing medium it uses fresh water treated with chemicals. When the water has gone through the system it is being cleaned and then re-circulated into the system. (Sethi, 2020)

For companies like Foreship, this means that planning of exhaust gas cleaning systems must also be seen from a broader perspective. A holistic perspective must be created to see opportunities for how systems should be planned and how the customer's needs should be met. Respondent 1 believes that a change that will occur is that the way of working for Foreship will change somewhat in the future, for example, closer cooperation with other companies will become more important, and a wider area of knowledge will become more important within the company. If the market and industry are introduced with new technologies and systems, those who plan to use these systems must also be kept up to date and renew their knowledge. An outsourcing of a certain part of the planning of a system will possibly become more common and more profitable, and the company itself will invest in becoming knowledgeable in a specific area while using partners for other detailed knowledge or planning. The ships are being more complex and custom-made, and a big working network between partners is a winner.

Interview 2 – Respondent 2

This interview was held with a special adviser at the Finnish Transport and Communications Agency (Traficom). Traficom is a Finnish authority that handles traffic, transport, registration and operational and safety questions within the Finnish transport system. The Respondent's tasks include certification of ships and approval of environmental issues. Everyday tasks include, for example, the approval of ships' plans, like SOPEP (Shipboard oil pollution emergency plan), as well as the handling of cases concerning ballast water management. In addition to these tasks, Respondent 2 is also in contact with the development of new rules and the issuing of certificates and exemptions for ships. For example, in Finland he is responsible for the new amendments coming in the IMO ballast water management convention. At EU level, Respondent 2 has been in contact with amendments regarding the EU MRV regulation. MRV (Monitoring, Reporting, Verification) is a regulation that sets requirements for ships to measure and report carbon dioxide emissions. Respondent 2 has a sea captain degree and later also educated as Master of Marine Technology. He has worked at Traficom (formerly Trafi) since 2012, and before that he worked at Neste Oil for about ten years with oil tankers and different office tasks.

However, the Respondent's working career began with various cargo ships that mainly carried bulk and other dry products (general cargo ships). He thus has a long experience of

ships and regulations and rules regarding ships and is therefore an ideal person to interview for this thesis.

As mentioned earlier, considering this work the MARPOL Annex 6 is the most relevant part of MARPOL Convention, and also Respondent 2 stated that the biggest amendments will affect this annex. According to him, the reduction of carbon dioxide emissions is the most relevant part of the annex right now. Today, measurements and control of various emissions are very topical and important, in order to find out the ship's energy efficiency. After measuring emissions from the ship for a certain period, the results are analyzed, and eventual actions are taken. For new ships, the EEDI (Chapter 2, section 9.3) is a measurement system that will be mandatory in the near future. For existing ships, there is a similar measurement system under development at the IMO, called EEXI (Energy Efficiency Existing Ship index). Respondent 2 says that with this system it is possible to determine if changes are needed regarding the ship's engines or propulsion to reduce carbon dioxide emissions. Other methods that have been proposed to reduce carbon dioxide emissions are limitation and optimization of the ship's speed and limitation of the ship's engine power.

Respondent 2 says that several of the upcoming emission limits do not impose requirements on the methods used by the ships to reduce emissions, as long as the amount of emissions is kept below the required level. When discussing what new updates are coming for Annex 6, Respondent 2 says that Tier 3 for nitrogen oxide emissions is forthcoming, but that the Tier level only applies to major engine conversions for existing ships, as well as for new ships. NRMM (Chapter 2, section 10) is also mentioned in connection with this. NRMM (Non-road mobile machinery emissions) are requirements regarding inland water emissions within the EU, which means that these requirements generally apply to smaller inland ships and boats, and not to larger cargo or cruise ships. Besides these updates on nitrogen oxide emissions and NRMM, Respondent 2 believes that IMO's GHG strategy entails various short-term actions to reduce carbon dioxide emissions for existing ships. What actions will apply are not yet determined but there are four different options. The first alternative is that the shipowner himself takes his own actions to reduce carbon dioxide emissions. The second option is EEXI, which was previously explained, and the third option is speed limitation and finally the last option is power limitation of the engines. Another upcoming requirement regarding Annex 6 is restrictions on black carbon emissions. Respondent 2 says that this requirement is still in its early stages and that the IMO has so far only decided the definition for black carbon and begun to develop measurement protocol for this substance in the exhaust gases. This restriction will probably only apply to traffic in Arctic areas, as

emissions of black carbon contribute strongly to the glaciers melting and the climate is warming. Some boundaries for which areas this applies are not yet determined, and Respondent 2 believes this will become more relevant within five to ten years.

Also, for Annex 4, new regulations or updates for existing regulations are forthcoming. Respondent 2 talks about a discharge ban on wastewater for cruise ships that will apply within the Baltic Sea, and which will come into force on 1.6.2021 for existing passenger ships. Type approval of the equipment for treatment of the wastewater will also be stricter. This means that ships will have to improve their equipment for the treatment of wastewater. Respondent 2 says that IMO has also discussed whether gray water discharges and discharge of food waste should be stricter. In today's situation, gray water and food waste can be released very freely, and it is common for them to be mixed with the black water and released via the same equipment. This is not very good, for example, food waste can contain a lot of fats that can disrupt the cleaning equipment and add nutrients into the water.

Respondent 2 also mentions a small amendment regarding the systems for treating bilge water. Bilge water is water collected at the bottom of the ship and equipment, called integrated bilge water treatment system (IBTS), is used to clean and treat this water. The amendment that is to come means stricter type approval of this equipment.

Respondent 2 also tells about a relatively large addition to MARPOL Convention concerning discharges of marine litter. This supplement is intended to belong to Annex 5 as this annex concerns the release of solid materials. It is not yet determined exactly how this supplement will be applied, but the intention is to achieve a reduction in solid waste from ships, even though technically all discharge of waste and especially plastic waste are prohibited in most sea areas.

Besides the discharge requirements for MARPOL's six annexes and BWM Convention, according to Respondent 2 there will be new requirements regarding biofouling, which concern organisms and that stuck to the ship's hull. He believes that these new requirements will not necessarily come true yet, but possibly within the next ten years. Also, anti-fouling paints will become a greater topic of discussion in the near future, as paints often contain chemicals and other harmful substances.

When discussing whether new requirements regarding ballast water management are forthcoming, Respondent 2 is pretty sure that big amendments are not to be expected, but possibly some small change. At present, data is collected on how different ships' ballast

water management systems have worked, and this information will be analyzed in the near future to consider whether the cleaning systems have worked well enough or if there is a need for improvements. If improvements are deemed necessary, small changes can be added to the ballast water management convention. However, Respondent 2 believes in the short-term future no changes will be made regarding these discharges.

When asked how Respondent 2 believes that new discharge requirements will affect the sale of new machinery systems. He points out that the installation and improvement of various machinery systems are generally very expensive, which means that unnecessary installations or installations just in case are not going to be made. Thus, some actions that improve energy efficiency also reduce operating costs of the ship, and because of this, shipowners may be willing to invest in that technology. Respondent 2 also notes that a straight answer to this question is very difficult to give, which may be due to uncertain times and major decisions for shipowners.

Respondent 2 believes ship conversions will increase, especially because of the GHG strategy's operational actions. If conversions have to be done to reduce exhaust emissions to approved levels, they will probably be done. However, Respondent 2 believes that major conversions are not profitable for old ships, which on the other hand, means more ship scrappings will be made than before.

Respondent 2 believes that in today's situation, the combination of heavy fuel oil and emission abatement technologies is the most popular way of operating ships and keeping sulphur oxides emissions low enough. In the near future, Respondent 2 also believes in an increasing use of LNG fuel. However, he thinks that in ten to twenty years, only the use of LNG fuel will not be enough to keep it below the approved emission levels, since IMO has set a goal that by 2050 carbon dioxide emissions will be reduced by 50 %, and this will not succeed only changing the fuel to LNG. Respondent 2 mentions artificial production of LNG could be an opportunity to reduce emissions. However, this opportunity is something that will probably not happen in the near future. What Respondent 2 believes will be very important in the future is optimization of machinery systems, and of the ships other systems, to make the ship operate as energy-efficient and environmentally friendly as possible. According to Respondent 2, the use of accumulators will certainly increase. He believes that ships could run on electricity from accumulators on, for example, fairways, and then during the sea voyage as well as at the ports the accumulators could be charged. The use of different

types of new fuels will also become more common, although today's trend is the use of exhaust gas cleaning systems and heavy fuel oil.

4.2 Most important aspects from the interviews

To sum up, it is hard to predict the future regarding upcoming requirements and legislation, but some new updates we already are aware of. Shipowners are constantly following the new legislation, and they will always avoid unnecessary costs if possible. Changes will happen, sooner or later, for almost every area in the world. Thus, some areas, like major ports in some countries, will have very strict emission and discharge requirements very soon.

Much of the old emission cleaning equipment will be forced to be updated, if it is worth it. Many ships are old and ship scrappings has increased the last years, and that lead shipowners to the question if it is worth to put too much money on emission cleaning equipment retrofits. The use of alternative fuels will increase under the coming years because shipowners are willing to try new methods to get the emissions under the maximum allowed level. If these new methods – like alternative fuels – really are better and cleaner is though hard to decide. New research is made all the time and belong with these, people's opinions change, because many of these emission questions are questions of interpretation. Also, alternative kind of engines will eventually be used more in the future, like dual fuel engines.

Today, it is very important for companies to be “green” and environmentally friendly, and because of this, even smaller companies see it more important to have environmentally friendly ships and other equipment. In the future it can increase the installations of emission cleaning equipment also for smaller ships. Optimization of ships engines will be more important in the future, this to get the emissions down, but also the operative costs down. Requirements regarding this will come into force and will be stricter along the future years.

New requirements and updates are upcoming for solid materials, like wastewater and food waste, as well as for marine litter. This means there will be stricter approval of cleaning equipment. Also, for ballast water management and biofouling, some small updates are likely to come.

Ship conversions and retrofits will probably increase, but it is hard to say when and at which level. Since climate change and environmentally friendliness are big topics nowadays, people are doing much research on alternative methods to get lower emissions and minimize the discharges of harmful substances.

4.3 Summary of theory and interview results

To get a clear overview of the upcoming requirements and eventual upcoming requirements, a summary has been created. As earlier mentioned, Annex 6 is probably the area that is the most current today, and for which it comes the most updates and changes. After the investigation is made and the interviews are held, it was clearly noticed that this was true.

4.3.1 Annex 6 Air Pollution

Based on Chapter 2.9.7 and 2.10 the regulations below bring upcoming updates:

1. Sulphur 2020 – New sulphur limits in ships fuel oil
2. Tier 3 – Reducing nitrogen oxide emissions, for retrofits it applies only if the ships undergoes a major conversion
3. GHG strategy – Reducing GHG emissions
4. NRMM – Emissions requirements regarding inland water emissions within the EU.

DNV GL has published a timeline showing most important upcoming requirements, presented below:

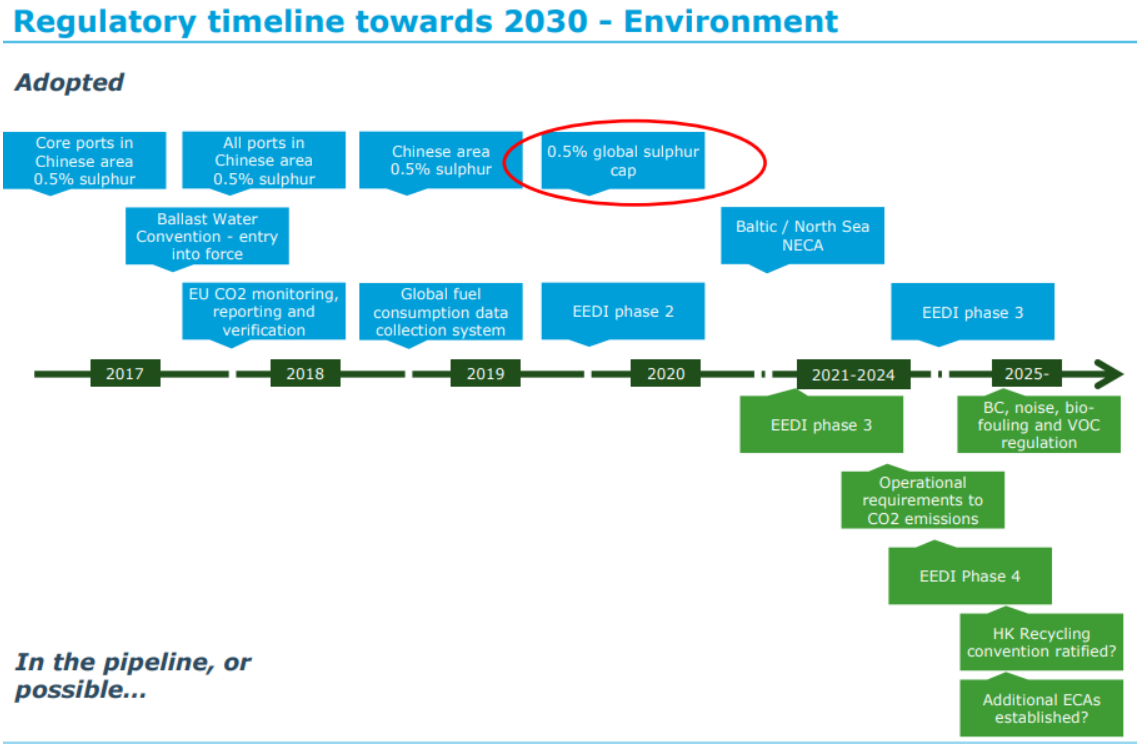

Figure 5. DNV GLs timeline towards 2030 (DNV GL, 2018)

4.3.2 Annex 4 Pollution by Sewage from Ships

Based on Chapter 2.7.2 and interview with Respondent 2, the regulations below bring upcoming updates:

1. Discharge ban on wastewater for cruise ships that will apply within the Baltic Sea
2. Eventual stricter requirements on discharge of gray water and food waste
3. Eventual stricter requirements on discharge of bilge water.

4.3.3 Pollution by Garbage from ships

Based on Chapter 2.8.3 the regulation below may bring upcoming updates:

1. Marine litter regulation – stricter requirements on discharge of solid materials.

4.3.4 Other

Based on interview with Respondent 2 and Chapter 2.11.1, the regulations below bring upcoming updates:

1. Eventual new requirements regarding biofouling – organisms that are stuck to the ship's hull
2. The latest requirements regarding BVM have a transition period up to 2024.

4.4 Sales opportunities

What sales opportunities does these upcoming requirements bring the machinery department at Foreship? That is the question that this chapter will give answers to. After analyzing the requirements and legislation research results as well as the interview answers, new opportunities have been listed and explained in this chapter. First the discharge/emission requirement/legislation is explained shortly. Then possible actions are presented which after eventual opportunities are mentioned.

4.4.1 Sulphur 2020

To meet the new sulphur limits, there are several options for ship owners, but focus is on minimize the amount of sulphur in the fuel. From 1 January 2020 the limit is 0,5 % m/m

(0,10 % m/m is ECAS). This requirement has already come into force at this day, but it is still relevant because similar requirements are likely to come, or this requirement may become even more stricter.

The main option is to use a fuel whose sulphur amount is under the limit (VLSFO Very Low Sulphur Fuel oil, ULSFO Ultra low Sulphur Fuel Oil), but other options are installation of exhaust gas systems, for examples scrubbers or use of alternative fuels, like LNG. (IMO, 2019) In the figure below is an estimated price difference between HSFO (Heavy Sulphur Fuel Oil) fuel and ULSFO fuel for the coming years.

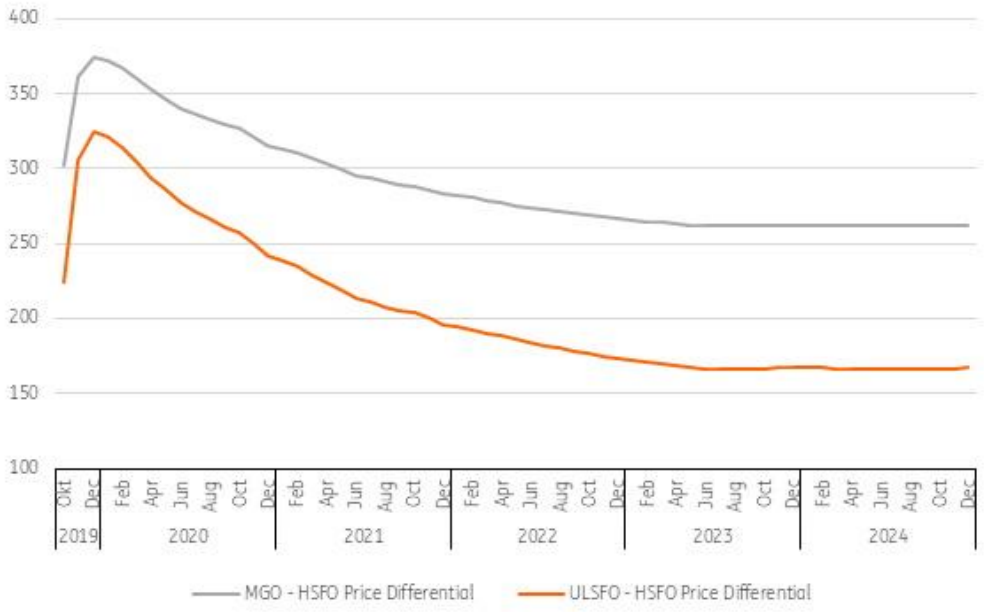

Figure 6. Estimated price difference between HSFO fuel and ULFSO fuel. (Hellenic Shipping News, 2019)

VLSFO Fuel

VSLFO Fuel (Very low sulphur fuel oil) is a fuel that has a sulphur amount of 0,5 %, which makes it to a compatible fuel even with the new sulphur requirements. This type of fuel is likely to increase because of these requirements.

Because VSLFO fuel has other qualities than regular fuel oil, modifications to the fuel system may be needed if a ship starts using VSLFO fuel. However, it depends very much on the fuel system the ship already has. Either modifications to the existing system may need

to be made or a new system will need to be installed. (The North of England P&I Association Limited, 2019)

Things that may need to be modified when switching to VLFO fuel:

- Installation of a fuel cooler
- New fuel storage tanks/ new fuel storage tank system
- Adjustment for the engines. (The North of England P&I Association Limited, 2019)

Installation of exhaust gas cleaning systems

One of the options to reduce the sulphur emissions is to install an exhaust gas cleaning system. Installation of a scrubber system is the most relevant cleaning system for these harmful substances in exhaust gases. (The North of England P&I Association Limited, 2019) There are two different types of scrubbers, open-loop and closed-loop scrubber. The future of the open-loop scrubber is very unsure, which probably will lead to more installations of closed-loop scrubbers. (Sandelin, 2019) Several countries have already banned the open-loop scrubber, and more countries are likely to join the list. (Ship&Offshore, 2019)

- More installations of scrubbers

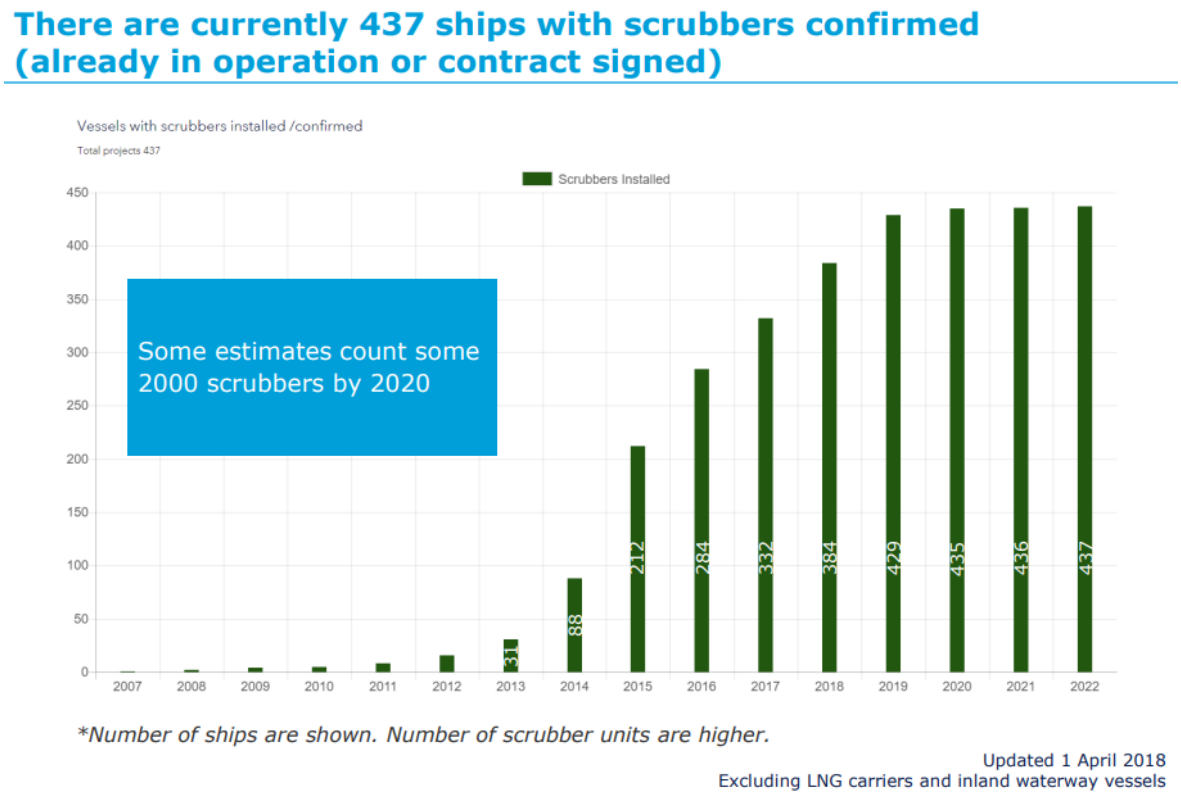

Figure 7. DNV GLs figure showing ships with scrubbers installed (DNV GL, 2018)

The figure below shows information about scrubber installations for different kind of ships. It shows already made installations and installations to come.

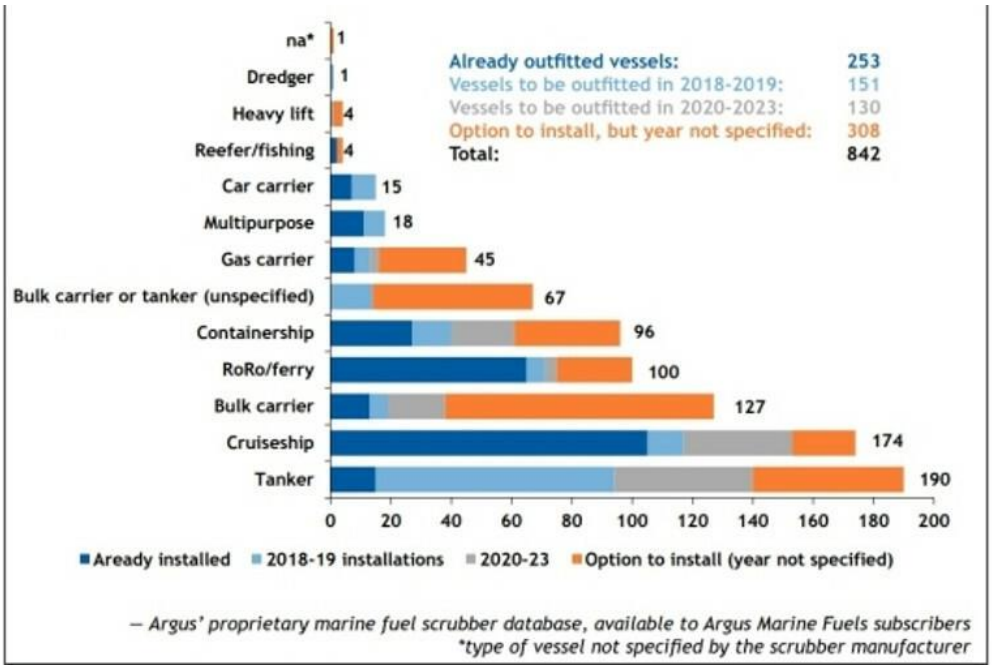

Figure 8. Scrubber installations (Bergman, 2018)

LNG

The use of LNG is also likely to increase in the coming years. (Sandelin, 2019) (Intovuori, 2019) The future of use of LNG as a ship fuel is thus still hard to predict, it depends on such things as pricing, and availability. Senior environmental consultant Martin Wold at DNV GL means that in 2026 we may have up to 354 LNG-fueled ships in the world, based on newbuilding data. (Gunton, 2019) Retrofit installation of an LNG system is an expensive operation, and therefore things as the ships age and future depends whether if the retrofit is fulfilled. (DNV GL, 2018) As Sandelin mentioned, the use of LNG fuel can be seemed as very environmentally friendly fuel at first, but after a time the view of LNG as environmentally friendly can change. (Sandelin, 2019)

- More LNG retrofit projects

DNV GL has published a figure showing comparison of LNG and Scrubber, shown below.

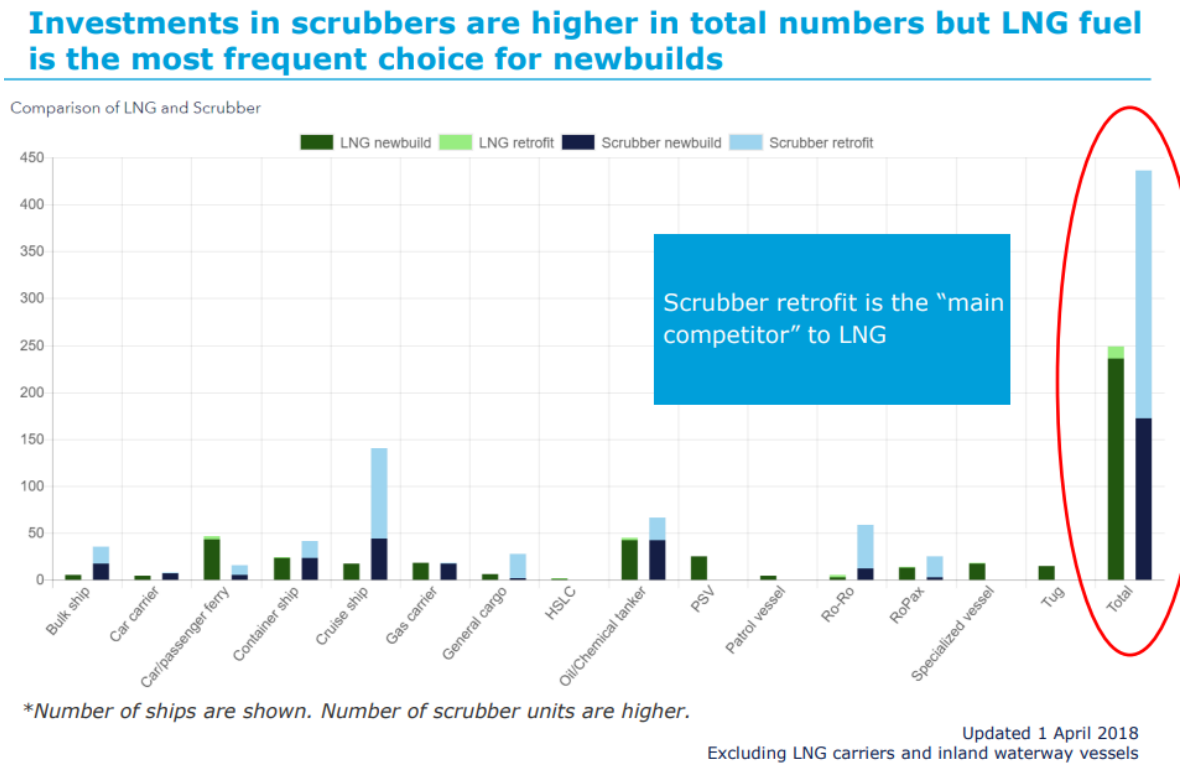

Figure 9. DNV GLs comparison of LNG and scrubber (DNV GL, 2018)

4.4.2 Tier 3

For existing ships, this new requirement only applies when the ship undergoes a major conversion. For ships operating in North American ECA and the United States Caribbean Sea ECA, the Tier 3 level came into force already in 2016, but for ships operating in Baltic Sea ECA or the North Sea ECA, the Tier 3 level is coming into force 1 January 2021. (IMO, 2019) To meet these new NO_x requirements, several options are available to reduce the amount of NO_x substances in the emission gases. (DNV - GL, 2015) These options are listed and explained below.

DF Dual Fuel Engine

DF Engine is an engine that can run on two different fuels, for example oil fuels and gas. Some conversions involve that the hole machinery system is being changed, and the HFO capability is being totally removed. If it is desirable to have the opportunity to run the engines on both gas and HFO, the conversion means a change of the engines to DF engines. (On the Mos Way, n.d.) Because the use of LNG as a fuel ship increases, DF engines may also be more common, and so the retrofit projects.

- More installations of or modifications into DF engines

SCR Selective Catalytic Reduction

SCR is a good alternative for reducing emissions like NO_x and CO_2 in exhaust gases. It does not only reduce emissions, it also improves the fuel efficiency and lower operating costs. To meet the Tier levels, installation of SCR can be necessary. (IACCSEA, n.d.)

- More installations of SCR systems

EGR Exhaust gas recirculation

EGR is a system for reducing mainly NO_x emissions, but also some other emissions, from the exhaust gases. The function of EGR is that the exhaust gases are recirculating through the engine before they are going out to the atmosphere. EGR is also used together with other exhaust treatment systems, like SCR or scrubber, to meet the strictest requirements. (EGCSA Exhaust Gas Cleaning System Association, 2014)

- More installations of EGR systems

The choice between EGR and SCR is not always easy for the ship operator, because these kinds of operations are big and expensive, and the optimal choice of exhaust treatment system depends on different factors which must be taken into consideration. (EGCSA Exhaust Gas Cleaning System Association, 2014) Below is a figure showing which system brings benefits depending on different factors.

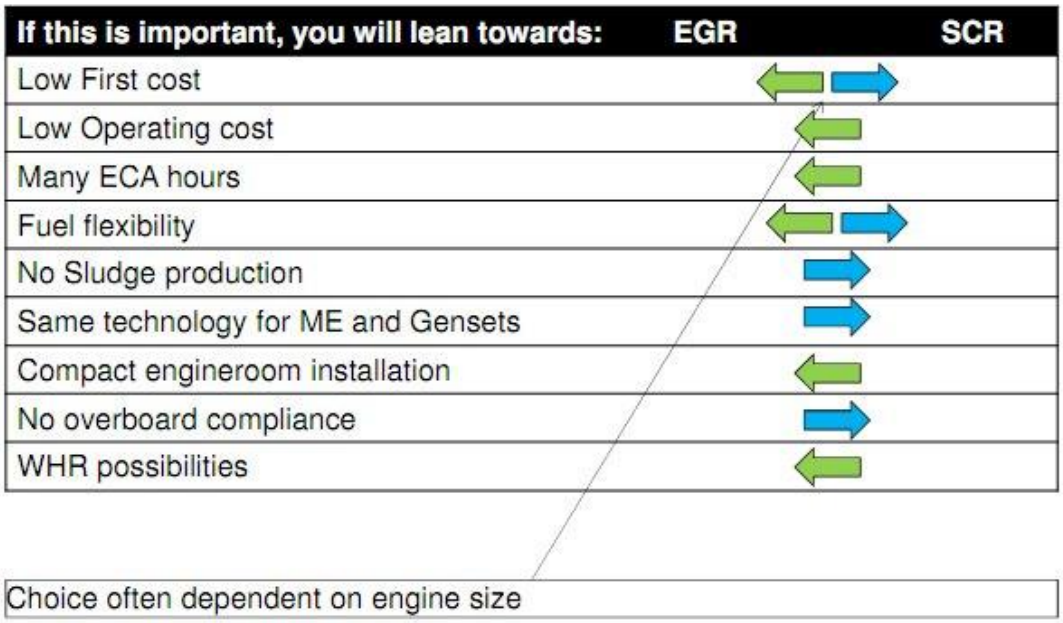

Figure 10. Benefits with EGR and SCR depending on different factors (EGCSA Exhaust Gas Cleaning System Association, 2014)

Fuel cells

Fuel cells is an alternative that actually produces zero emissions, besides heat and vapour. Fuel cells are not yet used in a very big scale, since they are still in need of development. Not only the development of the actual fuel cells is slowing down the realization of fuel cells for ships, also the fuel infrastructure and hydrogen supply require time to be further established. In the nearest future, some configuration with hybrid battery and fuel cells could be more common. These applications could apply power to smaller ships, like ferries, to auxiliary loads on bigger ships, like cruise ships, and apply shore power to docked ships. When fuel cells have become more developed, they could be applied for, ferries, cruise ships and river vessels. (Mace, 2019)

- Planning fuel cell systems and hybrid system

Hybrids/batteries

Hybrid-electric conversions have not actually been performed that much yet. Some single project has thus been performed, for example Wärtsilä has tried a battery hybrid propulsion project for one ship in Norway. Not only the emissions are being lower, also the fuel costs are lowering because of the use of electric when driving for example out from the harbor. (Hampel, 2019) The interest of electric-hybrid power systems is however increasing and are likely to increase the coming years. These systems do not only reduce NO_x, SO_x and GHG emissions, they also improve the energy efficiency. (Bureau Veritas, 2019)

- More hybrid-electric projects

4.4.3 GHG Strategy

Reducing GHG emissions is one of the big topics regarding emissions from ships. Many of the methods for reducing the GHG emissions has to do with improving the energy efficiency for the ships. (IMO, 2019) The ICCT (International Council on Clean Transportation) has published a list with methods and technologies that can be used for improving the energy efficiency and reducing the GHG emissions.

Table 11. ICCT s list of methods and technologies for reducing GHG emissions for ships (ICCT, 2011)

Propeller Polishing	Hull Cleaning	Speed Reduction
Autopilot Upgrade	Air Lubrication	Main Engine Retrofits
Water Flow Optimization	Hull Coating	Speed Controlled Pumps and Fans
Weather Routing	Wind Power	High-Efficiency Lighting
Propeller Upgrade	Waste Heat Reduction	Solar Panels

Things that may bring opportunities are:

- Engine retrofits
- Pump systems
- Propulsion system

Alternative fuels

An alternative to reduce the exhaust gas emissions is to use alternative fuels. Different fuels emit different kind and amount of harmful substances, which means that with some fuels the amount of harmful substances is low enough to meet the requirements. Besides LNG and low-sulphur fuel, there are other possible alternative fuels that can be used. Some of these are:

1. Methanol, bio-methanol & ethanol
2. Biofuels
3. Marine Gas Oil & Marine Diesel Oil (HELCOM, 2019)
4. Nuclear energy (Singla, 2019)

If a methanol conversion is in question, there are different technologies for this purpose. The most common technology is the Dual Fuel (DF) operation that is one of the technologies for diesel engines. This method uses diesel to ignite the fuel mixture, and the main fuel in the fuel mixture is methanol. (Dierickx, et al., 2018)

Mostly of the biofuels can be used directly without any retrofitting, or with only little retrofitting. (SHIP Technology, 2018)

Using marine gas Oil can cause trouble for some of the machinery systems. These troubles are fuel filters being chocked, fuel pumps not working correctly, fuel leakages, hot starts etcetera. (Wankhede, 2019)

- More dual-fuel retrofit projects
- Updates of different machinery systems because of troubles caused by MGO fuel

Nuclear energy in ships have been used as a fuel in ships already many years, mostly in military ships and submarines. Nuclear energy powered ships do not emit exhaust gas emission as other fuels do, which makes it a zero-emission solution. Thus, the discharge of the nuclear waste is a problem, because it is very harmful for the environment and for the human health. The benefits that come with the use of nuclear energy is many, besides the zero-emission solution, for example few refilling needs and good power to weight ratio are some of those. One reason why nuclear powered ships does not have become more attractive on the market, is that the acceptance by people. (safety4sea, 2019) Other reasons why nuclear

powered ships are not that popular today is that the nuclear waste is a problem, accidents can cause very disastrous situations and the availability of the nuclear fuel in the world is not enough. (Singla, 2019) It is hard to say how popular nuclear energy for ships will be, but in the short-term future it is unlikely they will come in use. Thus, in the long-term future, with the right planning and correct safety measures it is likely nuclear powered ships will be more popular, especially, when the exhaust gas emission requirements are getting more stringent. (safety4sea, 2019)

Operational energy efficiency measures, EEDI

EEDI is as earlier mentioned a project for enhancing the energy efficiency for new ships. The EEDI itself does not necessarily bring any new installations or retrofits project for existing ships. Though, a good way to improve the energy efficiency is switching to more efficient engines and other machinery equipment, for example the propulsion systems, and this is what EEXI is about for existing ships. (IMO, 2019)

- EEDI/EEXI is very actual today and it may bring machinery installation projects

4.4.4 NRMM – Emissions requirements regarding inland water emissions within the EU

Because of this new requirement, actions in form of retrofitting different equipment can be needed for reducing the emissions. For ships with diesel engines, for example diesel engines particulate filter or catalytic convertor can be installed. As in many other cases, the space and cost issue are factors that affects the chosen method of reducing the emissions. (NRMM, 2017)

- More installations of exhaust gas emission cleaning equipment, especially Selective Catalytic Reduction (SCR) systems

4.4.5 Wastewater discharge

In Juny 2021 the new regulation regarding discharge of wastewater directly into the sea, is coming into force for existing cruise ships operating in the Baltic Sea. If sewage treatment systems are not installed, the ships must discharge the sewage only to the port reception facilities. The sewage treatment system must have a capacity to reduce the amount of nutrients by the new regulations. Treated wastewater can then be discharged into the sea. (Eriksson, 2016)

- Installation of sewage treatment systems

4.4.6 Installation of ballast water management treatment systems

Since existing ships have time to adopt standard D-2 up to 2024, there will probably be some ballast water projects in the coming years. According to Clarkson Research Services there was about 950 ballast water treatment systems projects contracted in May 2019. If every ship that is sailing today still is sailing in 2024, the amount of ballast water treatment system projects would be even larger. It is still difficult to say how many of today's ships are sailing year 2024. (Jallal, 2019)

- Ballast water treatment system retrofit projects up to 2024

Summarization

To sum up the opportunities likely to come, a summarization has been made. The summarization is presented below. Some of the opportunities has been merged together to get a clearer view of the list.

1. More exhaust gas emission abatement projects; closed-loop scrubbers, SCR-systems, EGR-systems
2. More LNG-projects and LNG related machinery systems
3. More dual-fuel projects and updates of existing machinery systems
4. More hybrid and electric projects further into the future
5. Some sewage treatment system projects
6. Some ballast water treatment system projects

5 RESULT DISCUSSION

In this chapter I have analyzed and discussed the results. I have made a conclusion of the results and I have highlighted the most important things.

We are living in a time of change. Climate and environmental questions are important today and this is also evident when it comes to emissions questions for ships. Today, there are already many environmental requirements and legislation, and more are continuously coming, which can be seen in the theory section. In the results section we can see that the most and largest changes apply to new exhaust emission requirements, which naturally means that the most and largest opportunities come from here. It is difficult to know for sure what the future will look like regarding emission requirements and laws, as well as what actions shipowners intend to take. It is not at all certain that these installations listed will increase or increase to such an extent that it would be significant. My self-evaluation is that in the future, most emission requirements will be even stricter, which means that technology must develop even more. This in turn would mean more planning and development of machinery systems. It is therefore also important to keep up with the situation and the future situation, in order to be prepared in the best possible way.

As mentioned earlier, there are completely new systems and technologies that will be used in the future, some soon and some in the longer future. These long-term technologies are especially the use of fuel cells and accumulators as well as use of nuclear energy. The use of LNG is also relevant with new legislation and requirements to come. As long with the use of more alternative fuels, especially dual-fuel retrofit projects are likely to be more common in the short-term future.

If you analyze the results, I think that you can see that in addition to new technologies and methods coming, it may be time to think about how to handle a work project. In the future, specialized knowledge may become even more important than today, and then it could be good to prepare for it. Specializing in for example, LNG systems, could be something to invest in. Another thing to pay attention to is a that planning of modifications often require cooperation with the engine manufacturers to ensure that the emissions requirements are being achieved and that they meet the classification rules.

In summary, it can be stated that the workload does not appear to be decreasing, but as mentioned earlier, it is difficult to say whether it will increase or not. Sales opportunities will

probably exist for machinery systems but will probably change some character compared to today.

Answer to the question what environmental requirements and future legislation are upcoming is clear, but broad. The upcoming short-term requirements have clear rules and goals. They also have guidelines on how to follow them. The long-term requirements are not yet determined, but they are likely to be clearer the closer they get.

What opportunities these eventual upcoming restrictions give Foreship is interesting. The main opportunities are easy to foretell. Some new big requirements are upcoming, and they will affect the sale of machinery systems. To analyze the small upcoming amendments is harder, but also from these Foreship is likely to get more sales opportunities. This can be seen in the Result section.

6 DISCUSSION

This chapter presents reflections and thoughts on how the work has succeeded, if the goal has been achieved, problem areas, possible actions and suggestions for further research. It also shows what went well and what could have been done better, as well as what I have learned during the work.

6.1 Own thoughts

One difficulty with the work was to stay within the delimitations. Since the work was only about retrofit installations of machinery systems, it was very important to analyze the provided information. This was important because a large part of new requirements and new legislation only affect new shipbuilding, and not existing ships. Another thing that was difficult was deciding which information was relevant and which was unnecessary. The information used must also be fresh enough for the reliability to be as high as possible. I have therefore used many different sources to increase the reliability.

During the work I have developed and improved my English language skills and my communication and writing skills. I have also learned to be source-critical and to seek information in different ways.

Before I started with this thesis, I made a time schedule. There were also wishes from our school for when the work would be completed. In retrospect, I can say that I was a little optimistic with my own time schedule, since I planned to have a first draft of the results section completed in mid-December. The final version of the work was completed in March so in my opinion I stayed within reasonable limits

During the work, certain emission requirements came into force, which mean that when I started writing the work, they were still future requirements, while they were existing requirements when this work was completed. This meant that I had to rephrase some parts of the work.

I think the methods I have used have been reliable and enough. In order to get more viewpoints to the work, I could have used several experts in the field. Experts can interpret information very well and provide a clear and reliable analysis of the information available.

6.2 Theoretical and practical contributions

I believe and hope that this thesis can help make Foreship's machinery department be better prepared for the future. I believe that this work can at least be a guide in planning and predicting the future work situation. Since this work is about the future upcoming requirements, there is also a risk that they will not happen as planned. This means that some of the content of this work does not necessarily have to be accurate in the future. One suggestion for a practical action that the machine department at Foreship could do is to review the workload and the need for workers and try to draw up a future plan.

6.3 Did I reach my purpose?

The purpose of the work was to investigate future requirements and legislation regarding retrofits of machinery systems for ships. This so Foreship can more easily predict what the future will look like, in terms of workload, type of work and the need for specialized expertise. I think I have achieved this and come to a conclusion. The result I have come up with gives a good picture of what is likely to come in the marine sector.

6.4 Future research

In the beginning, it was mentioned that this topic is relatively broad, and this was also well noticed during the work. As the topic is broad and could be enhanced in some of the sub-areas, a proposal for further research is to find out more about some of the things I came up with in this study. For example, LNG in general is becoming more and more common in the ship industry, which means that a further investigation of specifically what is needed when planning LNG systems. Other emission abatement technologies, such as closed scrubber, also appear to be somewhat more common, which makes further investigation into this also necessary.

6.5 Afterword

I am satisfied with what I have accomplished and learned throughout the work. I have gained a greater insight into requirements and legislation for ships. I think I am going to have benefit from everything I learned from this work in my future working life. Finally, I would like to thank Foreship for letting me do my thesis work for them. Special thanks to my supervisor Jaakko Laaksonen for a helpful, understanding and constructive treatment throughout the work. From the University of Applied Sciences Novia, I want to thank my supervisor

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Appendixes

1. Appendix 1. Interview questions for Mr. Kristoffer Sandelin

2. Appendix 2. Interview questions for Mr. Ville-Veikko Intovuori

Interview questions for Kristoffer Sandelin **Appendix 1**

Background questions

1. What is your position in the company?
2. What is your education?
3. What previous work experiences do you have?

Core questions

Some new regulations regarding emissions of exhaust gases are forthcoming, some already within the next year and some within the next ten years.

1. Do you think there will be some new emission or discharge regulations in the future, besides those that are already published?
2. How do you think the new regulations will affect the sales of machinery systems?
3. If new regulations are forthcoming, do you think they will apply only to new builds or retrofits too?
4. Do you think ship conversions will increase or decrease in the future?
5. What emission cleaning methods do you think will be used mostly in the future?
6. Do you know some other person to interview for this purpose?

Interview questions for Ville-Veikko Intovuori **Appendix 2**

Background questions

4. What is your position in the company?
5. What is your education?
6. What previous work experiences do you have?

Core questions

Some new regulations regarding emissions of exhaust gases and discharges from ballast water are forthcoming, some already within the next year and some within the next ten years.

1. Do you think there will be some new regulations to MARPOL Annex 1-6 besides those that are already published?
2. Do you think there will be new regulations to the BWM Convention besides those that are already published?
3. Do you think there will be new regulations to some other specific area?
4. If new regulations are forthcoming, do you think they will apply only to new builds or retrofits too?
5. How do you think the new regulations will affect the sales of machinery systems?
6. Do you think ship conversions will increase or decrease in the future?
7. What emission cleaning methods do you think will be used mostly in the future?
8. Do you know some other person to interview for this purpose?