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IMO2020: one small step for maritime shipping, one giant leap for human health.
An analysis of IMO2020 and its impact on the future of shipping.

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Abstract

Maritime shipping is the backbone of international trade, and represent 80-90% of global trade. However, this comes with a cost, namely pollution. The shipping industry represent about 15% of global nitrogen oxide (NOx) and 13% of global Sulphur Oxide (SOx) pollution. This air pollution have a significant impact on decreasing quality of life in areas around heavily trafficked shipping lanes, as this air pollution can cause lung diseases and other health issues. The focus of this thesis is on the International Maritime Organization's global sulphur cap, also known as IMO2020. IMO2020 is a regulation which is cutting the sulphur level in fuel oil for ships from 3.5% to 0.5%. It is estimated that IMO2020 will cut sulphur emissions by 77%.

The goal of this study is to research how IMO2020 have affected shipping and how the industry will develop in the coming years, thus the problem statement is *How will IMO2020 impact the future development of maritime shipping.* This will be analyzed through the theoretical framework of the multilevel perspective, which is a theory geared towards understanding the dynamics of transitions. In order to answer this problem statement I have included 3 research questions;

1. Why is not other alternative niches considered a solution for IMO2020?
2. What is IMO2020 a result of?
3. Will IMO2020 lead to a transition or a transformation within maritime shipping?

The results from this study is that the alternative niche propulsion technologies, such as biofuels or hydrogen, was not able to exploit the opportunities of IMO2020 because of insufficient infrastructure, and research and development, leaving them too expensive for the market.

IMO2020 is a result of landscape pressure, as the knowledge on the consequences of air pollution have made people more aware, and thus their values of protecting the air and their health is increasing. This pressure of limiting air pollution is spreading to nation states, politicians, companies and industries, which again spreads into IMO discussions.

In the case of a transition or a transformation is it that IMO2020 can be seen as a step towards a transition, but IMO2020 itself did not directly lead to a transition within maritime shipping, based on usage of alternative fuels. However, IMO2020 is a successful regulation, as sulphur pollution from maritime shipping will be dramatically reduced.

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1. Introduction:

Maritime shipping is an important industry and function as a key player in global trade and growth, yet this comes with a significant contribution to pollution. In order to make a better future, improving global trade and growth are important tasks, but reducing pollution is also of upmost importance. This thesis will take a look at maritime shipping, why it is important, as well as the latest regulation from the International Maritime Organization (IMO) for setting a global sulphur cap (IMO2020). I will analyze IMO2020 using the multilevel perspective in order to see how the regulation was formed and how it can affect the future of shipping.

1.1 Maritime shipping:

The protection of the environment have become one of the most important issues of modern time, and this issue also include maritime shipping (Tan, 2006). The transportation sector is a key contributor for increasing pollution in the world. Maritime shipping is a complex activity to analyze, as it is inherently international and have a multi-stakeholder dimension. However, this complexity around shipping is why its issues need to be analyzed, and we need global actors to organize and help the sector to develop further (UNCTAD, 2019).

Maritime shipping is the backbone of world trade (UNCTAD, 2019), and represents about 80-90 % of international trade. (IRENA, 2019). In 2016, marine freight was responsible for 12% of the world's total energy consumption (EIA, 2016). However, maritime shipping is the most energy efficient form of transport, but due to the long distances and large volumes, the shipping sector have a serious issue with pollution. Its pollution represent about 15% of global annual nitrogen oxides (NOx) which is 3.2 metric ton per year and 13% of Sulphur oxides (SOx) which is around 2.3 metric ton (IRENA, 2019).

The fuel development for ships have been slow, but the tendency have been continuous over the years. In the 1920s there was a switch from coal to diesel, the 1950s saw a switch from diesel to Heavy fuel oil (HFO). More recently, there have been an increasing interest for cleaner fuels, and more specifically for Liquefied Natural Gas (LNG), because of IMO's vision for the future. However, as the interest for cleaner fuels and propulsion means have been caught be the shipping industry, the main barrier for implementing it is the economics associated with the different fuel types and propulsion means (IRENA, 2019).

Air pollution is not a new phenomenon, however in the last 100 years the knowledge and realization that polluted air can have serious health implications grown significantly. A significant proportion of today's modern nations have developed air pollution laws and is continuously working on reducing the health impacts from air pollution (Horstmeyer, 2011). The main elements of air pollution from shipping is SOx, NOx, and Particulate Matter (PM), this happens during fuel combustion. This is because these chemicals are natural compounds in the fuel. Fuel with a better grading, will naturally have lower SOx content. This happens through refining of the oil fuel (Anish, 2019b). Fine PM is a result from complex chemical reactions, such as when we burn fuel, which is then emitted into the air, and can cause sever health problems, such as damaging the lungs and thus causing life threatening lung diseases (Horstmeyer, 2011; Sachs, 2015).

The issue of air pollution can be viewed in comparison to the concept of the "tragedy of the commons". The tragedy of the commons is when a shared resource is used by individuals, with an independent self-interest behavior, that is contrary to the common good of all individuals, and thus end up spoiling or depleting the resource through the individuals collective effort (Hardin, 1968). In the case of air pollution and maritime shipping, one can argue that shipping is a common good as it enables nations, companies and people to participate in global trade in which enables prosperity and hope for a better life. However, this global trade emits a vast amount of pollution from the vessels that is degrading air quality and human health close to shipping lanes. As nobody owns the air, nobody have ownership and feel responsibility to protect it, and thus only a global initiative can help to mitigate the emissions and its consequences. IMO2020 is one of these initiatives.

1.2 Problem statement:

Pollution is a major issue in the world, however it is a broad topic. Therefore, I will focus on air pollution and more specifically sulphur pollution in maritime shipping. As IMO2020 is a relatively new regulation, most current research on it focuses on the potential it have on the shipping sector, refineries and economic impacts, as well as futuristic compliance methods such as biofuels (Chu Van, Ramirez, Rainey, Ristovski, & Brown, 2019; Halff, Younes, & Boersma, 2019; Lindstad, Rehn, & Eskeland, 2017; Ren & Lützen, 2017; Tyrovola, Dodos, Kalligeros, & Zannikos, 2017). Many articles that focus on emissions from shipping is focusing on the emission control areas and their impact (L. Chen, Yip, & Mou, 2018; Cullinane & Bergqvist, 2014) as well as health implications of shipping (C. Chen, Saikawa,

Comer, Mao, & Rutherford, 2019; Corbett et al., 2007; Sofiev et al., 2018). This thesis will rather focus on a holistic approach of maritime shipping, focusing on the global effects and the global potential of IMO2020, such as how to comply to the regulation and how it can change maritime shipping. Therefore, this research project will not focus on case studies of specific countries, ports, type of vessels or areas of interests, and rather have a more general approach to this study. The study is designed in this way because IMO2020 is a global regulation, and thus having a global perspective on it is an approach that will be the most suitable in order to fully grasp its impact.

The goal of this study is to get a deeper understanding of why IMO2020 is important, and the potential of IMO2020 to change the future of shipping. Thus, the problem statement for this thesis is "*How will IMO2020 impact the future development of maritime shipping?"* The problem statement will be analyzed through the Multi-level perspective. In order to answer this question in the best possible manner I have selected 3 research questions which will take a deeper look into the topic.

- Why is not other alternative niches considered a solution for compliance with IMO2020?
- What is IMO2020 a result of?
- Will IMO2020 lead to a transition or a transformation within maritime shipping?

I have selected to use the Multi-level perspective (MLP), which is a theory that is geared towards understanding the dynamics of socio-technical transitions, to analyze how IMO 2020 can create a transition within the shipping industry. This theory will help me illuminate the dynamics of a transition and the consequences of IMO 2020.

The next chapter of this thesis will focus on IMO, IMO2020 and the most relevant compliance methods. The chapter will have a short description of IMO's history, how we ended up with IMO2020, and some of the critique of IMO.

The third chapter explains the three main types of compliance methods towards IMO2020, LNG, HFO with scrubbers, and using VLSFO. The chapter will also briefly explain some of the most interesting alternative compliance methods. This includes nuclear, biofuels, batteries, Ammonia and hydrogen.

The fourth chapter is about the theoretical framework behind this thesis, namely the Multi-level perspective. This section of the thesis digs deeper into what makes a transition complex, how the MLP identifies the dynamics within a transition, and the difference between transitions and transformations.

The fifth chapter analyzes the methodology and design of this thesis. It shows what methods that have been used to collect data, research strategy, as well as the limitations and choices I have made during this research project.

The sixth chapter is the discussion, where the research questions will be discussed in the light of the problem statement, before the conclusion comes in the final chapter.

2. IMO2020:

This chapter includes parts that explains who IMO are, what they work with, and why they do so, as well as a section for IMO2020 and the enforcement of IMO2020. One part also briefly explain some of the consequences of using HFO and the uncertainties connected to the regulation, before a final section includes some of the critique against IMO.

2.1 IMO

As shipping is an inherently international business, it needs an international forum for discussing developments and issues of the sector. This is where IMO comes in. The IMO is a specialized agency of the United Nations. IMO function as the standard-setting authority for safety, security and environmental performance of shipping on a global basis, it thus creates regulatory frameworks and guidelines for the shipping industry (International Maritime Organization, n.d). Maritime shipping is most effective if the regulations and standards are implemented on a global basis, as shipping is the backbone of international trade. IMO covers all aspects of the shipping industry, such as ship-design, construction, operation and disposal of vessels, this is to ensure that the development trajectory of the sector is towards increased safety, sustainability and efficiency. One of the implications of IMO being a specialized agency under the United Nations is that the organization actively works towards 2030 agenda for sustainable development and the sustainable development goals. Promotion of sustainable development is thus one of the main priorities of IMO in the coming years (International Maritime Organization, n.d).

IMO was founded in 1948 at an international conference, and in the beginning, the organization mainly focused on maritime safety and navigation. In the 1960s IMO also started to become more aware towards oil spills through poor operating conditions or accidents, this led to the adoption of the international convention for the Prevention of Pollution from ships (MARPOL)(Lim, n.d.).

2.2 IMO2020

MARPOL was mainly focused on pollution by oil from ships (Annex I), noxious liquid substances, such as chemicals, transported in bulk (Annex II), harmful substances transported in packaged forms (Annex III), sewage discharges into the sea (Annex IV), and garbage disposal at sea from ships (Annex V) (Lim, n.d.). At the end of the 1980s, IMO started

working on prevention of air pollution from ships. This was based on scientific information on the effects of air pollution from ships had on the environment and human health. MARPOL is the international convention focusing on prevention of pollution of marine environment by ships, it include regulation aimed at preventing and minimizing pollution from ships. In 1991, IMO and MARPOL saw an urgent necessity of establishing an international policy on the prevention of air pollution from ships and decided to develop a new annex, and in 1997 IMO added Annex VI into MARPOL. This was a historic response by IMO to the urgent need to reduce emissions from ships. Since 1997, IMO have been working on regulating the emissions from shipping, such as NOx and SOx (International Maritime Organization, 2013; IRENA, 2019). However, Annex VI did not come into force until May 2005 (International Maritime Organization, 2013).

With Annex VI, IMO is limiting the Sulphur level in fuel oil for ships to 0,5 % from previously 3,5 %. This cut in the Sulphur levels started January 1 2020, hence the nickname "IMO2020" for this regulation. IMO decided to limit the Sulphur level in ships fuel oil in 2008, and confirmed it in 2016. IMO2020 will cut overall SOx emissions from ships by 77%, which is about 8.5 million metric tonnes of SOx. Another consequence of IMO 2020 is that particle matter will also reduced (International Maritime Organization, 2019a).

IMO2020 is designated for ships operating outside of emission control areas (ECAS). Within ECAS, the Sulphur content of fuel oil is regulated to be at 0.1%. Examples of ECAS are the North Sea area, the Baltic Sea area and the North American area. In order to trade within these areas, ships need a fuel which is compliant to 0.1% Sulphur content. One type of fuel which is compliant to 0,1% of sulphur content is the ultra low sulphur fuel oils (ULSFO) (International Maritime Organization, n.d.-b).

2.3 Enforcement of IMO2020

The Marine Environment Protection Committee (MEPC) is the main committee for IMO that focuses on environmental issues, which includes issues covered by MARPOL (International Maritime Organization, n.d.-a). However, the enforcement and monitoring of IMO2020 is up to the individual countries, and not the IMO or its subcommittee's (Hellenic Shipping News, 2020a). A flag state is the nation where a ship is registered. The nation that have their flag hoisted on a ship have regulatory responsibility for the vessel. The flag states have the obligation to exercise jurisdiction and control in administrative, technical and social matters,

such as construction, equipment and seaworthiness of the vessels. The flag state is responsible that the registered vessel is conforming to international laws, regulation and procedures, and thus have the responsibility to enforce and prosecute illegalities (Gavouneli, 2007). However, one big issue for flag states are that many of them are open registries. Open registries are flag states which have no or very little nationality requirements and often use open registries as income generation, and often do so through reduced regulatory burdens, low registration costs, and expedited certification, and are often smaller nations such as Panama, Liberia, the Marshall Islands etc. in order to attract the most ship owners. This enables cheap and fast maritime shipping, as up to 70% of global dead weight tonnage are registered in open registries (Watterson, Osborne, & Grant, 2020). Yet, the lowered regulatory framework of open registries also enable poorer environmental safety, vessel safety and crew safety, as well as not having the capacity to ensure compliance to IMO regulations (Watterson et al., 2020).

The coastal state is the nation that is projecting their sovereignty onto the sea, protecting and enforcing their jurisdiction over their maritime areas. However, the coastal state cannot deny the right of innocent passage through their territory as long as the vessel is not disrupting peace, good order or security for the coastal state and conforming to international rules and regulation. The jurisdiction of the coastal state is only to control if vessels operate lawfully in their territory (Gavouneli, 2007).

The port state can be seen as an expansion of the coastal state. The port state have certain rights and obligations in terms of enforcement of rules and regulation for the protection and preservation of the marine environment in the territorial sea. Because it is voluntary for a ship to be present at a port, the port state can thus control if the vessel is compliant with the territorial laws and regulation. The port state can exercise enforcement jurisdiction by requests from coastal states or the flag state, however the jurisdiction is permissive, and not mandatory (Gavouneli, 2007). Some examples of stricter regulation of the IMO guidelines are from Singapore, where open loop scrubber systems is prohibited within the Singapore port limit, or Norway where it is prohibited to discharge waste water in the fjords (Standard Club, 2019). If a port state experience a violation of relevant rules and regulation, the flag state of the vessel is responsible for further investigation and giving penalty for the violation (UNCLOS, 1982, Article 217).

2.4 consequences of HFO

The previously main fuel for ships was Heavy Fuel Oil (HFO), which is a residue from crude oil distillation. When this fuel is combusted in the engine, it releases Sulphur oxides, which is harmful for human health and can also lead to acid rain when it enters the atmosphere. IMO2020 will significantly reduce the amount of Sulphur oxides emanating from ships and this will lead to major health and environmental benefits, especially in areas close to ports and coasts (International Maritime Organization, n.d.-b). One study (James J. Corbett et al., 2016) estimates that if IMO2020 was postponed until 2025, it could contribute to more than 570 000 premature deaths worldwide between 2020 and 2025, where the most significant impact would be in areas close to ports and major shipping lanes. This can be avoided due to the reduction of particular matter (PM) from IMO2020. PM have several health implications for humans such as lung cancer, cardiovascular disease and asthma (James J. Corbett et al., 2016). As Ships releases both gaseous and particulate emissions, and ships are one of the most significant contributors to lowering air quality around the world, and strong wind can carry the air pollution from the coast further into the land (Chu Van et al., 2019). SOx and NOx emission from shipping can also contribute to acidification of the ocean. However, on a global scale the effects of this are small, but in shallower coastal waters where shipping is concentrated the impacts of this could be significant, such as threaten local biodiversity in the marine area (Eyring et al., 2010). This can lead to a decline in quality within the marine ecosystem (Tan, 2006).

2.5 Uncertainty surrounding IMO2020

One important factor of IMO2020 was the uncertainty connected to it. IMO announced the sulphur cap back in 2008, but it was not manifested until 2016. One of the reasons for this delay was that IMO was waiting for a fuel assessment study, where the aim of this study was to see if the refining industry had the ability to cover the demand for Very Low Sulphur Fuel Oil (VLSFO) when the global sulphur cap was implemented (Topali & Psaraftis, 2019). This delay made the stakeholders within maritime shipping uncertain, as they expected the compliance date to be further postponed and give them more time to adapt to the regulation. Ship owners would delay their response to the policy to a time period as close as January 1 2020 because of the burden of premature compliance (Halff et al., 2019).

Premature compliance of IMO2020 would punish the ship owners, as VLSFO are both more expensive than HFO, so there is no incentive for premature compliance as revenue for ship

owners would be damaged by it. Using Liquefied Natural Gas (LNG) as a method for compliance requires large amount of in front capital investment, however if the gas prices remains low it could offset the initial investment over the life span of the ship. Oil and gas prices are very volatile, and if gas prices would surge the LNG option would limit the potential revenue from the ship. Retrofitting ships with scrubbers does also require a large in front capital investment, however not as large as the LNG option. Installing a scrubber requires that the HFO discount relative to VLSFO is large enough to offset the initial investment capital cost. When ship owners are retrofitting their ships, they need to be dry docked for up to several weeks which removes potential revenue if the ship instead was in use (Halff et al., 2019). Depending on the price spread between HFO and VLSFO as well as the age of the ship, HFO with scrubbers on newbuilds is more profitable than newbuilds using VLSFO if the price spread is high enough. For older vessels retrofitting scrubbers is not profitable if the down payment time is longer than the expected remaining lifetime of vessel (Jiang, Kronbak, & Christensen, 2014).

Furthermore, this lack of premature compliance made it difficult for refineries to predict how much of the different compliant fuel they need to make for the shipping market. It could lead to a supply and demand shock, as there can be a collapse of the demand for HFO, and a surge for VLSFO (Halff et al., 2019). However, the spread between VLSFO and HFO have been reduced lately, which implies that the payback period of scrubbers are increased and furthermore making scrubbers not as economically attractive as they seemed to be in 2019 (Hellenic Shipping News, 2020b).

2.6 Critique of IMO

The political aspects of IMO have garnered some critique, including from the organization Transparency International. The critique from Transparency International (Amin, McDevitt, & Gibbs, 2018) focuses on the uneven influence of member states, the influence of open registries, the disproportionate influence of industry and the lack of delegate accountability.

The uneven influence of member states come from the fact that 2/3 IMO financial contributions comes from ten countries (which make the contributions based on their fleet size), this can lead to undue influence[1] amongst this small group of contributors.

[1] Undue influence is when particular group or individuals gain unfair advantage over public decision making at the expense of public interest (Amin et al., 2018, p. 3)

The case of open registries can also lead to undue influence as many of the worlds largest fleets sails under nations with open registries (such as Panama, Liberia, the Marshall islands, Malta and Bahamas) and at least 17 open registries are outsourced to private companies. This means that private companies can be delegates in IMO discussions, and thus debate and vote. This undermines the notion of transnational public interest, which is a basic premise on UN system of international governance, as these private companies can use the debates to exercise their interests (Amin et al., 2018).

In the case of disproportionate influence of industry, the attendance of industry representatives outnumber civil society representative 312 to 64. Another case of industry influence is that there are no rules governing the appointment of national delegates, this means that member states can directly appoint representatives from shipping companies, ship owners and others with an interest in shipping (Amin et al., 2018).

The lack of delegate accountability refers to the notion that member state delegates are protected against public scrutiny as journalists are forbidden to name public speakers at meetings without getting their consent as well as IMO reports do not reflect positions taken by individual representatives, this leads to an uncertainty around who is arguing for which policies (Amin et al., 2018).

3. Compliance methods:

Given the current technology, there are mainly three different options for compliance of IMO 2020 for ship owners.

1. Ships can run on liquefied natural gas (LNG).
2. Continue to use HFO, but process the air emissions through an exhaust gas cleaning system (EGCS), also known as *scrubbers*. These scrubbers are fitted in the ships with dedicated tanks to hold and treat wastewater from the process.
3. Switch fuel to VLSFO which have a lower sulphur content, such as Marine gasoil (MGO).

Each of these options have their costs and benefits, this leads to uncertainty of what solutions is the most beneficial for ship owners, however this depends on many factors, such as the operating conditions of the ship, its age etc. (Halff et al., 2019).

3.1 Using liquefied natural gas as fuel:

Liquefied natural gas is when natural gas is cooled to -162 degrees Celcius. When it is cooled to a liquid it's volume gets reduced to 1/600 times of its gaseous state, which significantly increases its storage and transportation efficiency (Balcombe et al., 2019). The primary component of natural gas is methane (Fun-sang Cepeda, Pereira, Kahn, & Caprace, 2019).

Currently, there are four main types of LNG engines, lean-burn spark ignition, low pressure dual fuel, high pressure dual fuel and gas turbine. Each have their different characteristics with strengths and weaknesses (Balcombe et al., 2019). LNG have been used as fuel for LNG carriers for about 40 years, however in later years the use of LNG as fuel have spread to other types of ships, and in 2017 there was 117 LNG-fueled vessels in commercial operation, not counting LNG carriers (Balcombe et al., 2019).

When LNG is used as fuel, sulphur emissions will be eliminated and particulate matter will almost be eliminated. However, methane slip[2] can occur. It is estimated that LNG engines have a methane slip of 2-5% of total throughput (Balcombe et al., 2019).

The greatest resistance towards LNG as fuel is that there is a global lack of infrastructure and bunkering facilities as well as the variable gas prices, this leads to uncertainty for ship owners

[2] Methane slip is when methane fails to combust in the engine, and gets released into the atmosphere (Balcombe et al., 2019).

whether they should buy LNG fueled ships or use fuels which is more commercially available (Fun-sang Cepeda et al., 2019). Another issue is that retrofitting ships into using LNG is very cost demanding, as LNG storage tanks require double the volume compared to conventional HFO tanks for the same energy content, due to density difference. Therefore, it becomes more economically favorable to use LNG for new-builds (Balcombe et al., 2019).

3.2 Exhaust gas cleaning systems:

The second option is to continue to use HFO and process the air emissions through an exhaust gas cleaning system (scrubbers). SOx scrubbing technologies have 2 main categories, Dry Scrubbing and Wet Scrubbing. Dry Scrubbing is mostly used on land-based industry, and Wet Scrubbing is mostly used in maritime shipping (Exhaust gas cleaning systems Association, nd.). Scrubbers are used to remove the SOx and reduce the PM contained in the exhaust gas. All scrubber technologies create a waste that contains the substance used to clean the exhaust gas, as well as the SOx and PM that was removed, and this waste have to be processed, stored and discharged in accordance to the IMO guidelines (Tran, 2017).

There are different designs of scrubbers, however wet scrubbers consists of these main components:

- A container that mixes exhaust from the engine with water, seawater or freshwater (or both).
- Some sort of treatment system to remove the pollutants from the (wash) water after the scrubbing process.
- A sludge handling facility, where the sludge from the wash water treatment system can be stored.

We can see these components, and how they interact to remove SOx, in figure 1.

Wet scrubbing enables the exhaust gas pass to through a liquid medium in order to remove the SOx from the gas by chemically reacting with parts of the wash liquid. The most common wash liquids are untreated sea water and chemically treated freshwater. Wet scrubbers are a technology that is both effective and simple, and which have been in use for industrial purposes for many years (Tran, 2017).

There are three different types of wet scrubbers, open loop system, closed loop system and hybrid. In open loop systems seawater is used to remove pollutants for the exhaust, and the

wash water is discharged back into the sea after use. This system is only effective when the seawater is alkaline, and the effectivity thus depends on the alkalinity of the water the ship is operating in. Open loop systems are simple and cheaper than the other systems (Standard Club, 2019).

Closed loop systems adds sodium hydroxide (caustic soda) to seawater or freshwater in order to achieve the required alkalinity for the scrubbing process. This require a separate tank for collecting the residual waste from the scrubbing process. This system incure additional expenses and logistical coordination in obtaining supplies and arranging for the discharge of the waste in storage facilities in ports (Standard Club, 2019). The final design of wet scrubbers is the hybrid system, this solution offers more flexibility, as it is a combination of open and closed loop, however it is more complex and therefore more expensive (Standard Club, 2019).

There are some issues related to the use of scrubbers. The main problem is that scrubbers does not fix the problem of pollution, it only moves it, from air to sea or land (in storage facilities). When the wash water from open loop scrubbers are discharged into the sea it can change the PH of the water, thus negatively impacting the marine biodiversity of the area. Wash water from open loop scrubbers must be treated and monitored to ensure that it is within the IMO discharge criteria, with no risk of harm to the environment. Despite the many regulations on the shipping industry, it is not an easy task to enforce compliance on the high seas as there are many irresponsible actors sailing on the ocean. However, many coastal and port states have imposed more stricter regulations on ships entering their waters (Tan, 2006), as seen with the earlier examples of Singapore, where open loop systems is prohibited within the Singapore port limit, and Norway where it is prohibited to discharge waste water in the fjords (Standard Club, 2019).

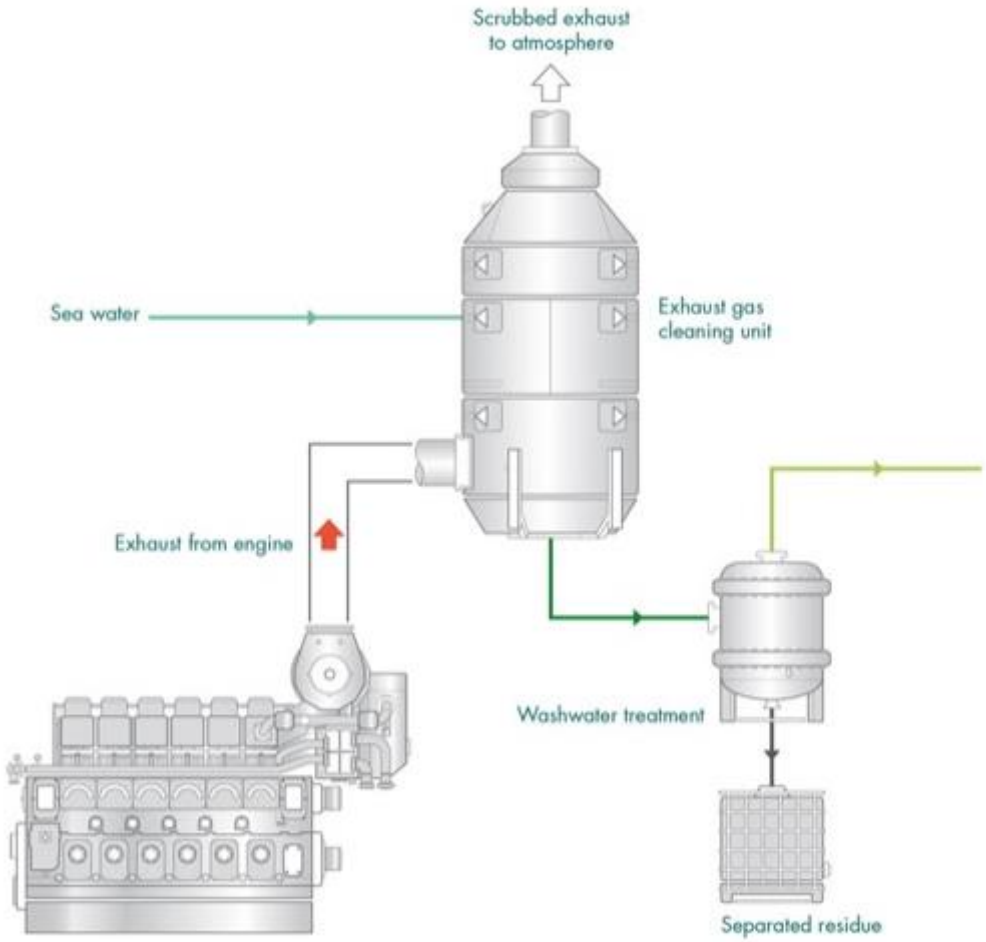

Figure 1: (Exhaust gas cleaning systems Association, nd.)

3.3 Very low sulphur fuel oil (VLSFO):

Since the 1950s HFO have been the most used type of fuel for shipping. HFO is a residual fuel, meaning it is the liquid product that is left over after the distillation process. It can been seen as a heavier fuel with higher viscosity and density than a distillate. The distillate is the product, which leaves the distillation process as a gas. VLSFO are mainly distillates, where the most common fuels can be grouped together as marine gasoil (MGO) (John Thomas, Scott Sluder, Micheal Kass, & Theiss., 2019). VLSFO is fuels with a sulphur content above 0.1% but meeting the cap at 0.5%, while ULSFO is fuels that have a maximum sulphur content at 0.1% (ULFSO is mainly used in ECA's) (Einemo, 2017).

The main benefit for ship owner to use VLSFO is that switching to VLSFO from HFO can be cheaper, as it requires minimal operational change, no significant capital expense or time out of service (Emily Billing, Tim Fitzgibbon, & Shankar, 2018). On the other hand, VLSFO is

more expensive than HFO, and as fuel represent 30-50% of operating costs of a ship it can significantly impact profitability, especially in the short term (Anish, 2019a).

3.4 Alternative compliance methods:

There are other alternative compliance methods for IMO2020, such as nuclear, biofuels, battery, hydrogen and ammonia. These compliance methods have their different positives and negatives, however they all have in common that they are not economically viable compared to the compliance methods mentioned above. Alternative niche technologies for propulsion have different technological, economic, environmental and social performances. One technology might be economically feasible, but have low environmental performance or social performance (Ren & Lützen, 2017). However these alternative compliance methods need further development in order to become economic feasible for shipping. The different alternative technologies that is in focus on this part of the thesis are Nuclear, Biofuels, Battery and Hydrogen/Ammonia.

3.4.1 Nuclear

According to one study (Ren & Lützen, 2017) nuclear powered vessels can be seen as the most sustainable alternative energy source. It is a mature and reliable technology, that have been in use for a long time by some military vessels and artic icebreakers. However, it is an expensive technology that have a bad reputation amongst the general public. In the last years a new type of reactor have gained more interest, a small modular reactor, which is smaller in output and size, that can be used in shipping. The small modular reactor can become economically viable by switching from economies of scale (which have been the economic principle of nuclear power) to economies of mass production (Royal Academy of Engineering, 2013).

3.4.2 Biofuels

Biofuels can be categorized as the first, second and third generation. First generation biofuels are produced from agricultural crops and is a mature technology (Bengtsson, Fridell, & Andersson, 2012). First generation biofuels is commercial, however they compete with food production. Second generation biofuels can be grouped into fuels produced biochemically or thermochemically of feedstock, such as municipal waste or forest residue. Second generation biofuels does not compete with food production. Third generation biofuels mostly related to

using algae as feedstock. The commercial use of biofuels are sulphur free, thus biofuels are compatible with IMO2020 (Tyrovola et al., 2017).

3.4.3 Battery:

The main benefit of using battery-fueled propulsion is that it has no operational greenhouse gas emissions. Another benefit is that vessels powered from batteries can save space from having no fuel tanks, however current batteries have relatively poor volumetric and mass density thus limiting the space gained from having no fuel tanks. The current battery technology is inefficient compared to the volumetric density of energy in HFO and VLSFO and thus becomes uncompetitive. The current lifecycle of relevant batteries is at maximum 10 years, but it averages around 5 years, and thus having to be replaced multiple times over a ships lifetime. This makes battery-fueled propulsion more relevant for smaller vessels with shorter sailing distances such as recreational or fishing vessels (Wu & Bucknall, 2016).

3.4.4 Ammonia/Hydrogen:

The benefits of using hydrogen is that it generate more energy per mass compared to HFO and VLSFO, as well as it have nearly zero greenhouse gas emissions when burned (Bicer & Dincer, 2018b).

Ammonia is a hydrogen carrier, meaning that it stores hydrogen in a chemical state. Ammonia is synthesized from hydrogen and nitrogen. Compared to hydrogen, ammonia have more efficient storage and transport attributes because it can store more hydrogen per unit volume than compressed or liquefied hydrogen. One of ammonias strengths is that it can be used for direct combustion (Bicer & Dincer, 2018a).

Both hydrogen and ammonia can be used in fuel cells onboard ships. However, hydrogen and ammonia needs to be produced in a efficient, clean and low-cost matter in order to be relevant for the shipping industry, for example from hydropower, as producing it from fossil fuels would be of little gain in terms of air pollution (Bicer & Dincer, 2018b). In the longer term, hydrogen should develop into a niche to be recognized. Hydrogen is more energy dense in comparison to HFO and VLSFO. However, the usage of hydrogen depends on development of infrastructure and efficient and clean production of hydrogen (Bicer & Dincer, 2018a).

4. Theoretical framework:

For the theoretical part of this thesis the multi-level perspective have been used. As this thesis aims to research how IMO2020 have impacted shipping and how the shipping industry will develop in the future, the multi-level perspective will give unique access about how the regulation came about and its impact on the future of shipping. The different levels within the theory will show the complexity around IMO2020 as well as how this complexity can lead to change within the shipping industry in the future.

4.1 Multi-level perspective:

In order to address the issues with pollution from maritime shipping, we have to address that the problem requires a socio-technical transition. Socio-technical transitions are systematic changes that involve alterations in multiple areas, such as transportation, energy, policy, consumer practices and infrastructure. A multitude of actors, ranging from policy makers, civil society and companies, influence socio-technical transitions through their actions. These multitudes of elements make transitions a complex and often a long-term process (F. W. Geels, 2011).

The Multi-Level Perspective (MLP) is an abstract analytical framework that identifies the relations within the dynamics of transitions. It is a middle-range theory, meaning it is not a theory of everything, rather is focuses on a more particular phenomenon, and in the case of MLP, the dynamics of socio-technical transitions. MLP is influenced by a variety of different theoretical traditions, such as evolutionary theory, social change, economics as well as technical studies (Grin, Schot, Rotmans, Geels, & Loorbach, 2010).

The MLP mainly consists of three levels, technological niches, socio-technical regimes and socio-technical landscapes, and in this thesis there will also be added a fourth level, political landscape based on Geels and Kemp (2007) and Langhelle et al. (2018). By separating the political landscape from the socio-technical landscape, one can show more clearly the importance of political decisions, and its impact on transitions and the interaction it have with the other levels. These levels provide different kind of coordination and structuration to activities in local practices and thus differs in stability and size. The interaction and trajectory within and between these levels is what produces transitions (Grin et al., 2010). In figure 2 we can see the interaction between the levels.

4.1.1 Technological Niches:

According to Grin et al. (2010) radical innovation often develops outside of existing regimes, where they act as incubation rooms to protect novel technology from the mainstream market. Technological niches can be seen as experimental projects where new technologies are exposed to actors from the selection environment under relatively protected circumstances. Networks of dedicated actors protect the niche by investing resources. The internal processes of a niche can be distinguished in three layers. First, the building of social networks that nurture and develop the novel technology. Second, learning processes and more knowledge improve performance and build a working socio-technical configuration. Third, articulation of future expectations and goals in order to guide learning processes and attract funding (Grin et al., 2010).

Niches consists of social networks that are small and unstable, where the actors within these social networks are willing to take risks (Grin et al., 2010). These actors hope their niche solution are eventually used in the regime or replace the regime. Niches are important in transitions as they can be seen as the seeds for change. Niches gain momentum when the expectations become more precise and accepted, when the niche becomes more dominant and when powerful actor join the social network, as powerful actors gives legitimacy and resources to niche innovations (Geels, 2011).

Of the main compliance methods for IMO2020, LNG can be seen as the niche technology. It could be the main disruptor for the regime in the short term. LNG have recently gained a bigger market share outside of LNG carriers. The main benefits of using LNG is that is a proven technology, as vessels transporting LNG have been using LNG as fuel for half a century. The use of LNG also have significant environmental benefits. An LNG fueled ship will reduce SOx emissions with nearly 100% and NOx emissions by about 85% compared to conventional HFO. However, the biggest issue of using LNG as fuel is the infrastructure as there is a critical need to supply the vessels safely, efficiently and reliably. Another important issue is ship design, in terms of existing ships could be retrofitted with LNG engines within a cost effective manner or is newbuilds required in order to make LNG into a useful fuel (International Maritime Organization, 2016)

4.1.2 Socio-technical Regimes:

Regimes guide research and development activities in particular trajectories, which leads to incremental innovation within the regime. A regime consists of three types of rules; cognitive rules, which can be the belief systems and goals. Regulative rules, which is standards and laws. Normative rules, which are values and behavioral norms. These rules can create routines for workers that can blind them for developments outside their focus. These three types of rules give the socio-technical system stability (Grin et al., 2010).

Regimes are more stable than niches, as the social networks are larger, and regulation, markets, infrastructure etc. have gained clear rules and structuration (Grin et al., 2010). Regimes are thus a place of established practices and rules, which function as a solid structure that stabilizes the existing system. This can be both technological and cultural. Innovation can happen within regimes, however, it happens incrementally with small adjustments leading to a more stable development trajectory (Geels, 2011).

The regime in this case is the major stakeholders in maritime shipping, mainly ship owners, refineries and ship builders. Ship builders are the actors that build the vessels, with different specifications, depending on what the ship owners want. Economic efficiency is arguably the most important factor for ship owners, thus selecting vessels that can produce profit most efficiently is thus a key parameter. The refineries are the ones who produce fuel for the ships. Refineries face uncertainty about the quantity of the different fuels for production, as the ship owners decide which option to go for. Refiners face an increased demand for VLSFO in which they cannot meet, which in fact would lead to a spike in the VLFSO price (Hellenic Shipping News, 2019). This predicted price spike tempted a lot of ship owners to go for the scrubber option for their vessels. These stakeholders have an established structure, where change within the regime happens incrementally, this can be seen with scrubbers. These small developments keep the core of the regime stable. Scrubber enacts the regime to continue as normal before IMO2020, and thus keeping the regime in a status quo.

4.1.3 Socio-technical Landscape:

The landscape is the broad background structure that influences action, it can be seen as a exogenous environment that is beyond the direct influence of regimes and niches, on the contrary the landscape is the influence on the regime and niche (Grin et al., 2010). The landscape level reflect the societal values, ideologies, demographical trends and economic

patterns onto regimes and niches. Landscapes can thus develop and change but it is very slow and incremental, however radical changes can happen such as wars (Geels, 2011).

The broad background structure that influenced IMO2020 is pollution. In order to protect the air quality close to shipping lanes and ports, it is important to limit the pollution as much as possible to ensure peoples health. IMO2020 can be seen as a reflection of society's increasing focus on and understanding of how pollution can damage the environment as well as human lives. As air is a common property, meaning it is accessible for all, it has historically been polluted without limit, also known as the tragedy of the common. The most effective way of limiting air pollution is through regulation. This regulation can come from organizations, such as IMO in this case, or national governments (Jacobson, 2002). In that sense, one can say that IMO2020 may be the first step towards putting a price on air pollution from shipping.

4.1.4 Political landscape:

Geels and Kemp (2007) introduces the political landscape as a more dynamic landscape, where revolutions, new coalitions and ideas can create a room for systematic change. Langhelle et al. (2018) argues that the political landscape should be considered as a separate level. The reason for this is that it is a more dynamic level, including political power struggles, as well as pressure on the landscape level can be mediated and socially contructed through the political landscape (Langhelle et al., 2018). The policy makers in the political landscape are actively engaged with the niches and regimes to form options that can solve political problems, outmaneuver political opponents, and benefit the niches and regimes (Langhelle et al., 2018).

IMO is the political landscape in this thesis, as it is the UNs specialized agency for the maritime industry. IMO consists member countries as well as interest organizations that promote their nations and industry interests and in some cases the interests of humanity. These actors represents different niches, regimes, or even landscapes, such as environmental NGOs promoting more environmentally friendly shipping. These actors battle amongst each other to win influence and get political traction for their interest.

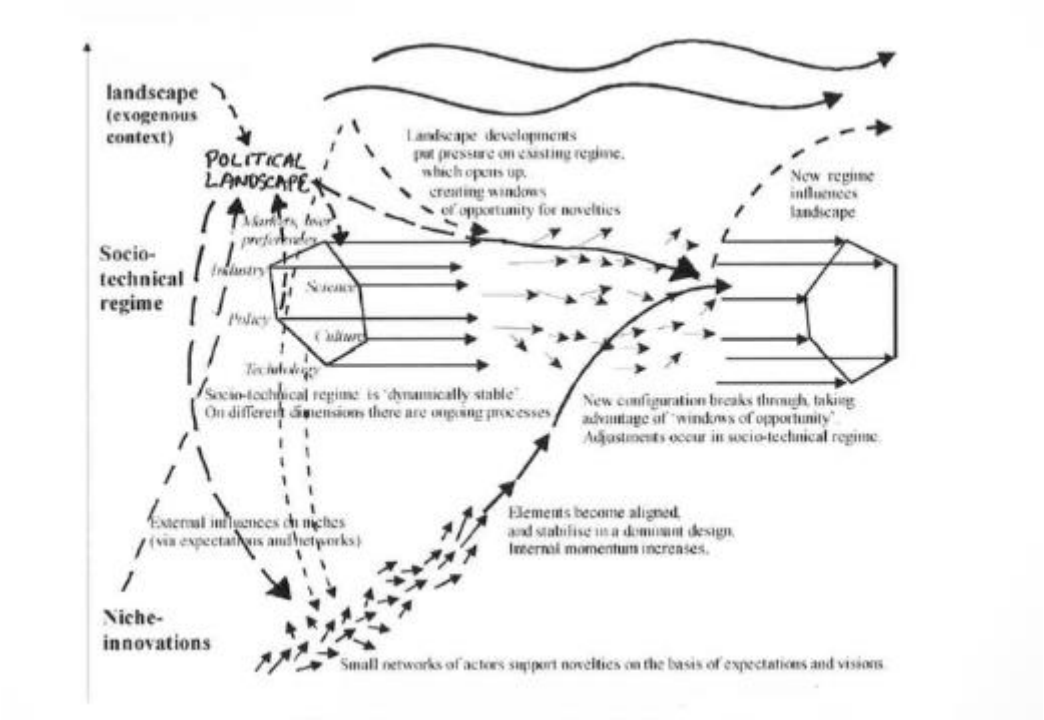

Figure 2: from Langhelle et al. (2018).

4.2 Transition versus transformation:

In order to understand the complex dynamics of a transition, we have to understand what transitions are. Grin et. al. (2010, p. 11) argue that transitions have the following characteristics:

1. Transitions are evolutionary processes. They involve both the development of technical innovation and the use of technical innovation in civil society.
2. Transitions are processed through multiple actors, this can be interactions between businesses, consumers, academia, policy makers and interest groups.
3. Transitions are radical shifts from one socio-technical system to another, radical meaning the level of change and not the speed of change. Radical innovation can be rapid and lead to creative destruction, but they can also be slow and incremental.
4. Transitions are long-term processes, 40-50 years. Breakthroughs can be quick, however the preceding innovational journey of a socio-technical system usually takes a long time.

Geels (2011) see transitions as a shift from one regime to another regime. The niche and landscape levels function as "other concepts", because they are defined in relation to the regime, as the niche technology and practices deviate from the regime, and the landscape is an external environment that influences the interaction between the niche and regime.

Grin et. al. (2010) view transformation as a pathway towards a transition. Transformation happens through moderate landscape pressure on the regime, forcing it to reorient their system. Niche innovation will not replace the regime as they are not developed sufficiently enough to take advantage of the landscape pressure. Societal pressure might mobilize the regime to take action according to the landscape pressure, which will influence the regimes innovation practice. This will lead to new regimes growing out of old regimes through cumulating changes and reorientations, where niche innovation within the regime do not disrupt the basic system.

"*If there is moderate landscape pressure (disruptive change) at a moment when niche-innovations have not yet been sufficiently developed, then regime actors will respond by modifying the direction of development paths and innovation activities*" (Grin et al., 2010, p. 57).

In the transformation pathway, outside pressure play an important role, as outsiders translate landscape pressure and draws attention to negative externalities in which regime actors have neglected. Outsiders can mobilize public opinion and lobby for tougher regulations. However, another important factor is evolutionary dynamics. As societal pressure grows, regime actors will use their adaptive capacity to reorient their development direction. If the development fit with the societal pressure the mutation will propagate and thus leading to a change within the regime (Grin et al., 2010).

Hölcher, Wittmayer and Loorbach (2018) claims that transition and transformation is not mutually exclusive, both terminologies have somewhat of a distinction on how to describe, interpret and support societal change. The difference in their definitions stem from the different research communities. One example of this is that the research communities that focus on global environmental change refer to transformation as a fundamental shift in the interaction and feedback between the human and the environment. However, transitions are mainly focused on fundamental social, technological, institutional and economical change from one regime to another. Transitions thus focus more on analyzing changes and interactions between those elements of society, while transformations is more focused on

grander, largescale changes in whole societies, that involves interaction between the human and biophysical system. One example they have on this distinction of the terminologies is that the outcome of a transition is to go from a unsustainable system state to a sustainable, while the outcome of a transformation focuses on avoiding a undesirable system through creating a safe and just operating space for humans and the environment (Hölscher et al., 2018).

According Sovacool (2016), a study of the mainstream views of energy transitions, a broad definition of an energy transition involves a change in an energy system, most often a particular fuel source, technology or prime mover. As a transition is measured over time, usually from an insignificant market share to a significant share, about 25% of national or global. “Grand transitions” happens when they reach 50% market share. A transition will most likely also consist of many small transitions which build up to a bigger and more easily identifiable transition. Historically, a transition takes 50 to 70 years for a resource to gain a large market share, sometimes even longer (Sovacool, 2016).

Based on the information above, one could argue that transitions generally have a bottom up development, as niches are the innovators that pressure regimes and eventually replace the regime. Transformations have more of a top down development, as the landscape pressure the regime and thus leading to a transformation within the system. Feola (2015) mention that the general idea of a transformation is a major, fundamental change, as opposed to minor, incremental changes as one could argue is traits more relevant for transitions. Brown et al. (Brown, Kraftl, Pickerill, & Upton, 2012) argues that transformation is typical used to describe radical restructuring of social landscapes and where a transition is seen as incremental processes of change. Thus, one can arguably differentiate between transformations as largescale radical changes, which can be fast-paced, contrary to transitions which most often are small incremental changes that develop over longer periods of time that eventually changes one regime to another. One example of a transformation is automation and robotics as they have the potential to change the way humans live and work, and thus our economy, when they gain access to a significant market share. An example of a transition is the energy transition to coal from traditional biofuels. Coal used 60 years to reach 50% of the world’s primary energy source from around 1840 to 1900 (Smil, 2016). The transition example of coal shows the transition aspect of going from one energy regime (traditional biofuels, such as wood) to another (coal) takes time as it develops from a niche to a regime. This can also be seen in shipping as the alternative niches is under research and development, and some such as LNG can currently be used to replace the current HFO/VLSFO fuels, yet it

takes time to gain market share. While the top-down development of a transformation will most likely shake the regime to the core, potentially limiting their power through regulations or policies. In the case of shipping, a strict environmental regulation in the future could disrupt the fossil based fuel suppliers, and with the example of automation and robotics can make ships and ports fully automated (or operate with a small crew) in the future.

5. Design and Method:

This chapter describe and explain the process of data gathering and the methodological process used in this thesis. I have used three different methods;

1. Literature review, where I did an in-depth review of already existing scientific articles, reports and newspaper articles about IMO2020 and other relevant topics, such as the multi-level perspective.
2. Interviews, the interviews was done with people in the shipping industry, where I tried to get supplement information about things I could not find in the literature review.
3. Questionnaire, the questionnaire was done instead of an interview as one respondent preferred a questionnaire rather than doing an interview.

By using three different data collection methods, the reliability and validity of the thesis is improved. Reliability is, according to Neuman (2014), when the method the researcher uses to gather information gives consistent and dependable data. Whereas validity is the truthfulness and correctness of the method used to gain data, meaning that it indicates how well what you measure matches with what you use to understand what you are researching (Neuman, 2014).

5.1 Research strategy

There are several different strategies for doing research and answering research questions. The research strategy is the path the researcher takes for answering their questions. The main research strategies are the inductive and the deductive, retroductive and abductive research strategy (Blaikie, 2010).

According to Blaikie (2010) the inductive research strategy is most useful for answering "what" questions. "*The aim of the inductive research strategy is to establish limited generalizations about the distribution of, and patterns of association amongst, observed or measured characteristics of individuals and social phenomena*" (Blaikie, 2010, p. 83)

Blaikie (2010) claims that the deductive research approach is most efficient for answering "why" questions, because this approach will enable the researcher to explain patterns they have observed. The aim of the deductive research strategy is to test the relevance between to concepts by finding an explanation for an association between the two concepts (Blaikie, 2010).

Another approach is the retroductive, which is best suited for answering "why" questions according to Blaikie (2010). This strategy is about discovering the underlying mechanisms which, in particular contexts, explain observed regularities and causes. The logic used is the process of building hypothetical models of mechanisms and structure that are thought to produce the empirical phenomena the researcher observed.

However, in order to answer the selected research questions in the best possible way, my research strategy have been dominated by the abductive research strategy. Blaikie (2010) view the abductive research strategy as an approach which is good for answering both "what" and "why" questions. The aim of the abductive research strategy is to discover why people act as they do by the uncovering the reasons that provide the orientations for their actions. The abductive research strategy differs from the inductive and deductive strategies by including the meanings, interpretations, motives and intentions of people which direct their behavior. This creates a social world that is experienced and perceived by the people, an abductive researcher goes into this world and tries to understand, describe and discover it from the inside alongside the members of this world (Blaikie, 2010). Danermark (2002) argues that social scientist rarely discovers something new, they mostly reconceptualize already known phenomena in a new perspective. Social researchers describe, explain and interpret findings in a new context, where what is new is how the researcher understand and explain the connections and relations of what is observed (Danermark, 2002). This creates plausible interpretations rather than a logical conclusion (Dey, 2004).

As I have done interviews with members of the industry, I used the knowledge they gave me in order to explore and describe how the shipping industry reacted to IMO2020 and to understand their perspective. This enabled me to discover why the different levels of the multilevel perspective reacted the way they did. The landscape pushed for reduction in air pollution, member nations did not want to disrupt their industry too much in order to keep the regime relative stable, and thus the market selected the compliance methods based on economic efficiency within the regulatory guidelines of IMO. By using the abductive research strategy, I will not discover anything new in this thesis, on the contrary, I will explain connections and relations based on what I have observed during literature review and interviews and re-contextualize the observations into plausible interpretations with the use of multi-level perspective.

Arguably my research in this thesis is a mix of descriptive and explanatory research. Descriptive research is about going in depth and describing an issue, situation or relationship,

while explanatory is about explaining why something happens in a specific way (Neuman, 2014). Based on this, one can see that the thesis goes into describe the relationship between the levels of the multi-level perspective and how they relates to IMO2020 and the shipping industry. It is explanatory in the sense that it identifies the sources surrounding IMO2020 as well as why it developed the way it developed.

5.2 Qualitative research

This thesis is made by using qualitative data. The goals is to rethink old ideas and develop new ones based on new observations, where I connect ideas and create theoretical relationships. However, this process requires that the researcher is self-aware and conscious about the data collection process as the researcher is analyzing data others have collected and analyzed themselves (Neuman, 2014). In broad terms one can say that research is about obtaining knowledge in a structured manner, which should improve understanding of the topic (Aspers & Corte, 2019). Improved understanding means that the academic community have developed new insights into a known topic, or learned something completely new about a topic (Aspers & Corte, 2019). Aspers & Corte (2019) define qualitative research as "*an iterative process in which improved understanding to the scientific community is achieved by making new significant distinctions resulting from getting closer to the phenomenon studied*" (Aspers & Corte, 2019, p. 155). This implies that qualitative research is about how to do research, generating and analyzing data, and the outcome of the research, which is to improve knowledge about the topic (Aspers & Corte, 2019).

5.3 Literature review

In the early phase of this thesis I did literature review of relevant academic articles, reports and newspaper articles in order to expand my knowledge on the topic of IMO2020. Literature review is a study of past research on the same topic or research question. It is based on the understanding that knowledge accumulates and grows as researchers continue to build on what is already known (Neuman, 2014). Doing a literature review helps me to understand what is already known about the topic of IMO 2020, and what I needed to focus on in my thesis in order to extend the knowledge.

5.3.1 Academic literature

In order to find relevant reports and articles on the topic I used Google Scholar with the search terms "IMO2020" and "global sulphur cap". However, this was too broad, and thus had to add more keywords such as "consequences" or "maritime shipping" etc. to narrow down the results. One article I found by doing this was "The likely implications of the new IMO standards on the shipping industry" by Halff, Younes and Boersma (2019). The article is peer-reviewed, which means the article have been independently evaluated based on its qualities and merits by several professional researchers and found acceptable (Neuman, 2014). The abovementioned article is the one most similar to this thesis, by focusing on the possible consequences of IMO2020, however it lacks the political aspects of IMO2020, and thus leaves room for me to explore the political aspects further in this thesis.

However, as this thesis have a broader focus on IMO2020 and how it affects the future of maritime shipping, the relevant academic literature for this thesis is also quite broad ranging from technology development and feasibility, to health impacts of air pollution, to political issues, as well as literature relevant for the theoretical framework.

As mentioned in the introduction, IMO2020 is a relatively new regulation. It was announced in 2008, but was not manifested until 2016, and came into action 1. January 2020. This means there are little information and data about the actual consequences and impacts of IMO2020 and more focus on "what can happen?" This can be seen with the article mentioned above "*the likely implications of the new IMO standards on the shipping industry*"(Halff et al., 2019). The article is focusing how IMO 2020 will affect future innovation within the maritime sector, where the authors argue that the uncertainty around the announcement in 2008, manifestation in 2016, and the implementation in 2020 led to ship owners waiting as long as possible in order to figure out what compliance method would be most economically efficient, as those ship owners who complied early was penalized instead of rewarded.

In the compliance method section the thesis focuses on the three main compliance methods for IMO2020, LNG, Scrubbers and VLSFO as well as alternative niche compliance methods, namely nuclear, biofuels, battery, ammonia and hydrogen. The nuclear section is based on the article "*selection of sustainable alternative energy source for shipping: multi-criteria decision making under incomplete information*"(Ren & Lützen, 2017), where the authors argue that nuclear technology is the most sustainable propulsion technology for shipping. The biofuel section is based on two articles, "*Environmental assessment of two pathways towards the use of biofuels in shipping*" (Bengtsson et al., 2012) and "*The introduction of biofuels in Marine*

sector" (Tyrovola et al., 2017), where both articles shows the possibilities of using biofuels in shipping. The ammonia and hydrogen part uses two different articles by Bicer and Dincer, "*Clean fuel options with hydrogen for sea transportation: A life cycle approach*" (2018a) and "*environmental impact categories of hydrogen and ammonia driven transoceanic maritime vehicles: a comparative evaluation*" (2018b) in order to show the benefits of hydrogen and ammonia. As for why these articles have been selected is because they provide relevant information about the niche fuel technologies in a maritime context.

The theoretical framework in this thesis is mainly based on the book by Grin et al. "*transitions to sustainable development: new directions in the study of long term transformative change*"(2010) and the article "*the multi-level perspective on sustainability transitions: responses to seven criticisms*" (2011) by Geels. Both the book and the article is about understanding transitions, and how transitions can develop under complex circumstances, and explain how the multi-level perspective is useful to explain and understand transitions. However, in order to create more depth in the theoretical framework other articles have also been used, such as Sovacool's article "*How long will it take? Conceptualizing the temporal dynamics of energy transitions*" (2016) that have been used as a supplement about transitions, and the article "*Transition versus transformation: what's the difference*?" (2018) in which have been used as a critique against transition. Geels, Sovacool and the authors of the book "*Transitions to sustainable development: new directions in the study of long term transformative change*" (2010), John Grin, Jan Rotmans and Johan Schot are all leading experts on the topic of socio-technical transitions and the theoretical framework of the multi-level perspective.

The reports which have been used for this thesis is from UNCTAD (United Nations Conference on Trade and Development), IRENA (International Renewable Energy Agency), EIA (U.S. Energy Information Administration), KonKraft (For the Norwegian Shipowners Association), CE Delft, and Transparency International. The reports have been used to gather for more general information about how these different organizations envisions the future for shipping and how different fuels can play a part in these visions of the future, and the report from Transparency International is to better understand some of the critique of IMO.

5.3.2 Newspapers and webpages

Newspaper articles have also been used in this thesis. This is because newspaper articles provide up to date knowledge on recent events, which is the reason I have selected the relevant newspaper articles for this thesis. The different newspapers I have used are Marine Insight (Anish, 2019a, 2019b), Hellenic Shipping News (Hellenic Shipping News, 2019, 2020a, 2020b) and Finansavisen (Skarsgård, 2020). Marine Insight provides new information on a variety of subjects related to the maritime industry. Hellenic Shipping News are an online newspaper focusing on Hellenic and international shipping news. These newspapers are some of the leading newspapers within the topic of maritime shipping. The articles used in this thesis from those newspapers was in an early phase of research in order to get broader knowledge on the topic. Finansavisen is a norwegian financial newspaper which is focusing on financial news, mainly related to the norwegian market. Finansavisen is one of the top Norwegian newspapers within the topic of economy and market and thus having a lot of relevant information about shipping, although most information are related to the Norwegian sector. The article from Finansavisen was used because of its relevancy towards hydrogen and its updated knowledge on it.

For information gathered from webpages I have mostly used the IMO's official website. This is to get general information about IMO, such as who they are and what they do, from their perspective, as well as more specific information about IMO2020 from their viewpoint. Their webpages is easy to navigate and have updated news related to IMO concerns.

5.3.3 IMODOCS

I have also used IMODOCS, which is IMO's own database for meeting summaries, relevant articles and documents from IMO. In order to use IMODOCS you have to register an account, and in this case a public account. In order to find relevant documents one have to use keywords such as "MEPC 70" or "MEPC 75", this represent the 70th or 75th session of the Marine Environment Protection Committee (MEPC). The database have been used to find documents that have played a role in their meetings and which have had an impact in their decision making, such as the article "*Study effects of the entry into force of the global 0,5% fuel oil sulphur content limit on human health*" by Corbett et. al. (2016) which was submitted by Finland at the 70th session of the Marine Environment Protection Committee. This study is about how a possible implementation delay of IMO 2020 from 2020 to 2025 could contribute to more than 570 000 premature deaths. However, most of the documents that have been used

in this thesis are from the 75th session of the MEPC. This includes MEPC 75/5/5 which is a document about how some of the fuel blends designed to meet the IMO 2020 standards are significantly increasing black carbon emissions, as well as document MEPC 75/5/7 which is arguing that the assumptions made in 75/5/5 is based on flawed assumptions. Both those documents are based on the results from PPR 7-8 which concluded that fuel blends with aromatic compounds will have a direct impact on black carbon emissions. PPR is the sub-committee on pollution prevention and response within IMO. The reason these documents have been used is because they show the consequences on IMO 2020 and some of the uncertainty connected to the regulation. IMODOCS was also used to find relevant NGO's from MEPC 70th session, which I could interview for this thesis. The main reason for using documents from MEPC 70 is because that is the session where IMO approved the IMO2020 global sulphur cap implementation date, as well as a mandatory data collection system for fuel oil consumption in addition to creating a roadmap for reducing GHG emissions from ships. Documents from MEPC 75 was used as it would be the most recent MEPC meeting, however due to Covid-19 situation the meeting was postponed, yet one can read the submissions to the meeting, but not the results from the meeting.

5.3.4 Summary

Based on the literature review my niche for this research project it to connect the dots from the more technical aspects of compliance methods and alternative compliance methods, to the political aspects of IMO2020, and how these dots of information can be seen in the light of the multi-level perspective in order to create a transition within maritime industry. The existing literature on IMO2020 is fragmented between the aspects mentioned above based on the given field of the researchers, this leave a golden opportunity to try to connect these dots in order to get a better understanding of IMO2020 and how it will impact the future of maritime shipping.

5.4 Interviews

The primary goal of an interview is to obtain accurate information from another person. The interviewer gather information by asking prearranged questions to the interviewee, where the responses are recorded. For this thesis, I have used open ended questions because they give the option for a free response from the interviewee. Open ended questions also give the

researcher more freedom to ask relevant follow up questions from an earlier response. An open ended interview format can twist into becoming more like a dialog, thus requiring verbal communicating skills from both the interviewer and the interviewee as well as the interviewee might get off track with their responses and give irrelevant information. It is therefore important for the interviewer to control and structure the interview in a way that reduces the amount of irrelevant information as much as possible without damaging the mutual trust and comfort between the interviewer and the interviewee (Neuman, 2014).

Some advantages of open ended questions are that they are open for an unlimited number of possible responses. They can be answered in detail, in which can lead to the discovery of unanticipated findings. In terms of complex issues open ended questions can give respondents the space to answer adequately, as they allow for creativity and self-expression. Disadvantages of open ended questions include different interviewees can give different degrees of detail in their responses. Questions may be to general thus confusing interviewees, which can make them loose direction. Respondents can also be intimidated by some questions, but I have sent my prearranged questions to the interviewees before the scheduled interview so they were aware of the main questions. Open ended questions also requires a greater amount of respondents time, if they have a busy day, this could be limiting the quality of the interview (Neuman, 2014).

5.4.1 My interviews

One major issue of interviewing is the invasion of privacy (Neuman, 2014). Some the prearragned questions used in the interviews searched for the personal beliefs and opinions of the interviewees about IMO2020, it is thus important that we had mutual respect towards each other, the interviewer treat the interviewees with dignity, and that the interviewer will protect the information received. In order to protect the interviewees, they have the option to remain anonymous as well as to read, critique, edit and delete information they find wrong or misunderstood from our interview. My research project have been approved by NSD, this means that my method for collecting, usage and storing of data is within the requirements for privacy laws.

I have done 2 interviews and one questionnaire over email for this thesis, one interview was over skype and the other one was over Microsoft Teams. As the interviews was done over the internet, internet connection can be a problem, however, it was not a significant issue in my

interviews. The biggest issue I had regarding to interviews was getting interviews from relevant people and organizations in the shipping industry, as most did not reply or was not willing to participate. My biggest misjudgement with interviews was that I scheduled them to last about 30 minutes, but both lasted about 60 minutes. However, this did not lead to any problems for me nor the interviewees, as the interviews continued until we were finished. The questionnaire sent over email, and the results from the questionnaire was good and sufficient. During the interviews, the interviewees kept a high degree of relevancy in answering my questions and did not really get off-track in a problematic matter. My range of questions for the interviewees and questionnaire consisted of political questions about IMO to more technological questions about different niche technologies.

My interviewees, who agreed to be mentioned with full name, is Maria Kouboura and Christian Bækmark Schiolborg. Maria Kouboura is a naval architect and marine engineer who works for the Institute of Marine Engineering, Science & Technology (IMarEST), where she is currently a senior policy manager, following up the IMO2020 legislation. IMarEST is a non governmental organization which have consultancy status at IMO, and is the first institution that brings together marine engineers, scientists and technologists into a multidisciplinary professional organization (IMarEST, n.d). It is one of the largest marine organizations, and where the main goal of IMarEST is to promote scientific development of marine engineering, science and technology (IMarEST, n.d).

Christian Schiolborg is a marine engineer, currently working at BIMCO, where he mostly is focusing on fuel issues as well as issues related to MARPOL Annex VI. BIMCO is the world largest organization for ship owners, ship brokers, and agents. About 60% of the worlds merchant fleet, measured in tonnage, is a BIMCO member (BIMCO, n.d). The main purpose of BIMCO is to secure a level playing field for maritime shipping, BIMCO thus work to promote and secure global standards and regulations (BIMCO, n.d).

Both interviewees work for NGO's which have been granted consultancy status at IMO, this means that the organizations work with IMO. Both organizations represent the regime at IMO, BIMCO represent it more directly as its main members ship owners, charterers, ship brokers and agents, while IMarEST is leaning more towards the technical and engineering aspects in IMO discussions. However, as I asked for personal beliefs and opinions in some of the questions, and both interviewees participation and answers in this thesis reflect their personal opinions and knowledge and not their affiliated organizations.

5.4.2 Questionnaire

As mentioned earlier, one of the participants in this research project preferred to be anonymous and answered the questions over a questionnaire instead of doing an interview. A questionnaire is a fixed set of questions that is sent to the respondent (Neuman, 2014). The questionnaire used in this research project included the same questions as those used in the interviews, which was open ended questions, searching for both professional knowledge and personal opinions about the topic. However, the questions used was better suited for interviews as they were too open for a questionnaire. This resulted in short answers, however, the answers were precise and on point. Ideally, the questions should have been designed for a questionnaire, as this would probably have enabled for more in depth answers from the respondent. However, one positive aspect from the questionnaire was that the respondent took a lot of time before answering, enabling the respondent to use relevant sources for the answers as a supplement to their personal opinions and knowledge. The respondent of the questionnaire currently works at an organization that have consultancy status at IMO, and the respondent have previously worked in the IMO secretariat, and have followed IMO discussions since 1991. Thus having a lot of knowledge on the topic of this thesis.

5.5 Limitations and choices

As this study was done in the spring and summer of 2020, data collection was hampered by the outbreak of the Covid-19 pandemic. The Covid-19 pandemic significantly impacted the world economy and thus severely putting additional stress on the maritime industry. This can have affected my thesis, in terms of low participation for interviews in a stressful time for people working in the maritime industry.

Another limitation of this research project is that the political aspects of IMO is a sensitive area of interest, which made it difficult to get answers that went deep into the politics of IMO during the interviews.

During this thesis I have made some decisive choices in terms of theme and focuspoint. In terms of the theme of the thesis I have selected to focus on the shipping industry in a holistic perspective. As the shipping industry is inherently a international phenomenon, I thus think that viewing the consequences of IMO2020 in a holistic perspective will give a more interesting thesis about IMO2020, rather than doing a more specific case study. However, this

will lead to more vagueness in the thesis as it can become to abstract and wide compared to a more specific case study.

I have also chosen to focus on the short term compliance method of LNG as a main niche in regards to IMO2020 as it would be more likely to be a successful niche rather than the alternative niches mentioned in the thesis. This is because the use of LNG is more developed than the other niches and thus the industry would be more willing to use it when it would eventually become economically efficient. However, it suffers from much of the same issues as the alternative niches, thus limiting its impact for IMO2020 more than I expected.

6. Discussion

This section of the thesis will discuss the data gained from both the interviews and questionnaire, as well as the literature review in light of the problem statement. The problem statement of the thesis is "*How will IMO 2020 impact the future development of maritime shipping?"* and this will be analyzed through the multilevel perspective. In order to elaborate the problem statement, this chapter is divided into three main parts, namely the research questions of the thesis:

1. Why is not other alternative niches considered a solution for compliance with IMO2020?
2. What is IMO2020 a result of?
3. Will IMO2020 lead to a transition or a transformation within maritime shipping?

These research questions is discussed, and further divided into different sub sections within themselves. By addressing the research questions in this systemized manner, the different aspects of the problem statement will be more easily shown and potentially understood by the reader.

6.1 Why is not other alternative niches considered as a solution for compliance with IMO2020?

Maritime shipping is an expensive business, where the largest percent of the voyage cost is the cost of fuel, representing about 47% (Stopford, 2008). This cost thus become one of the main expenditures of running a ship and a main issue regarding compliance to IMO2020.

According to Kouboura (personal communication, 30.april, 2020) compliance with the IMO2020 regulation is up to the shipping companies to decide which compliance route to choose while enforcement lies with nation states.

When it is up the industry to figure out how to comply to the IMO2020 regulation, there are two main factors which dominate how to comply to IMO2020, cost effectiveness and infrastructure. As Schiolborg (personal communication, 1.May, 2020) mentioned in the interview, infrastructure is important, as shipping require a fuel that is available in every continent and region as well as the price setting of the fuel. Why would a shipping company use an alternative option that is more expensive than the carbon-based options that are compliant with IMO2020.

6.1.2 Nuclear propulsion

So why is not nuclear propulsion a feasible technology for merchant shipping? As mentioned earlier in this thesis the technology is mature, and ships do not need to refuel for multiple years. However, as Kouboura (personal communication, 30.april, 2020) points out the safety aspects of the available technologies should not be overlooked. Accidents do happen, and always will happen, and an accident with a nuclear fueled ship would have large environmental and potential human health consequences. The safety concerns would be a major cost driver amongst ports, shipyards, factories as well as insurance for the vessels (Royal Academy of Engineering, 2013). According to Roscini (2002) the security aspect of nuclear vessels and vessels carrying nuclear waste have led to a modernization of the right of innocent passage. The concept of security do not only have a political and military meaning, but now also consist of environmental security, as a fundamental aspect of territorial sovereignty is protection of its territory against threats, and in this case a threat could be environmental degradation of fishing industry and tourism if a nuclear incident happens at sea. Foreign nuclear ships could therefore be denied access through a particular fragile marine ecosystem based on the potential threat of a nuclear incident (Roscini, 2002). Schiolborg (personal communication, 1.May, 2020) points out that nuclear fueled vessels would become a political issue, as a coastal state or a port state you would not necessarily want foreign nuclear fueled vessel calling into your port. The potential for an accident could create dissatisfaction and worry amongst the local inhabitants living close by the port or shipping lane. This is because of the social values in the landscape. People want to feel safe and not only for themselves, but also for ecosystems. If this feeling of security is under threat, people will use their power to influence and potentially change the local political landscape in order to try to protect their security. Another potential aspect of nuclear propulsion is related to the life cycle of a vessel. When the ship is recycled, could the reactor and fuel potentially be weaponized and sold on the black market and therefore pose a threat? This and other questions would have to be investigated (Christian Schiolborg, personal communication, 1.May, 2020), Schiolborg emphasized that he is not an expert on nuclear propulsion. In order to combat the abovementioned factors it is clear that nuclear merchant shipping would need a strong regulatory framework developed by IMO before the technology would be considered relevant for the industry.

6.1.3 Biofuels

In the case of Biofuels, the biggest drawback is supply, meaning that commercially available first generation biofuels would need a lot of land in order to produce enough fuel for supplying the demand from the shipping industry. Because of this competition over land with food production, first generation biofuels largely becomes unattractive as a fuel for shipping, furthermore Schiolborg (personal communication, 1. May, 2020) mentioned that first generation biofuels are considered a nogo because of this competition with foodstock. This can be seen as a political issue as it will hurt food supply on a global scale, and could also potentially drive up prices for non-biofuel crops as supply of those would be reduced. According to the Royal Academy of Engineering (2013) first generation biofuels would require the landmass twice the size of the United Kingdom in order to supply the current worldwide fleet of merchant ships, and the production of first generation biofuels are not very efficient and create a significant amount of biomass or organic waste. However, as second and third generation biofuels does not compete with food production they have a lot more potential compared to first generation. Their biggest issue is infrastructure, if their production technique and supply becomes efficient, the demand would be there, but currently it is not enough second generation biofuels to cover the demand globally. According to Schiolborg (personal communication, 1.May, 2020) there are some ship owners who use biofuels, but that is for mixing biofuels with the carbon based fuel, and Maersk is currently researching second and third generation biofuels. Another issue is the content of fatty acids in some of types of biofuels. Fatty acids are corrosive and thus depending on the level of fatty acids in the fuel, there is a variability in performance, degradability and stability, in which furthermore have impacts on handling, storage, treatment, engine operations and emissions. Because of this, engine manufacturers, ship designers and ship builders need to be in close contact in order to reduce these impacts (Royal Academy of Engineering, 2013). These problems make biofuels suitable for medium to long term solutions for the maritime industry as the technology needs for research and development in order to become economically viable. This is because even though biofuels have a strong actor in Maersk doing research and developing for its potential, it still lack pressure from the political landscape. In order for biofuels to be available worldwide a lot of port states need to develop their infrastructure in order to secure vessels with a economic viable biofuel, and this requires political willingness. However, before this political willingness will show up, the niche actors and developers must show that the technology is feasible on a global scale and will be economically viable.

6.1.4 Batteries

Kouboura (personal communication, 30.april, 2020) believes that the use of battery technology for propulsion is not a viable solution at the moment. This is due to the fact that in ocean going shipping you would have to compromise a lot of space to make room for the batteries, this means less cargo and thus making the voyage less profitable, if profitable at all. However, Kouboura (personal communication, 30.april, 2020) feels more optimistic about batteries in short distance shipping, such as ferries, where the batteries can be charged often, thus taking less space away from cargo, as well as taking off peak loads if necessary. However, Schiolborg (personal communication, 1.May, 2020) emphasizes that if the power that charges the batteries are not renewable, batteries make little sense in an environmental perspective. The battery technology of today do not have the energy density that long distance shipping requires. Currently, batteries would be most useful as a hybrid solution for small and medium sized vessels going on short distances (Royal Academy of Engineering, 2013).

6.1.5 Hydrogen and ammonia

A similar case as mentioned above, is with hydrogen, as hydrogen have enormous potential for long distance shipping. However, it only makes sense if it is produced from renewable sources. According to Schiolborg (personal communication, 1.May, 2020) hydrogen is one of the potential alternative fuels that can be used in combustion engines, turbines as well as fuel cells. This decreases the amount of redesign needed on existing engines. The biggest concerns about hydrogen is that it is highly flammable, as well as it needs a global infrastructure in order to be relevant for maritime shipping. This is also relevant for ammonia, which is highly poisonous, and also requires global infrastructure in order to be a relevant fuel. Schiolborg (personal communication, 1.May, 2020) also mentioned a interesting problem statement about ammonia, as it is produced from hydrogen, why would you use ammonia when you can just use hydrogen? The life cycle footprint would be lower if hydrogen would be used instead of ammonia. As both hydrogen and ammonia have security concerns, a regulatory framework is needed before they can gain a significant impact on maritime shipping (Royal Academy of Engineering, 2013).

6.1.6 Summary

The main impediments for these potential compliance methods are: Infrastructure, regulation, research and development (life cycle assessments). The abovementioned niches will be categorized in terms of level of development and their potential for replacing the regime based on the research that have been done in this thesis for long distance voyages.

Hydrogen is rated as having the biggest potential in long distance voyages because of its high energy density as well as its compatibility with current engine technology. However, it needs time to develop infrastructure around it. One example of this could be development of offshore windfarms in order to produce renewable hydrogen for shipping purposes, but this will take time to develop. Hydrogen also lack a life cycle assesment (Anonymous, personal communication, 2020). Thus making hydrogen only a contender for the regime in the longer term. By producing hydrogen in a renewable manner it will also have a low impact on climate change and will be a reliable source of fuel, nonetheless hydrogen will have a high cost of investment, and possibly fuel price and operational costs (Hansson, Månsson, Brynolf, & Grahn, 2019). However, hydrogen must also be considered in contrast to the efficiency of electrolysis process as well as storage facilities (Gilbert et al., 2018).

In terms of biofuels, the most likely type of biofuel that could destabilize the regime is third generation biofuels as it have the potential to be produced on an industrial level and thus having larger supply levels than second generation biofuels for long distance voyages. However, third generation is lagging in research and development can thus be categorized into a long term contender for the regime. Biofuels also lack life cycle assessment (Anonymous, personal communication, 2020). If biofuels becomes viable in the future, the CO2 emissions would also be drastically reduced compared to HFO and LSFO. Biofuels have relatively low operational costs and have strong safety aspects (Hansson et al., 2019), yet third generation biofuels are a lagging far behind other alternative fuels, and second generation do not have the infrastructure available, and will most likely not have it for some time in order to supply a global demand.

Battery technology is ready for short distance voyages, such as ferries, but the current battery technology have too low energy density for long distance voyages. Unless battery technology will go through a energy density revolution in the future, batteries cannot be seen as a contender for the regime in long distance voyages. Batteries also lack Life cycle assessments (Anonymous, personal communication, 2020). In short distance shipping, the main type of battery used is Li-ion batteries, which have advantages in energy and power density for these

distances, yet it they have an disadvantage in safety. Different conditions, such as overcharging, overdischarging, heating, short circuits which can cause a fire hazard (Andersson, Wikman, Arvidson, Larsson, & Willstrand, 2017).

Nuclear propulsion on the other hand does not need a worldwide infrastructure for fueling purposes and it is technologically mature and reliable for use in merchant shipping, however, the political ramifications of an accident adds an amount of weight that makes nuclear propulsion not a strong competitor against the regime. As well as it lacks strong standards and guideline, these issues makes it a challenge to implement nuclear propulsion. Another issue is that operational requirements for merchant vessels differ from the requirement of the military vessels using nuclear propulsion, thus the reactor systems will have to differ (Peakman, Owen, & Abram, 2019). The main barriers for nuclear propulsion is economic uncertainty surrounding insurance in terms of sufficient finance to cover the costs of an accident, port restrictions, disposing of nuclear waste in terms of how is responsible for handling the waste, and finally the cost and training of staff in order to operate a nuclear vessel (Peakman et al., 2019).

6.1.7 Industry responses to IMO 2020

The niches mentioned above clearly needs more time with research and development in order to economically viable for use in maritime shipping. As IMO only give guidelines for how to comply it is up to the individual member nations to do the research and development, as well as facilitating infrastructure in order give the niches better viability. One example of this is Norway, where a consortium of companies have been given funds from the Norwegian government to develop a complete supply chain for hydrogen at Mongstad industrial park. The goal of this project is to facilitate hydrogen as a fuel for maritime shipping as early as in 2024 (Skarsgård, 2020). However, in order for this to be an international success, other nations are required to facilitate supply chains for hydrogen at their ports. As a vessel goes from A to B, it makes little sense to use hydrogen if only A have the capability to supply it efficiently.

Interest organizations within IMO could use their influence on individual member nations in order to promote niche technologies such as hydrogen. However, Non-governmental interest organizations do not have any voting power in IMO meeting, but they are admitted to any meeting, and with an invitation, NGO’s can express their opinion and research on any subject

on the agenda (International Maritime Organization, 2019b). The member nations thus have to cooperate and compromise for developing regulatory frameworks for the alternative niches within IMO, such as IMO2020. But, as mentioned earlier, it is up the industry to find ways to comply to IMO2020.

The industry will focus on what is most commercially effective, in the case of IMO2020, it is the carbon-based solutions of LSFO or HFO with scrubbers. Thus making the alternative niches of little relevancy for compliance with the regulation, as the carbon-based solutions is within the parameters of IMO2020 and more cost effective. Switching to LSFO or using HFO with scrubbers enable the regime to a large degree to continue with business as usual. In the long term these solutions can be seen as incrementally small adjustments within the regime where the established practices and rules still give the current regime a stabilizing structure, where the development trajectory is to create more efficient engines for the use of LSFO and HFO. Scrubbers will reduce SOx emissions by minimum 95% and PM emissions at least 60% (Tran, 2017). Scrubbers keep the regime stable by keeping the fuel market relative intact, as it is not as distruptive technology, but an enabling technology, meaning that HFO can still be used after IMO2020 because scrubbers remove SOx emissions, thus keeping HFO within the compliance of IMO2020.

However, due to the complexities of the consequences of IMO2020 as well as the business as usual approach by the market forces, one study submitted by Finland and Germany (2019) indicated that some of the VLSFO blends which have large amounts of aromatic compounds will increase black carbon emissions. These VLSFO blends resulted in a increase of black carbon emissions by 10%-85% compared to HFO. Based on this FOEI, WWF, Pacific environment and CSC (2020) wants that MARPOL Annex VI to prohibit the use of VLSFO blends that increases black carbon emissions. Contrary to this, a study submitted by IPIECA and IBIA (2020) argues that the VLSFO blends are not the sole reason for a potential increase in black carbon, but it is in combination the engine and operational conditions of a vessel. However, this issue shows the problem of trade offs, VLSFO is fixing the problem with sulphur emissions but it creates a new problem. This issue can also be seen with scrubbers, where the open loop system transfer the sulphur from the air to the sea. The political landscape have been influenced by this issue, as many nation states have strong restrictions or banned the open loop system in their waters. This will impact the ship owners and their investments in scrubbers in two ways. First, investments in scrubbers are mostly attractive for vessels that consume most of their fuel in ECA’s. Second, the unceritainty about future

regulations is making the investment case unclear, as investing in something that can be unprofitable in the next few years is risky (CE Delft, 2016). Additionally, as a consequence of the covid-19 situation, the fuel spread between HFO and VLSFO have decreased, thus the payback period of a scrubber is significantly increased and installment of scubbers have significantly dropped (Wackett, 2020).

6.1.8 LNG

As opposed to the alternative niches mentioned earlier, LNG engines are a mature technology as it have been in use in LNG carriers for about 40 years. In terms of a short term solution for compliance with IMO2020, using LNG as a fuel will eliminate SOx, significantly reduce NOx and PM, which is the main benefit of switching from HFO to LNG. However, the gas market is very volatile, as of now gas prices as low, which is an incentive for using LNG, but depending on supply and demand it can increase in a couple of years. Low gas prices can make LNG cost competitive compared to HFO and LSFO. Due to the volatile market, LNG can be attractive for a couple of years and then the market can suddenly turn around and decrease the incentive to use LNG (Fun-sang Cepeda et al., 2019). Kouboura (personal communication, 30.april, 2020) argues that when shipping companies make a decision to invest in retrofitting to LNG engines or LNG fueled newbuildings, they evaluate the market, the trade route, the fuel prices, the initial cost of investment and the return on investment. In volatile markets, the gas price shouldn't be the only parameter to consider. However, in terms of environmental considerations the use of LNG have certain issues, such as methane slip, thus it cannot be seen as a long term solution. Another issue is infrastructure, as LNG bunkering facilities needs to available worldwide in order for it to become a fuel to be reckoned with outside of LNG Carriers. For large vessels on long distance voyages storage capacity is also an issue, as the space needed for fuel storage would take away space from cargo (Fun-sang Cepeda et al., 2019). However, the biggest issue is that retrofitting LNG engines is still more expensive than retrofitting scrubbers or switching to VLSFO, and based on the operating profile of a ship, such as the route, distance and fuel availability, scrubbers or VLSFO is more economically efficient than LNG engines. For these reasons LNG was not ready to exploit IMO2020, yet it still have the opportunities to grow into a medium term compliance method towards 2050.

6.2 What is IMO2020 a result of?

Air pollution, human health, economic growth are all underlying aspects which is important to consider when doing this research of how IMO2020 came about and why the world want such a regulation. IMO2020 is a result of many years of discussions at the IMO, but this chapter will dig deeper into how the different levels of the multilevel perspective have influenced and pressurized IMO and IMO2020.

6.2.1 Landscape pressure

Arguably IMO2020 can be seen as a result of landscape pressure. As economic growth have continuously given humanity increased welfare, air pollution have continuously followed the economic growth. However, as our knowledge about air pollution is increasing, so does our willingness for limiting the negative consequences for air pollution. One example of this is the pursuit of sustainable development, which is a concept about uniting economic growth, environmental sustainability and social development indefinitely (Dryzek, 2013). These pillars of wellbeing is also a core of IMO, as they are a specialized agency under United Nations with the responsibility for safety and security of shipping, as well as the prevention for atmospheric and marine pollution (International Maritime Organization, n.d). Therefore, IMO2020 can be seen as a reflection of this, where the values of the member nations and the consultancy organizations towards economic growth (where international shipping is the backbone for international trade), health of their people as well as protecting their local environment from the negative consequences of air pollution from ships. One study (Winebrake, Corbett, Green, Lauer, & Eyring, 2009) claims that a lower sulphur content in shipping fuels will lead to a prevention of 45 000 premature mortalities. However, the health impacts are only one factor amongst many (such as climate change and ocean acidification) in the complex relationship between shipping emissions and fuel quality (Winebrake et al., 2009).

As Schiolborg (Personal communication, 2020) pointed out during the interview it is pointless to use a propulsion technology is the fuel is non-renewable, such as batteries or hydrogen fueled with fossil sources. As the socio-technical landscape consists of many different elements, such as economic pattern and societal values. Economic profitability is an important factor, as it creates wealth to nations and the regime. This reflects into the landscape, where pressure to protecting the status quo of wealth creation in the industry is a key target for

member nations. However, the growing concern about air pollution amongst the general public have also influenced their governments and thus discussions in the IMO, such as Norway which have pressed for sulphur emission reductions in IMO since the 1980s (FOEI et al., 2020). Another interesting factor is that many of the member nations take UN regulations into parliamentary law, and thus those member nations exert UN visions back into IMO discussions and then again into IMO regulations.

6.2.2 Political landscape pressure

However, IMO2020 can also be seen as a result of political landscape pressure as it is the member nations of IMO that have voting power. This means that it is the member nations that discuss, vote and compromise in the IMO forum for the regulatory guidelines. Economic improvement is something all member nations of IMO strive for. One important to factor in IMO according to Kouboura (personal communication, 30.april, 2020) is that compliance of IMO2020 regulation is up to the shipping companies to decide which compliance route to choose, while enforcement lies with member States. The shipping industry in the respective member nations, as well as relevant interest organizations will influence and aid the relevant member nation to promote what is best for their industry within the parameters of IMO2020. However, the questionnaire (Anonymous, personal communication, 2020) argued that it is usually the member nations who wish to keep the regime stable, as the output from IMO will often lead to changes in their parliamentary law, in which government officials wish to avoid unless there is clear justification that the output is acceptable to their parliament. As what IMO decides usually gets implemented, the shipping industry will usually ask “how” and this can be seen as a somewhat of a resistance towards the decision from IMO (Anonymous, personal communication, 2020). As the social values of the general public spills over to the political landscape, the political landscape will steadily adopt them and integrate them in their politics, in which again will influence the development in IMO decisions. However, a critique of IMO is that it is consensus based, this will often lead to an aim for the lowest common denominator in discussions in order to reach consensus between members. This can be seen in the light of a regulation or standard is better than no regulation or standard (Bognar-Lahr, 2019). However, when consensus is too difficult to achieve, voting will occur, yet voting is often avoided is it can lead to splits between different member states (Psaraftis & Kontovas, 2020).

In regards to the critique from Transparency international (2018) towards IMO, undue influence can happen with the unbalanced influence from the industry in the national delegations in IMO discussions, however in discussions with emphasis on environmental issues delegations are often included with ministers or other actors with environmental concerns to negate the undue influence from the industry. However, as it is the shipping industry itself that was pushing for tighter regulations through IMO the abovementioned points was beneficial for the public interests. One article (Psaraftis & Kontovas, 2020) that is discussing the statements made by Transparency International, argues that the most potent influencers in IMO is Japan, USA, Germany, Norway and China (in this order), based on delegation size and total submissions to the IMO, and furthermore that IMO should reform its political landscape in order to become more transparent and thus limit the potential for conflicts of interests. In the case of the Norwegian delegation to MEPC 70, one delegation member is representing the ministry of environment, and the 19 other members of the Norwegian delegation represent different sections within maritime industry or industries with interests in maritime shipping, such as the Norwegian maritime authority, DNV GL, and Statoil (Now Equinor).

According to Svensson (2011) the oil industry and the oil producing states (mainly high sulphur oil production states such as, the Arabian states and Venezuela), in the first phase of the global sulphur cap (1980s-1997), delayed the final decision with intense debates. Their concern was over the cost of the sulphur cap, as they wanted to protect the market of residual fuels to be used for shipping fuel, which was the only remaining large market for residuals. The oil industry showed the potential costs of increased fuel prices would spill over to the shipping industry, as fuel costs represent about 47% of the total voyage costs (Svensson, 2011). This would increase the cost of shipping, making commodity prices rise, which again could increase the competition with landbased transportation, this increasingly led to some flag states as well as coastal states supported the arguments from the oil industry and high sulphur oil producing states (Svensson, 2011).

6.2.3 Regime pressure

The industry itself can also excert pressure, and regime pressure towards the member nations in IMO discussions can have a strong impact. One example of regime pressure is Maersk, which have confirmed that they will explore new fuel development and concluded to focus on alcohol based fuels, bio-methane fuel and ammonia (Maersk, 2019). If their fuel development

is successful they will likely influence relevant member nations, nation where Maersk have a strong foothold on the local economy, to create a supply chain for the fuel as well as promoting a global supply chain so it can be useful on a global scale. However, as for why large companies, such as Maersk, is increasing their focus on environment and sustainability is likely due to landscape pressure. This can happen through activist investing, where more environmental and sustainable conscious shareholders uses their vote in general meetings and thus have a chance to impact the company from within and from there force it to increase their focus on environmental and sustainability concerns (van Duuren, Plantinga, & Scholtens, 2016). In the case of Maersk it will might not make the company more profitable per se, but it does show to the public that they have strong values that corresponds to the values of the general public. This can also be seen in Maersk's sustainability report from 2019, where the CEO claims "*sustainability is expected by our customers to be a part of everyday business and embedded in everything we do*" (Maersk, 2019, p. 6). In order for Maersk to be a relevant company in the future is thus have to adopt the landscape values into their own.

In terms of adopting values from the public into their own, one example of this is Maersk investments in to the niche fuels mentioned above. If this investment into developing their own niche fuels becomes successful, Maersk have the legitimacy and the resources to promote it into other parts of the regime, as they would need a supply chain. Furthermore, Maersk can pressure the political landscape to increase the national and possibly the international political institutions to increase focus on their niches, which can speed up integration of the potential fuels as it can come into regulation and laws.

Another example of regime pressure can be seen in Norway, where hydrogen is getting a stronger position in the maritime industry. The Norwegian shipowner association (which represents the Norwegian maritime industry) with the aid of the Norwegian oil and gas industry wants to produce hydrogen from natural gas with Carbon Capture and Storage, as well as pressing for offshore wind farms that can produce hydrogen for maritime use (KonKraft, 2020). Furthermore, the Norwegian government have recently released a new hydrogen strategy, where they will facilitate and stimulate the Norwegian maritime industry towards hydrogen use with an increase in research and development (Olje og Energidepartementet & Klima og Miljødepartementet, 2020). However, in order for this to be successful it requires international cooperation and a global supply chain, thus, the Norwegian maritime industry needs to promote hydrogen into IMO regulatory guidelines. This type of regime pressure can be seen as industry pressure, and can be viewed as opposite from the

Maersk example earlier, as it is the nation state which do the promoting and forces niche development through stimulus and benefits to the companies that comply and fulfill the nation states targets.

6.2.4 Summary

Based on the factors mentioned above we can clearly see that IMO2020 is a result of complex issues, however the stronger factor behind IMO2020 is the landscape pressure of air pollution. The general public wants safe and breathable air (Andrews, 2017), and these values spills over to the political landscape as governments and interest organizations are rooted in certain values and discuss and compromise in IMO, where the regulatory framework and guidelines which is developed by IMO is based on these values. As clean and breathable air is an important factor for a healthy life, it is upmost important that IMO and the member nations does their part and try to reduce the impact of air pollution from shipping vessels close. The general public can impact the political landscape through elections, and thus force forwards values more aligned with protection clean air. Although pressure from the political landscape is the key actor in decision-making towards policies, regulation and laws in compliance with cleaner and breathable air, it is quite clear that is the landscape which influences the decision-making regarding IMO2020 as a response to the public that the political actors involved in IMO2020 have some political will. Based on the arguments mentioned earlier in this chapter, regime pressure can only be seen as a response to the landscape as the regime is forced to adapt or face the risk of becoming irrelevant. It thus becomes clear that the landscape pressure is felt at both the political landscape and in the regime.

6.3 Will IMO2020 lead to a transition or a transformation within maritime shipping?

As the alternative niches clearly needs more time to develop further before they can be evaluated as significant competitors towards the fossil based fuels, as well as, IMO2020 is a result of landscape pressure. These factors raises the question of will IMO2020 lead to a transition or a transformation within maritime shipping?

6.3.1 The case for transition

One can see IMO2020 in the light of Sovacool's (2016) arguments that a transition is a change in energy system, and in this case a fuel switch from fossil fuels to cleaner fuels,

usually consists on many smaller transitions which combined leads to a larger transitions. IMO2020 is one of these smaller transitions which, to a certain degree, disrupts the current regime, however the regulation itself will not enable a direct fuel switch from fossil based to renewable based. Arguably, the possibility for stricter regulations in the future is likely, as we can see with IMO's vision to reduce GHG emissions with 50% compared to 2008 levels by 2050 (International Maritime Organization, 2019a) will require some restrictive regulations. Although sulphur is not considered a greenhouse gas, one would assume that IMO will eliminate sulphur emissions in the future when alternative fuel technology would enable it, as pressure from the landscape will not fade the coming years with the public's knowledge on air pollution and its consequences will only grow. Thus, following the logic of Sovacool's arguments (2016) where a transition consists of many smaller transitions going from an insignificant market share towards an significant (about 25% market share), and further into a grand transition (when a fuel would get about 50% market share) seems somewhat possible with hydrogen as well as biofuels in the long term. However, for them to reach a grand transition seems very unlikely as nation states would have to change and develop their industry on massive scale, as well as cooperate with other nations in order to create global infrastructure for the fuels. Arguably, if the different niche technologies would gain significant market share in the future it would most likely be divided somewhat evenly, such as hydrogen, ammonia and biofuels share the market in long distance shipping, in comparison to the current market situation, where fuels from oil are dominating the market.

Based on the arguments from Grin et. al. (2010) we can see the evolutionary process of IMO2020 as a continuous discussion which in fact have developed into a regulation. This evolutionary process can also be seen with scrubber technology, where it was mainly used onshore in industries such as fertilizer production. Scrubber technology have thus been redesigned and transferred from onshore industries towards use in maritime shipping (Christian Schiolborg, personal communication, 2020).

We can also see that multiple stakeholders have been involved with IMO2020, where the interaction between the stakeholders it what shaped the end-product of IMO2020. This interaction between stakeholders is of consumers and governments, governments and IMO and NGO's and the industry. As it is the market that decides how to comply to the IMO2020 regulation, the market will choose the most effective measures within compliance. However, this will likely lead to a slow and incremental technology development within the regime

instead of rapid and creative destruction of the regime. The current market forces will create a stable regime, but the innovational journey within the regime will take longer time, which can lead to a long term transition process. This is because the niches was not fully developed for IMO2020, and thus the regime responded by selecting the most efficient compliance methods. In terms of IMO2020 the market can be seen as the ship owners, operators and charterers which select the most cost effective ship for their needs, thus they had no incentive for the extra investment for the using the different niche alternatives.

However, regarding IMO 2050, the niche alternatives will be more developed and potentially ready to exploit the opportunity to grab a significant market share. An example of this can be the example mentioned earlier in the text with Norway and hydrogen. This example shows how a nation state tries to force development on a niche in order to give it stimulus for development and a potentially raise its chances for gaining a significant market share. One reason for nation states to force development on a niche is due to landscape pressure as argued earlier in the thesis. However, this can be seen as an indirect effect, while the more direct effect is that the nation state wants to developed their industry into new potential areas of interest that can change the society in the future, and hopefully become an industrial leader within the field. And, as Norway historically have been a sea nation, it is in Norway's bests interest to continue with this industry in the future as well.

The arguments mentioned above can be seen with Grin et al.'s (2010) basic premise for a transition is about structural changes in subsystems in our society. Norway and Maersk is then conducting transition management, which is when one tries to influence the system into going the direction one want it, where the goal is to solve the problem(s) involved.

6.3.2 The case for transformation

In the case of a transformation, this study reveals that the implementation of IMO2020 have a top down approach. The regulation was formed by landscape pressure and political pressure as it is air pollution that is the backbone for the regulation, and IMO control the trajectory of the regulatory framework for IMO2020. As Grin et. al. (2010) argues that the transformation pathway is happening through landscape pressure on the regime, forcing it to reorient their system, this will not lead to niche technology replacing the regime. However, societal pressure will make the regime take action in relevance with the landscape pressure, while not

disrupting the basic system of the regime. This can be seen with Maersk, where the increasing knowledge and action against air pollution have influenced their innovation practice towards developing new cleaner fuels as well as protecting their image, as one of the biggest shipping companies, that is willing to change with the societal values and not against them. As societal pressure grows the regime will use their capacity to reorient their values and development, and if this development fit with the societal pressure, the mutation within the regime will happen and thus leading to a change (Grin et al., 2010).

The Maersk example shows that the niches was not ready for IMO2020, and thus the regime (Maersk in this case) itself have to develop and control the trajectory of the niches in order to meet the pressure from the landscape. When the regime control the trajectory of the niche, the development of the niche will be more stable and will not disrupt the current system in an explosive manner, thus keeping the current rules of the regime relatively intact. If Maersk is successful with their developments of the niche fuel technology, they would most likely still be the largest shipping company, as they will not be largely disrupted by upcoming external niche developments.

The Maersk example also illuminate the idea of strategic niche management. Strategic niche management is that a niche innovation journey can be facilitated by the creation of niches in protected spaces which allows for experimentation and growth with co-evolution of the technology, practices and regulatory structures (Grin et al., 2010). This enables Maersk to steer the development of their alternative fuels in their desired path.

6.3.3 It is on a transformation pathway towards a transition

As Feola (2015) puts it, the general idea of a transformation is major fundamental change. This did not happen with IMO2020 as it led to incremental development within the regime towards a system that did not fundamentally changed the market, consumerism nor the interaction between the human and the biophysical world. Despite IMO2020 not creating a largescale transformation, it can be arguably be seen more as a regulation that have the potential to lead to a transition in the future, as the policy did create a small change in the development trajectory in the regime. This can be seen in the light of Grin et. al. (2010) where a transformation is a pathway towards transition, through new regimes growing out of old regimes with continuously cumulating changes and reorientations within its system.

The history of IMO global sulphur cap highlights the issue of ship emission were raised in the 1980s, however a global cap was not adapted until 1997 with a 4.5% cap. This came into force in 2005, but it was almost immediately revised, and in 2008 IMO agreed to reduce the sulphur content in marine fuel to 0,5% in 2020, yet it was not manifested until 2016, and in 2012 IMO implemented a sulphur cap at 3.5% (Svensson, 2011). These smaller changes, with the most fundamental change in 2020 from 3.5% to 0.5%, is not a largescale radical change. IMO2020, and the prior sulphur caps, did not change the system significantly and enabled a status quo within the regime in order to ensure business as usual.

Based on the arguments above it is clear that the concept of transition and transformation is somewhat interlinked and have several similarities. This can largely be seen with the arguments of Grin et al.(2010) as transformation is a path towards transition, as well as with the arguments from Hölscher et al.(2018) where the main distinctions of the terminology of transitions and transformations comes from the different research fields of the researchers. Both transition and transformation is about changing a system, however one could argue that the main differences is the speed of change and severity of change, and based on the arguments of Hölscher et al. (2018) the type of system, for example technological system or societal system.

However, as Geels (2011) points out, a transition is a shift from one regime to another regime. A regime change did not happen as the industry selected the most efficient solutions available, fuel switching to VLFSO or using HFO with Scrubbers. The Niche technologies lack regulatory guidelines, life cycle assessment as well as infrastructure, and was thus not ready to exploit the opportunity of IMO2020. However, in the long term, IMO2020 can thus be seen as an important step in a potential transition towards a cleaner shipping industry. Therefore, one could argue that IMO2020, and the shipping industry, is leaning towards the arguments of Grin et al.(2010) that it is in a transformation pathway towards a transition.

The arguments mentioned in the chapters above can be seen with Grin et al.'s (2010) basic premise for a transition is about structural changes in sub systems in our society. Norway and Maersk is then conducting transition management, which is when one tries to influence the system into going the direction one want it, where the goal is to solve the problem(s) involved. The systems in this sense is about structure (infrastructure, markets, and institutions), culture (collective set of values, norms and perspectives), and practices (behavior, routines). The culture is important as a transition usually involves a change of

mindset, and this change of mindset is what enables a transition to develop. However, the shipping industry can be seen as a system with multiple actors involved and consists of complex interactions. This makes transition management a difficult task, in sense that Norway can force a national hydrogen transition, but if that hydrogen transition does not get traction on a global level, it becomes useless. This is because international shipping requires a fuel that is available worldwide, and not only in some countries, and thus the problem will not be solved for the shipping industry on a global scale. IMO itself have the possibility with transition management, as delegates can change the mindset of other delegates through discussion and thus creating regulations that can fundamentally change the structure, culture and practices within maritime shipping (Grin et al., 2010).

7. Conclusion;

The problem statement in this thesis is "*How will IMO 2020 impact the future development of maritime shipping?"* and in order to answer it in the best possible manner, I have analyzed the problem statement through the theoretical framework of the multilevel perspective. The thesis consists of three research questions:

1. Why is not other alternative niches considered a solution for compliance with IMO 2020?
2. What is IMO2020 a result of?
3. Will IMO2020 lead to a transition or a transformation within maritime shipping?

The research in this thesis have shown some of the complexities around the shipping industry and IMO.

In the first research question, the core of the arguments where that the alternative niche technologies was not able to utilize the opportunity of IMO2020 and status quo remains strong, yet we can see the future potential of for example hydrogen, which seems to get more and more traction as a potential fuel for the future. However, the alternative niche technologies are lagging in research and development as well as infrastructure. IMO facilitates guidelines and the regulatory framework and thus the market can decide for itself how to comply to IMO2020, and as the niche technologies was not ready, the industry went for the compliance methods which was most commercially effective, mainly fuel switching to VLSFO or installing scrubbers and using HFO. LNG is a mature technology that could exploit the possibilities of IMO2020, however the technology was to expensive for non-LNG carriers and thus was not able to reap the benefits. Yet, LNG have a large potential as a temporary fuel until 2050, when stricter IMO regulations about GHG emissions will likely be in place.

The core of the second research question is that pressure from multiple levels have influenced IMO2020, yet the main driver is the pressure from the landscape level which further influence the political landscape and the regime pressure. The societal values of wanting clean and safe air amongst the public have spilled over from the landscape level onto the political landscape level, and the regime have to react and adopt those values in order to stay relevant for the future. Because of this, the landscape pressure, as well as the pressure from the political landscape, and the regime, will have an influencing impact at future IMO discussion and regulations, and have clearly influenced IMO2020.

The third research question digs deeper into factors within IMO2020 that can create a transition or transformation in maritime shipping. Based on the arguments made one can say that IMO2020 is leaning more towards the characteristics of a transition, as it did not create a largescale transformation but rather create a small trajectory change within the regime. However, in the case for a transformation it is quite clear that IMO2020 have a top down approach, where the landscape pressurize the regime, forcing the regime to reorient their system, which will not allow niche technology to replace the regime, which is shown by the Maersk example. Although the terminology of transition and transformation is intertwined, the argument made in this thesis shows that IMO2020 is leaning towards the transformation pathway towards a transition.

IMO2020 is a success story, in regards to their to goal significantly reduce SOx emissions. SOx emissions will be reduced with 77% from all ships, which in fact will have positive health benefits on populations close to ports and shipping lanes, and premature deaths as well as other health implications will be reduced. However, this does not come without a cost. Some of the new VLSFO blends may increase the amount of black carbon emissions, and scrubbers only move the problem of sulphur emissions from the air to the sea or land.

After doing research for this thesis it is clear that the direct impact from IMO2020 on the future development of shipping is fairly status quo regarding fuel technology, however the regulation will bring significant health benefits. Using the multilevel perspective to analyze IMO2020 shows the complexity surrounding the regulation, as there a multiple layers of influence affecting the decision making in IMO. However, as this research was done with a time limit, I was not able to fully explore the topic. Further research on the topic could be about the potential health impacts of IMO2020, if the results is as positive as it was projected. Another interesting topic to research is how the different national delegations impact decision making in IMO, in terms of how different setups between industry members, environmentalists, career politicians etc. in national delegations affect outcome in IMO discussion. Life cycle assesments of the different niche fuel technologies would also be an interesting future research topic.

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