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Tittel *:	Shipping Stakeholders Risk Management Perspective Based on Drivers, Barriers, Enablers and Collaborative Partnerships During the Transition to Sustainable Fuel
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Master Thesis

- Shipping Stakeholders Risk Management Perspective Based on Drivers, Barriers, Enablers and Collaborative Partnerships During the Transition to Sustainable Fuel -

Study Program

MSc in Business, Major in Supply Chain and Operations Management

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Supervisor

Eirill Bø

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Secondly, we thank our interview objects for giving us valuable information considering our data collection phase. Our interviews were exciting, encouraging and gave us relevant insight into how the actors relate to our chosen topic.

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Thank you,

Håkon Løkensgard | Nitharrshan Sangarapillai

Abstract

The transition to sustainable fuels in shipping is necessary to satisfy the requirements set by the International Maritime Organisation and the European Union. The shipping industry's emission rate is increasing and has the potential to decrease through greener fuels. The transition poses several risks for shipping stakeholders. However, this master thesis limits its focus to fuel producers, shipping companies and ports. This paper analyses how drivers, barriers, enablers and collaborative partnerships support the three stakeholders' ability to identify- and mitigate their respective risks considering the transition. A qualitative study based on expert interviews was conducted to address the topic and answer the research question adequately. The research is based on nine expert interviews, five in-depth presentations during our attendance at Nor-Shipping 2023 and literature. The results revealed the main drivers to be regulations and policies, economic and financial drivers and sustainability. The main barriers are fuel feasibility barriers and prices- and costs of greener fuels. The main enablers are fuel feasibility enablers and economic and financial subsidies to satisfy the stakeholder's long-term investments due to the industry's capital intensity. The results also reveal the importance of collaborative partnerships to make progress and strive to find solutions that collectively benefit all stakeholders. Lastly, the results revealed identified risks for the three stakeholders and the respective risk mitigation strategies using the COSO ERM framework. In all essence, the results revealed that risk management, by addressing drivers and barriers, facilitating enablers and encouraging collaborative partnerships, decreases the risks that face the three stakeholders in the transition to greener fuels.

Table of Content

Table of Content - Figures & Tables

List of Abbreviations

CII	Carbon Intensity Indicator
CO2	Carbon dioxide
COSO	Committee of Sponsoring Organisations
DNV	Det Norske Veritas
EEDI	Energy Efficiency Design Index
EGCS	Exhaust Gas Cleaning System
ERM	Enterprise Risk Management
ETD	Energy Taxation Directive
ETS	Emission Trading System
EU	European Union
FAME	Fatty Acid Methyl Ester
FMA	First Mover Advantage
GHG	Greenhouse Gas
HFO	Heavy Fuel Oil
HSFO	High Sulphur Fuel Oil
HVO	Hydrotreated Vegetable Oil
IEA	International Energy Agency
IFO380	Intermediate Fuel Oil With A Maximum Viscosity of 380 centistokes
IMO	International Maritime Organisation
kWh	Kilowatt Per hour
LNG	Liquified Natural Gas
LSMGO	Low Sulphur Marine Gas Oil
MARPOL	Marine Pollution
NOx	Nitrogen Oxide
PM	Particulate Matter
SOx	Sulphur Dioxide
ULSFO	Ultra Low Sulphur Fuel Oil
VLSFO	Very Low Sulphur Fuel Oil

Chapter 1 - Introduction

1.1 Aim & Motivation of the Thesis

This master thesis investigates how risk management practices can reduce risks for stakeholders towards the transition to sustainable fuel in the shipping industry. The three stakeholders are fuel producers, shipping companies and ports. Our thesis seeks to investigate how their drivers, barriers, enablers and collaborative partnerships influence the decision-making processes considering crucial risk mitigation strategies of the stakeholders to adapt and implement sustainable fuels in their operational procedures. Existing research provides insights into the drivers, barriers, and enablers of transitioning to sustainable fuels in the shipping industry. However, there is a knowledge gap regarding how these factors interact in managing risks from the perspectives of fuel producers, shipping companies, and ports and how collaborative partnerships can be leveraged to mitigate identified risks further.

Firstly it is essential to address how much of an influence the shipping industry has on a global level, both economically and environmentally. The industry represents 80% of the world trade and emits approximately 3% of the total greenhouse gas emissions (Balcombe et al., 2019), (Schwartz et al., 2020). The distribution of GHG emissions produced by the global shipping industry in 2018 shows that carbon dioxide represents 91,32%, which indicates that the transition to greener fuels can reduce GHG emissions drastically (Statista, 2023a; Appendix 1). 3% of the total emission is approximately 700 million metric tonnes of CO2 annually, and the International Energy Agency (IEA) forecasts a decrease to 120 million metric tonnes by 2070 (Statista, 2023b; Appendix 2). Due to the severity of climate change, it is crucial to assess how to decrease the environmental impact and eventually decarbonise the shipping industry. The initial driver for the whole industry is the GHG strategy published by the International Maritime Organisation (IMO) to reduce GHG emissions to decarbonise the shipping industry (IMO, 2023d; Appendix 3). The thesis will dig into the three stakeholders' drivers, barriers, and enablers towards adapting alternative fuel. In addition, view how collaborative partnerships can assist in creating risk mitigation strategies for the identified risks.

Firstly, the drivers for the three stakeholders will emphasise how (1) regulations and policies, (2) economic and financial drivers, and (3) sustainability enhances the transition to alternative fuel. Secondly, the most significant barriers that counteract and disincentive the transition process is (1) fuel feasibility barriers and (2) prices and costs of alternative fuel. Lastly, the enablers towards the transition are (1) fuel feasibility and (2) economic and financial subsidies. Furthermore, our thesis strives to emphasise how collaborative partnerships have a significant role in risk management. Our research will investigate how collaborative partnership improves stakeholder risk management practices.

The drivers, barriers and enablers examined the underlying motivation and the specific challenges the stakeholders face. Our thesis seeks to thoroughly investigate how to effectively mitigate risks and minimise the potential impact by implementing feasible strategies during the transition to alternative fuel by examining the three themes deeply; (1) Drivers, Barriers, and Enablers, (2) Collaborative Partnership, and (3) Risks and Risk management for each stakeholder. Our research will provide valuable insights and recommendations for developing risk management strategies that can facilitate a feasible transition.

1.2 Problem Statement

Effective risk management strategies are vital to successfully navigate this transition and ensure the adoption of sustainable fuels with minimal risk. Furthermore, the literature we have reviewed emphasises greatly the broader challenges and opportunities associated with sustainable fuels, but related to risk management practices, there is limited research that specifically addresses how the three stakeholders shall position themselves in the transition phase. The knowledge gap hinders the developing and implementing risk management strategies suited for the stakeholders in the shipping industry's transition. This leads us to our research question:

How can risk management reduce shipping stakeholders' risks based on drivers, barriers, enablers and collaborative partnerships in the transition to sustainable fuel?

The stakeholders require evidence-based insights and recommendations to develop effective risk management strategies. Our thesis seeks to fill the knowledge gap and serve as a guide for managing risk in the shipping industry, considering the transition to sustainable fuel from the stakeholder's three perspectives. To answer our research question, we have conducted a qualitative study which is emphasised thoroughly in Chapter 2.

1.3 Justification and Contribution to the Research Area

Our thesis aims to identify the current risks and contribute to risk management practices which can be used by all the stakeholders through a flexible framework. During the thesis different terminologies are used for sustainable fuel such as alternative fuel, greener fuel, cleaner fuel and environmental-friendly fuels. The risks that the industry faces today will change towards 2050. It is essential to continuously explore new drivers, barriers and enablers in this industry to implement suitable risk management practices to support the three stakeholders in an uncertain future. Our research contributes to a more thorough understanding of the risks and risk management considering the current situation and applies to the three stakeholders. Due to the level of uncertainty in the shipping industry, it is challenging to conclude with a fixed solution based on our risk mitigation practices which apply to all the stakeholders. However, since we have thoroughly examined and justified the risks, we are confident that we have established risk management strategies that can be applied to the stakeholders. By identifying effective risk management strategies, our thesis strives to ease up the decision-making process in the industry.

Furthermore, our research contributes to a broader research of the possibilities to achieve sustainable shipping practices, which are further beneficial to the environment, solely based on risk management practices that protect the interest of the respective stakeholders. In addition, our research seeks to navigate efficiently towards the required transition. Our research fills the knowledge gap on how drivers, barriers and enablers interact in managing risks from the stakeholders' perspectives and how collaborative partnerships can be leveraged to mitigate identified risks further.

1.4 Limiting the Scope of Research

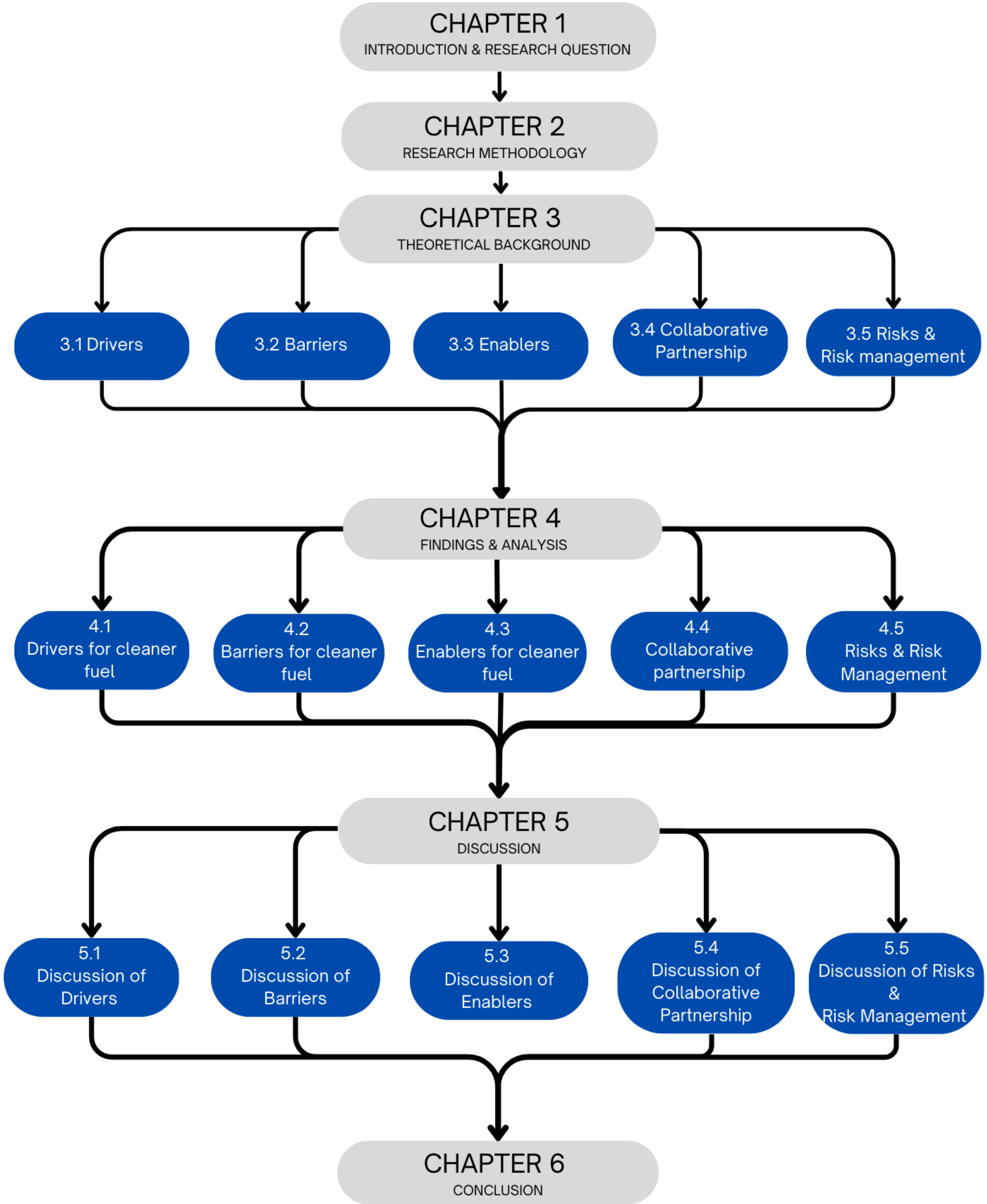
Numerous topics can be investigated in the shipping industry. During the interviews, we discovered that the interview object's focus covered their willingness to take risks considering the transition. We also discovered that collaborative partnerships were mostly favoured among the stakeholders, which was emphasised significantly and the main topic at the Nor-Shipping 2023 conference. Additionally, we wanted to investigate why the stakeholders hesitated to develop suitable and sustainable operational procedures aligned with the objectives set by IMO. This further highlighted the necessity to investigate the drivers, barriers, and enablers of the stakeholders to discover their hesitancy in transitioning towards implementing alternative fuel options.

As emphasised, IMO demands that the shipping industry stakeholders operate more sustainably. Practically, it means conducting significant investments to satisfy the demand from IMO and other regulatory entities. However, the shipping industry is capital-intensive, and the lack of risk management practices and feasible solutions suitable for existing infrastructure or fleet is present, naturally making the stakeholders hesitant. This field of research is very relevant and has enormous potential for further research, which will benefit the stakeholders significantly. Thus we have investigated how drivers, barriers and enablers describe the behaviour of the stakeholders and how collaborative partnerships are a vital risk management practice which can decrease the risks stakeholders face during the transition to greener fuels.

1.5 Thesis Structure

The structure of this paper is firstly to elaborate the methodological approach in the thesis. Chapter 2 justifies the conducted research strategy and design and why qualitative study with expert interviews is the most practical approach for our research investigation. Within Chapter 2, we emphasise how the primary - and secondary data is collected. The secondary data collection is further elaborated in detail in Chapter 3, emphasising the vital theory related to drivers, barriers, enablers, collaborative partnership and its importance for the stakeholders. Lastly, in chapter 3, it is emphasised what risk management is and how the decided frameworks and tools can help to mitigate and establish practices that apply to the stakeholders. Chapter 4 highlights the findings extracted from the primary data collection. Furthermore, in Chapter 5, based on the findings in Chapter 4, a thorough discussion is conducted by comparing the theoretical background with our findings. Chapter 5 emphasises the most critical risks and how those risks can be mitigated for the stakeholders. In Chapter 6, our conclusion is presented in order to answer the research question. Furthermore, Chapter 6, it is suggested aspects for future research and the research study's limitations. The thesis structure is illustrated in the figure below.

Figure 1 - Illustration of Thesis Structure



Chapter 2 - Research Methodology

Throughout the thesis, our methodology and work process is structured to answer our research question. Through a qualitative research strategy and primary data collection based on expert interviews and secondary data collection based on relevant literature, we have obtained the information we need to be able to address how fuel producers, shipping companies and ports can manage their risks based on drivers, barriers, enablers and collaborative partnerships in the transition to greener fuel.

2.1 Research Strategy

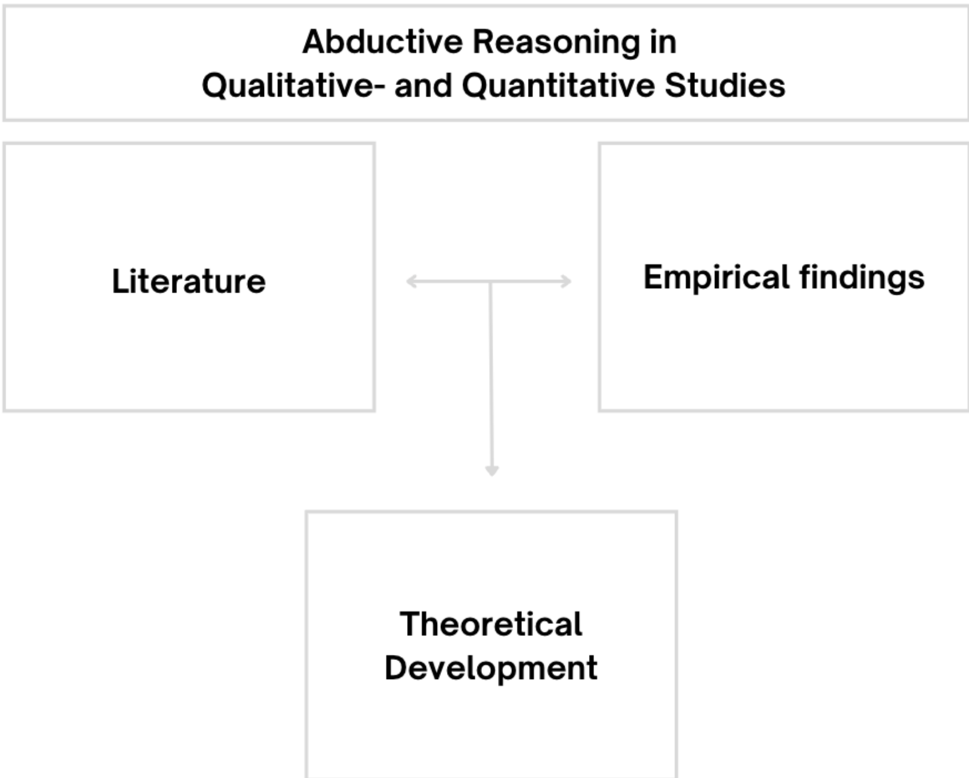
A research strategy can be defined as either quantitative, qualitative or mixed-method. The research strategy refers to the technique the researchers used to compile and analyse the data obtained from the study (Bell et al., 2019). When gathering and analysing data, quantitative research strongly emphasises quantifiable information. Instead of using numbers, the qualitative research technique expresses ideas through words and visuals (Bell et al., 2019). Combining quantitative and qualitative research, we can create a study based on a mixed method that analyses data based on numerical and non-numerical data. Even though we viewed and applied lots of numerical data through analyses and reports, it does not justify applying a mixed method approach because we are not conducting any quantitative analyses such as regression models.

We conducted a qualitative research strategy to understand better how the knowledge of drivers, barriers, enablers and collaborative partnerships may support the shipping industry in reducing risks considering the transition to greener fuels. We can acquire that deeper understanding using qualitative research since it allows us to interact closely with experts in the shipping industry and their collaboration partners, who can contribute with their perspectives. Additionally, we wanted to view the feasibility of the most relevant fuels in order to discuss how realistic their implementation is. In addition, it is essential to understand details within the different fuels, e.g. size of investments related to risks, cost-benefit analyses and provide specific objectives for different actors.

2.1.1 Scientific Approach

Deductive and inductive research methodologies are frequently distinguished by researchers (Bell et al., 2019). The inductive strategy makes particular observations and adds to the theory through discoveries, whereas the deductive approach concludes what is previously known and tests the theory (Bell et al., 2019). A third strategy, known as abductive, which involves switching back and forth between literature and empirical data, is a combination of the first two methods, which creates theoretical development. We have chosen the abductive approach for our thesis, illustrated in the figure below.

Figure 2 - Abductive Reasoning in Qualitative- and Quantitative Studies, made by authors based on Bell et al. (2019).



Abductive reasoning, also known as systematic combining, will be used in our study because it overcomes the drawbacks of deductive and inductive research (Bell et al., 2019; Dubois & Gadde, 2014). Abductive reasoning aims to create explanations for observations by first observing them and then continuously comparing theory and data (Bell et al., 2019; Dubois & Gadde, 2014). This provides a better understanding of how risk might be reduced by acquiring greater knowledge of drivers, barriers, enablers and collaborative partnerships between fuel providers, shipping companies, and ports. The abductive approach allowed us to start with theoretical research, gain understanding from primary data, and then create theoretical insights into the variables influencing our topic. A preliminary theoretical study of how risk management can reduce the three stakeholder risks based on driver, barrier, enablers and collaborative partnerships in the transition to alternative fuel was undertaken in the early stages of the thesis development. We improved our data collection through our primary collection due to an insufficient investigation into our initial research question. An abductive approach made it easier to examine and redefine our problem statement and theoretical background regularly. In order to ensure that the existing literature and theoretical basis were in line with our master thesis progression, changes to our theoretical background were made continuously throughout the whole primary data collection period. We also improved our research by updating our initial conceptual framework and adding new data from our primary and secondary findings.

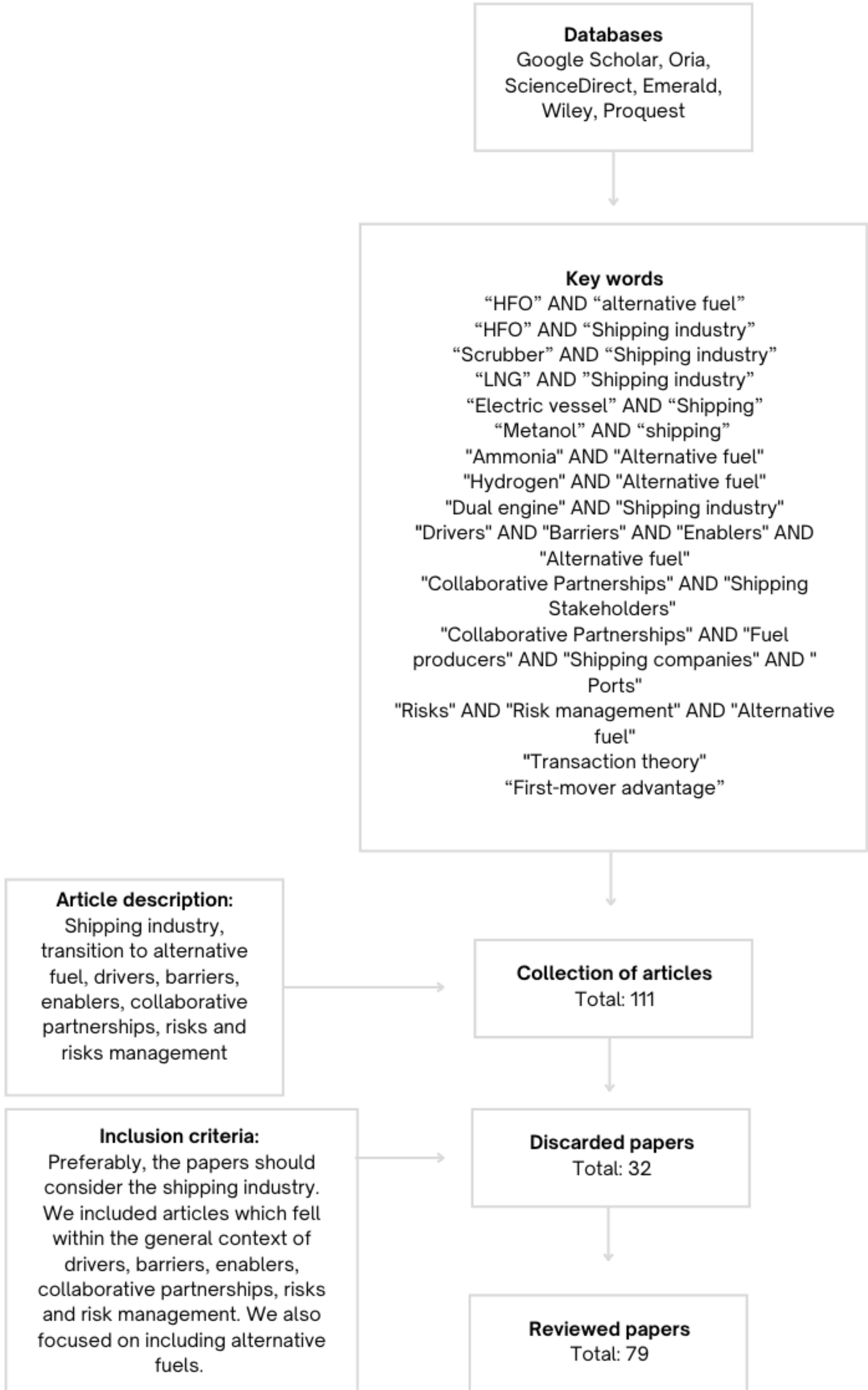
2.2 Research Methods and Design

Single and multiple case studies were discussed during the research design phase. However, we chose expert interviews as our research design since they are frequently undertaken to understand better a particular issue (Bell et al., 2019; Bogner et al., 2009). Additionally, expert interviews were the most suitable fit as we focused on the three stakeholders. It was exciting to interview various shipping industry professionals and attend Nor-Shipping 2023 to broaden our understanding of the topic. Due to their in-depth expertise and domain experience, the experts are recognised as specialists and offer valuable insights into their view of the transition to alternative fuel. Considering our expert interviews, we created an interview guide focusing on three themes; (1) Drivers, barriers and enablers considering the transition of fuel, (2) Collaborative Partnerships and (3) Risks and risk management. Before the interviews, we adapted the interview guide to suit the interview object and extract relevant information.

2.3 Literature Study

In the 21 century, the focus on alternative fuels has gained more attention. However, it accelerated in 2011 because the International Maritime Organisation (IMO) initiated its first regulatory measures to reduce GHG emissions. In 2018, IMO published an initial GHG emissions strategy to decarbonise the shipping industry through a short, medium and long-term plan (IMO, 2023d). In light of this initiative, we have focused on secondary literature from 2018 until 2023 in our theoretical background. However, since alternative energy is well-researched, we have availed ourselves of literature from 1985 to 2023. To construct a structured theoretical background, we used specific keywords and search strings, which we used throughout our search for relevant literature. The literature used was found through Oria (BI Library) and Google Scholar. ScienceDirect, Emerald, Wiley and ProQuest were the academic databases that were utilised the most frequently. We primarily reviewed peer-reviewed articles published in international journals to ensure high-quality papers. Important and relevant documents were collected from trustworthy websites, i.e. IMO's official website. Different reports were collected from some of our primary interviews as they were eager to support us with relevant information. The reports were written by the companies our interview objects worked for, which helped as this gave insight into how the shipping industry views regulatory implementations. However, we read the reports objectively, as we could imagine them somewhat biased. View Figure 3 to get a complete overview of the applied literature.

Figure 3 - Literature Overview and Selection Process, made by authors.



2.4 Data Collection

In qualitative research, data collection is a crucial component of the study. As primary data, researchers frequently conduct interviews or questionnaires, and as secondary data, they collect information from reports and existing literature. Gathering data offers the chance to gain first-hand understanding and insight into the problem statement. Along with data collection comes considerations in handling the data. To a more significant extent, it is essential to protect the collected data due to several factors, such as obeying the degree of information sensitivity and anonymity set by the interview objects. In addition, we will be considered more reliable by the interview objects by following ethical norms and standards.

2.4.1 Primary Data Collection

Our research consists of primary- and secondary data collection. Primary data collection is defined as data collected and conducted by the researcher (Bell et al., 2019). In our primary data collection, we conducted semi-structured interviews as the base of our research design to gather detailed and hands-on data, explanations and results from our interviewees. We created an interview guide (Appendix 4) focusing on three aspects; (1) Drivers, barriers and enablers considering the transition to alternative fuel in the shipping industry, (2) Collaborative partnerships and (3) Risks and risk management. Through the interviews, we asked open-ended questions, which resulted in the interview being highly fluent. This made us lead the direction of the interview and, at the same time, let the interview object highlight the critical aspect of the topic. Before the interviews, we adapted the interview guide to suit the interview object to extract relevant information. Due to the characteristics of a semi-structured interview, we did not necessarily follow the interview guide step-by-step as some interviewees began to dig deeper into topics they were committed to and specialised in. Some interviewees were so committed to our topic that they spoke non-stop for several hours. This resulted in a deeper understanding of our topic in a short period which we were later able to investigate further. To get the best outcome of the interviews, we got familiar with the settings of where and how the interview would take place. During the interviews, we transcripted our interviewee's answers to our questions and sent them back to them for confirmation. Table 1 below lists the interviews we did, showing the interviewees' date, ID, type of stakeholder, company ID, title, duration and type of interview.

Table 1 - Interviews, Interview Objects and Nor-Shipping Conference

Date	ID	Stakeholder	Company ID	Title	Duration and Interview Type
07.02.2023	ID-1	Shipping company	C1	Logistical director	2 hours - Physical
07.02.2023	ID-2	Shipping company	C2	Ship broker	2 hours - Physical
16.02.2023	ID-3	Port	C3	CEO	1,5 hours - Physical
07.03.2023	ID-4	Shipping company	C4	CEO	1 hour - Digital
08.03.2023	ID-5	Port	C5	CEO	1 hour - Digital
13.03.2023	ID-6	Fuel Producer	C6	CEO	4 hours - Physical
14.03.2023	ID-7	Port	C7	Marketing director	1 hour – Digital
15.03.2023	ID-8	Shipping company	C8	Senior advisor	1 hour - Physical
15.03.2023	ID-9	Port	C9	Head of plan and environment	30 min - Digital
NOR-SHIPPING 2023 CONFERENCE					
07.06.2023	ID-10	Private equity fund	C10	Co-Founder & Managing Partner	45 min - Physical
	ID-11	Shipping company	C11	Business developer	45 min - Physical
	ID-12	Fuel Producer	C12	Business developer	45 min - Physical
	ID-13	Shipping company	C13	Investment director	45 min - Physical
	ID-14	Shipping company	C14	Strategy manager	45 min – Physical

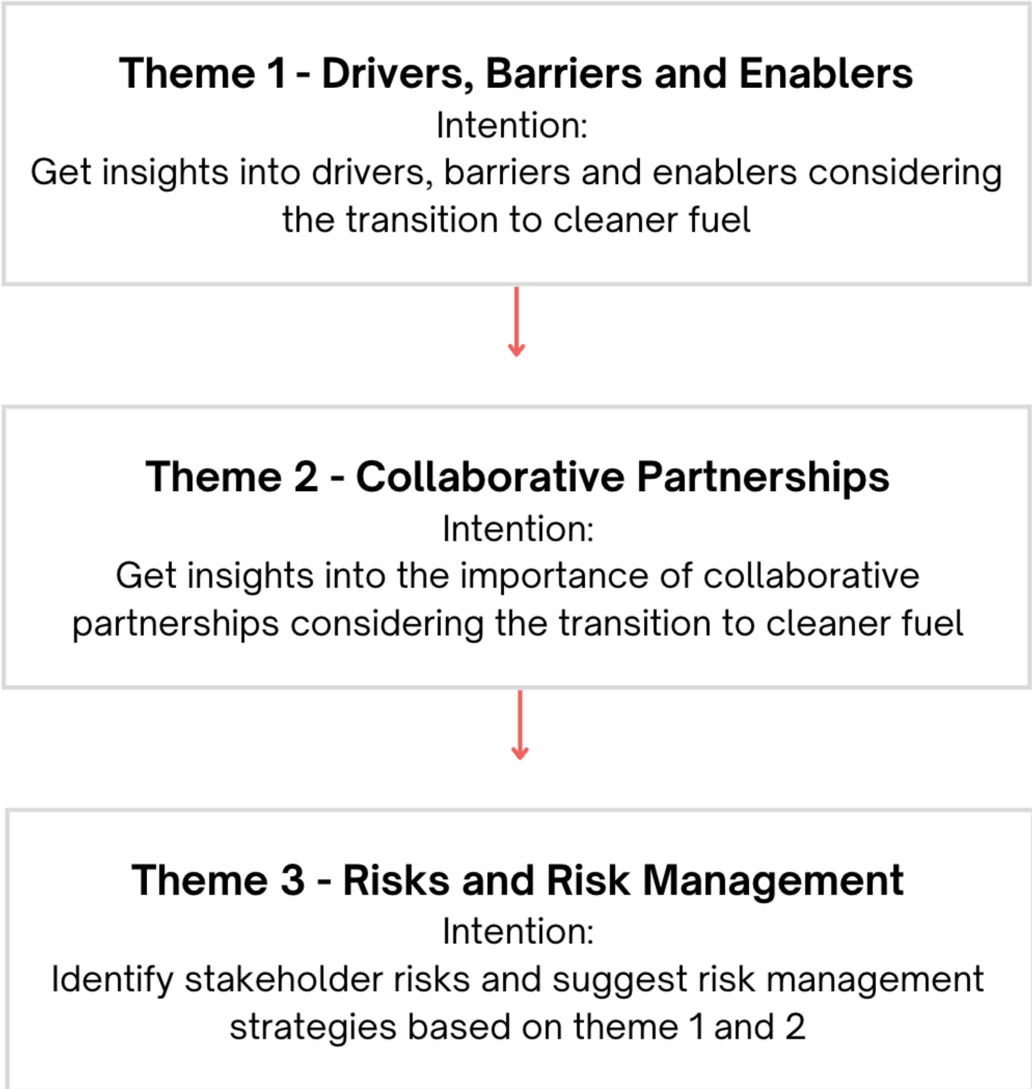
2.4.2 Secondary Data Collection

Our secondary data is previous research focusing on peer-reviewed articles. In addition, we have collected documents and reports related to our research topic and used them as secondary data. Bell et al. (2019) highlight that our findings in primary data collection can deviate from our secondary data collection. Especially the data collected from peer-reviewed articles. Deviation can, for instance, occur by the time gap between the creation of the secondary literature and facts that occur during our investigation while analysing our primary data collection. However, we have been able to draw new conclusions and findings by comparing data withdrawn from our primary interviews compared to secondary research.

2.5 Data Analysis

Analysing qualitative data collected from primary and secondary research was overwhelming initially since a significant amount of data was available. There are specifically two strategies where we will conduct a thematic analysis. Firstly, it is to be aware of factors such as repetitions, categories, metaphors and analogies, transitions, similarities and differences, linguistic connectors, missing data, and lastly, theory-related data (Ryan & Bernhard, 2003). One of the most frequently used criteria for determining a pattern within the data is the emphasis on repetition (Bell et al., 2019). To define the most frequent themes, we will also emphasise this criterion and look into the transition of the different topics being discussed in the interviews. Secondly, we find it essential to find similarities and differences between the interview objects to find common grounds and consider missing data. We created three themes illustrated in the figure below to implement the two thematic strategies.

Figure 4 - The Thematic Approach of the Thesis, made by authors.



Theme 1 is drivers, barriers and enablers considering the transition to alternative fuel, theme 2 is collaborative partnerships, and theme 3 is risks and risk management. The themes are based on the thesis topic, interview guide and the most relevant themes discussed during the interviews. When analysing and comparing our primary data against our secondary data, we could map out the knowledge gap, simplifying how we wanted to write the thesis.

2.5.1 Primary Data Analysis & Secondary Data Analysis

Structuring primary data can be challenging since the interviewees contribute with much information in a short period, but having conducted nine interviews with a thematic approach and attended Nor-Shipping 2023, where we attended five company presentations which also facilitated a discussion panel to broaden our primary data collection.

Secondary data can also be structured by redundant data and by the most frequent similarities and differences in the collection. Using a thematic approach assisted us in excluding non-valuable data and let us highlight valuable data (Bell et al., 2019). In order to be information critical and ensure the same level of new and relevant data gathered from our primary data collection, most of the second-hand literature used is from 2018 until 2023.

2.6 Quality of Research

Reliability, replicability, and validity are three of the most critical factors for evaluating business and management research (Bell et al., 2019). According to Hammersley (1992), relevance is presented as an evaluation criterion, arguing that validity is still essential. The importance of a topic in its field, or its contribution to the literature in that field, determines its relevance (Hammersley, 1992). Lincoln et al. (1985) and Guba et al. (1994) argue that reliability and validity are not the most suitable methods for creating and measuring qualitative research quality, and other criteria are needed. Therefore Guba et al. (1994) suggest that scientific quality shall be divided into trustworthiness and authenticity as criteria. Trustworthiness is separated into credibility, transferability, dependability and confirmability (Lincoln et al., 1985).

Credibility is crucial because it influences the credibility of the findings and if the data collection matches the theoretical concepts (Bell et al., 2019). To ensure credible research, we focused on respondent validation and triangulation. To get respondent validation, we sent our findings from our interviews to the respective interviewee and got their confirmation. In addition, we used triangulation by collecting and using both primary and secondary data sources to conduct our study (Bell et al., 2019).

Transferability considers the findings to be applied to other sectors, situations or contexts (Bell et al., 2019). If our study is transferable, it can be viewed as generalised. However, Williams (2000) and Onwuegbuzie and Leech (2009) both drew attention to possible issues with generalisation in qualitative research. The proposed transferability of a research study with a relatively small sample size could be questioned. Therefore, Bell et al. (2019) argue that it is nearly impossible to know how the empirical findings can be generalised to other contexts when conducting interviews with a small number of individuals and organisations in a single industry. Our sample of interview objects is all national based except ID-4, an international shipping company. In addition, ID-1, ID-13 and ID-14 operate mainly globally but are based in Norway. The organisations involved have international experience through their global supply chains and therefore correspond with international regulations and technology. In addition, all the other interview objects dealt with international actors to some extent, providing an international experience. However, interviewing almost just national-based experts serves as a limitation since the shipping industry and the transition to alternative fuel is at another scale internationally. By interviewing more international actors, such as international ports and fuel producers, we could have substantiated the transferability of our study to a greater degree.

Guba and Lincoln (1994) introduce the concept of *dependability* as a counterpart to reliability in quantitative research to establish the trustworthiness of qualitative research. In order to ensure dependability, we have made sure that the interviewees have been given anonymised ID codes based on correct GDPR management. Additionally, all stages of the research process are documented, safely stored and easily accessible for externals to review, assess and critique our process (Bell et al., 2019).

The concept of *confirmability* addresses the concerns about our ability as researchers to analyse and present our findings objectively (Bell et al., 2019). We built our master thesis on our previous assignment in the subject research methodology, where we collected amounts of secondary data. Therefore, we have built up knowledge of the different stakeholders, technologies and a general idea of the direction the transition to alternative fuel is heading. However, when we started conducting interviews for our primary data collection, we realised that different stakeholders had different views considering the transition to greener fuel. This was insightful as we expanded our knowledge and conducted a more objective study than our previous assignment.

Additionally, one of the authors had a familiar affiliation to ID-1 and ID-2 and a non-familiar but personal affiliation to ID-4. However, to increase our confirmability, we conducted these interviews with this in mind to extract the primary data objectively. Considering the other interview objects, we ensured an objective data extraction by conducting interviews with objects we had no affiliation. However, we acknowledge that total neutrality is unattainable in business research, as Bell et al. (2019) also argue, but we will strive to be as objective as possible.

Authenticity expresses concerns research's broader social and political implications (Bell et al., 2019). In order to get differentiated viewpoints during the expert interviews we ensured to interview all the different stakeholders. In total, we conducted nine expert interviews, where the interviewees were experts and held positions within fuel production, shipping companies and ports. However, the authenticity of our research breaches slightly due to the numbers of interviews in the respective fields. Underneath fuel production, we conducted only one interview, and underneath shipping companies and ports, we conducted four interviews in each category. Within fuel production, we should have conducted significantly more interviews to ensure a higher level of authenticity of our research. However, to increase our study's level of authenticity we attended

Nor-Shipping 2023 which is Norway's most recognised shipping conference. We attended five company presentations separated between three shipping companies, one fuel producer, and one private equity fund. We especially appreciated the presentation by the fuel producer which gave opposing viewpoints to the one fuel producers we interviewed. Whether our sample size of nine in-depth expert interviews and the attendance at Nor-Shipping 2023 watching five presentations, and asking questions to key shipping stakeholders is enough to answer our research question is questionable. However, due to the time-horison of the master thesis we believe we have a solid possibility to conduct an answer to our research question while contributing to a firm foundation for future research.

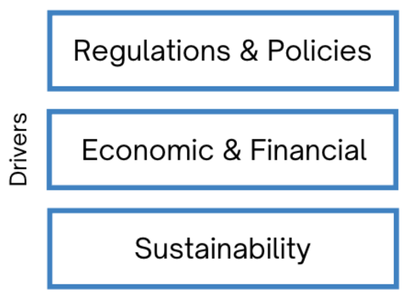
Chapter 3 - Theoretical background

The theoretical background and literature collection are structured to be able to answer the research question. The information in our theoretical background will allow the stakeholders we address to understand the most critical points of reference considering the transition to greener fuels. Firstly, drivers, barriers and enablers will be highlighted considering the transition to greener fuel. Afterwards, transaction theory to view the investments producers, shipping companies, and ports must implement to facilitate the implementation of alternative fuel on a larger scale is emphasised. Moreover, the theoretical background sheds light on first-mover advantage, principal-agent theory, and the theory that underpins how collaboration between the various stakeholders will help to reduce risks. Lastly, we will emphasise how risk management will support the various actors to identify, assess, prioritise and manage relevant risks.

3.1 Drivers Considering the Transition to Sustainable Fuels

According to Longarela-Ares et al. (2020), a driver in the shipping industry is characterised as a factor which encourages investment in energy efficiency measures in the shipping industry. Drivers considering the transition to alternative fuels in the shipping industry are considered regulations and policies, economic and financial drivers, and aiming to reach sustainability goals, as illustrated in the figure below.

Figure 5 - Listed Drivers Considering the Transition to Cleaner Fuels, made by authors.



3.1.1 Regulations and Policies

The regulations, policies and environmental objectives implemented by the IMO and the EU, considering the shipping industry, have been essential to the transition to alternative fuels. IMO is a specialised agency of the United Nations charged with ensuring the safety and security of shipping and preventing marine and atmospheric pollution by ships. The activity of IMO supports the UN's Sustainable Development Goals. IMO is the international standard-setting organisation for the safety, security, and environmental performance of international shipping. IMO's purpose is that ship operators cannot simply cut costs and compromise on safety, security, and environmental performance to solve their financial problems (IMO, 2023c). Its primary duty is to provide a just and efficient regulatory framework for the shipping sector that is widely embraced and implemented. IMO was established to adopt legislation which governments are responsible for implementing. If a government accepts a convention set by IMO, it agrees to implement it as its national law. The specific legislation affecting the transition to alternative fuel implemented by IMO was the Marpol Convention - 1978/83 Annex VI, which prevents air pollution from ships. This entered into force on 19 May 2005, establishing limits on sulphur oxide and nitrogen oxide emissions from ship exhausts and prohibiting the intentional emission of ozone-depleting substances (IMO, 2023b).

On 15 July 2011, IMO adopted a chapter in Annex VI which enacted the first international obligatory regulations to increase ship energy efficiency (EEDI) and therefore aimed at reducing GHG emissions from ships. The EEDI for newly built ships is a highly essential technical metric and aims to promote the use of equipment and engines that are more energy efficient. The EEDI is a non-prescriptive, performance-based process that allows the industry to choose which technologies to implement in a specific ship design. As long as the required energy efficiency is met, ship designers and builders can use the most cost-effective solutions to comply with the regulations. The EEDI provides a specific metric for a given ship design, expressed in grams of carbon dioxide

(CO_2) per ship's capacity mile. To simplify, the lower the EEDI, the more energy-efficient the ship design is (IMO, 2023a).

IMO has taken additional measures in the past decade, including additional regulatory measures and the adoption of its initial GHG strategy in 2018. IMO's initial GHG strategy was adopted to reduce GHG emissions from international shipping. Aiming to phase out GHG emissions and setting levels of ambition, IMO has a set of short-, medium- and long-term goals. The short-term goal involved promoting operational and technical measurements until 2023, such as the EEXI and CII rating system. All ships must calculate their acquired Energy Efficiency Existing Ship Index (EEXI) from 1 January 2023 to assess their energy efficiency and start collecting data for the reporting of their annual operating carbon intensity indicator (CII) and CII rating. The medium-term goal is to reduce carbon intensity by 40% by 2030, relative to 2008 levels, by introducing market-based approaches and low-carbon or zero-carbon fuels. Long-term measures call for using zero-carbon or fossil-free fuels in ships to reduce carbon intensity by 70% by 2050 compared to 2008 levels (Rutherford & Comer, 2018; IMO, 2019; Appendix 3).

In order to update the initial GHG strategy, IMO agreed to review the Initial Strategy to adopt a Revised IMO Strategy on reducing GHG emissions from ships in July 2023 (IMO, 2023d). This summer, IMO will probably implement more ambitious revisions as their initial GHG strategy has been active for five years, and they have now gained more data and insight into how the GHG strategy has affected the shipping industry. At the same time, they will probably carry out revisions based on how their GHG strategy develops over time. However, the main point is to document how IMO's legislation and regulations implemented by nations have affected the shipping industry in the transition to alternative fuels.

In addition, the EU has established an emission trading system (ETS) and an Energy Taxation Directive (ETD). The EU ETS was established in 2005 and operates according to the "cap and trade" theory. The overall amount of certain greenhouse gases that the operators covered by the system may emit is limited. Over time, the cap is lowered to reduce overall emissions. Operators purchase or receive emissions allowances within the cap, which they can exchange with one another as necessary. The restriction on the overall amount of available allowances ensures they have value. While trading gives flexibility that ensures emissions are reduced where it is least expensive, the price signal encourages emission reductions. It encourages investment in cutting-edge, low-carbon technologies. An operator must give up enough credits yearly to adequately cover its emissions or face severe fines. If an installation lowers its emissions, it can keep the extra credits for future use or sell them to a different operator who needs them (EU, 2023a). The EU's Energy Tax Directive (ETD), which was implemented in 2003, establishes structural guidelines and minimum excise duty rates for the taxation of energy goods used as electricity, heating fuel, and motor fuel. As long as the minimum rates are followed, each Member State is allowed to determine its rates. In order to reflect the EU's energy and climate policy frameworks, which call for at least a 55% reduction in greenhouse gas emissions by 2030 and a climate-neutral continent by 2050, EU ETD was established and has been continually updated (EU, 2023b).

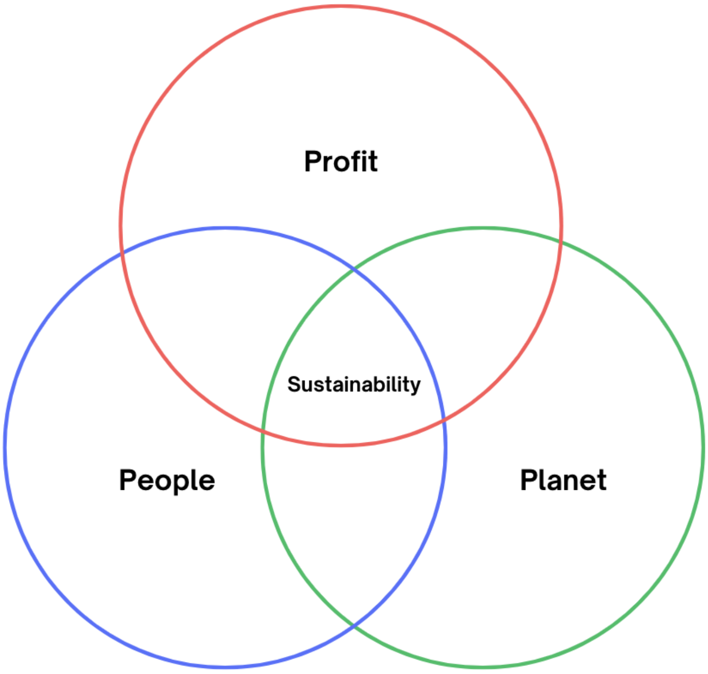
3.1.2 Economic and Financial Drivers for Sustainable Fuel

In relevance to our topic, the economic drivers will be mechanisms that reduce the barrier to making investments related to the transition to alternative fuel. Such drivers that enhance the transition are accessibility to capital, external financing and public financing, and splitting the associated risk among the different stakeholders (Longarela-Ares et al., 2020). More precisely, access to capital is referred to as the possibility of getting financing through loans or subsidies. External or public financing is called governmental financing or financing from organisations such as Enova. Furthermore Longarela-Ares et al. (2020) emphasise that management related to energy-cost can lead to reduced operating costs and, thus, increased profitability, which can eventually be considered a driver. The economic drivers for the shipping industry are explained by the potential benefit of transitioning to alternative fuel. According to Nian et al. (2019), LNG as an alternative fuel may offer cost savings in the long run due to reduced maintenance costs. Furthermore, it is emphasised by Agudelo et al. (2022) that access to resources and funding opportunities was the main driver for being a first mover considering the transition. Respectively for biofuel, the drivers to exploit this resource are due to increased global oil prices. The determined price of HFO is defined by, e.g. disruptions in the supply chain, uncertainties and volatile prices (Kumar et al., 2013). Furthermore, biofuel can be implemented within the existing combustion system (Svanberg et al., 2018). Moreover, the most common financial drivers for electric propulsion systems are motivated by return on investment, lower fuel costs, and first-mover advantage. For methanol, one of the economic drivers is the low production cost obtained due to the ability of the plants to produce significantly more compared to fossil-based plants (Svanberg et al., 2018), and ammonia, on the other hand, is pointed out to be the most economic carbon-free fuel compared to VLSFO carbon-free fuel (Gerlitz et al. (2022).

3.1.3 Sustainability & Triple Bottom-Line

Sustainability, as a general term, is a social, economic and environmental concept that aims to balance the economic and societal concerns regarding the challenges related to the environment. It also considers the possibility of meeting the present needs without limiting the same need for the later generations. More precisely, related to the shipping industry, the sustainability aspect is a driver intended to eliminate the environmental impact of ships (Fasoulis & Kurt, 2019). The triple bottom line is a sustainability framework that considers the components; people, planet and profit, as illustrated in the figure below.

Figure 6 - Triple Bottom-line Framework, made by the authors.

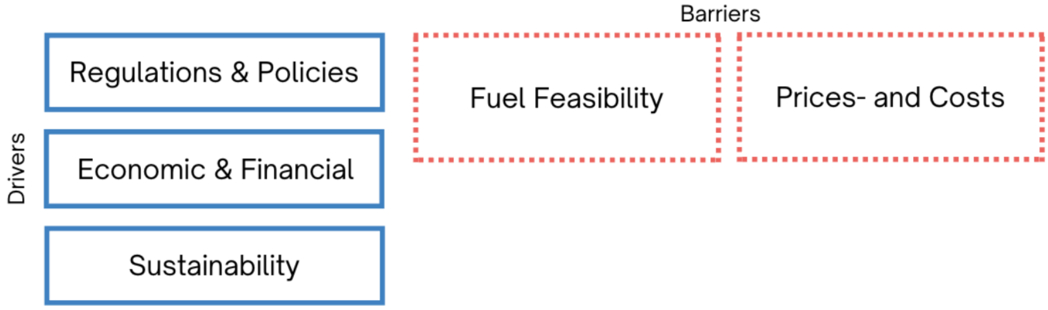


The framework is an approach to sustainable development that considers social, environmental and economic aspects in the decision-making process. This approach aims to ensure that business operates not only financially profitable but also socially responsible and environmentally sustainable (Fasoulis & Kurt, 2019). Specifically in the shipping industry, the component planet considers, e.g. regulations set by IMO in order to reduce GHG emission, while the component people ensure safety concerns related to alternative fuel and lastly, profit considers whether the alternative fuel is financially beneficial (IMO, 2023d; McKinlay et al., 2021; Solakivi et al., 2022).

3.2 Barriers Considering the Transition to Sustainable Fuels

There are barriers related to the feasibility of the different fuel options associated with greener fuels. Another vital barrier to consider when looking at the transition to alternative fuels is the prices and costs of the various fuels, as illustrated in the figure below.

Figure 7 - Listed Barriers Considering the Transition to Greener Fuels, made by authors.



3.2.1 Fuel Feasibility Barriers

DNV conducted a study on how shipowners experience the instalment of scrubbers and if it affects their operations. The study highlights barriers to using scrubbers. Those are backlog because of instalment duration of scrubbers, leakage and corrosion of SOx, and sensor failure, which means that the ships control systems can get the wrong data and therefore cause an unnecessary operational response or falsely suggest that the emission is within the limits which can cause a penalty for shipowners (DNV, 2020).

Song (2021) explains the difference between low-carbon and zero-carbon fuels for ships, e.g. LNG and ammonia, respectively, are called environmental-friendly fuels. According to Song (2021), the most optimistic choices of environmental-friendly fuels are LNG, ammonia, methanol, biofuel and hydrogen. McKinlay et al. (2021) believe the choice is between hydrogen, ammonia and methanol. However, Rutherford & Comer (2018) state that not all options are necessarily the best long-term choices. The environmental-friendly fuels discussed as the most optimistic options towards reaching the goals of IMO are LNG and ammonia (DNV 2018a). However, the forecasts of the most optimistic fuels may change drastically due to technological innovations and feasibility concerns (DNV 2018a). DNV conducted another set of scenario analyses based on the goal of decarbonisation by 2040, which resulted in very different paths (Song, 2021). Therefore, the barrier is the uncertainty considering what fuel the shipping industry will utilise in a long-term perspective considering technical feasibility.

There are several barriers to adopting LNG as a marine fuel. Schinas & Butler (2016) highlight the barriers based on existing facts and acceptable risk exposure. Market trends, operational risk, aftermarket, and regulations have a significant say in decision-making. For instance, no patterns indicate that ships with reduced emission rates attract more customers. Furthermore, it is also unlikely that higher freight rates and costs determined by price dynamic will be acceptable in the market due to being more environmentally friendly (Psaraftis & Larsen, 2010). Operational risk is related to the global availability of LNG. Specifically, there are barriers related to LNG bunkering facilities and LNG availability along the routes that the ships are serving. The geographical constraint determined by the availability of LNG limits the market opportunity and expansion of a firm that operates on LNG ships as well. (Schinas & Butler, 2016). Additionally, LNG is mainly intended as a transition fuel. LNG as a substance is not predicted to be a long-term option for the shipping industry because it is initially a fossil fuel. However, it is the cleanest fossil fuel and is more technologically accessible to power ships than other environmental-friendly fuels (Lindstad et al., 2020). The fact that LNG is seen as a transition fuel leads to a barrier for shipowners. The reason is that shipowners will naturally be sceptical of investing in an LNG-powered ship if it is not a long-term alternative.

Moreover, Gerlitz et al. (2022) discuss the barriers to ammonia's exploitation. Ammonia-propelled vessel technology, supply of ammonia and its value chains include necessary infrastructure upgrades and real-world applications that are still in work (Kurien & Mittal, 2022). An important note regarding the storage of liquified ammonia is the importance of storing it at the correct temperature of -34 degrees Celsius (McKinlay et al., 2021). This leads to the storage process being slightly more challenging on ships. Comparing the production of ammonia with the production of HFO, Law et al. (2021) emphasise that ammonia consumes approximately 26,8 times more energy than the production of HFO from natural gas steam and 37,1 times more energy produced from solar panels before it equals the same energy efficiency as HFO. Law et al. (2021) also highlight the relative energy loss of creating ammonia from natural gas and solar panels to be 45,3% and 53,5%, respectively. As it is less energy efficient, it creates a barrier for ammonia as an alternative fuel for fuel producers and shipping companies. Further, it is emphasised among scientists that ammonia is extremely toxic. Considering the health exposure, pollution of ammonia has a significant impact with long-lasting effects for both humans and ocean life. Acceptable exposure is, however, regulated by different legislations (Green Shipping Programme, 2021). Additionally, production, distribution and capitalisation are still underdeveloped, which makes the implementation of ammonia more relevant to be considered as a long-term alternative (Gerlitz et al., 2022).

Thirdly hydrogen is considered an environmentally favourable option. However, it has some barriers similar to the other fuels. Hydrogen has a significant flammability range in the air, making it potentially explosive. While this is manageable, new norms and regulations for hydrogen storage may be required, potentially resulting in more significant costs and size requirements (McKinlay et al., 2021). To further consider hydrogen as a usable fuel, it is essential to have an approach that considers the energy density. Hydrogen is considered a lighter fuel than the industry's mainstream fuel HFO. However, hydrogen needs a 3.6 - 4.5 larger storage volume to provide the same energy conservation as HFO (Law et al. (2021).

Concerning operating with electrical vessels, Schmidt et al. (2017) mention the barriers related to electrical vessels to be correlated with the operational cost. This is primarily driven by battery cost and capacity, electricity prices or fuel needed to create electricity for charging, mainly from the aggregate. There are three types of electrical ships: plug-in hybrid, hybrid, and all-electrical. The plug-in and hybrid ships combine a traditional diesel engine and a battery. The difference between a plug-in hybrid and a hybrid ship is that the excess energy charges a hybrid ship, and an electrical grid charges the plug-in hybrid ship. (Perčić et al. 2022). The vessels that are hundred per cent electrical driven use electricity for all operational procedures of the ship, naturally. It is essential to highlight the barriers to operating with electrical vessels. Energy and power density, lifetime of the battery, operating temperature range, battery cycles, efficiency and cost performance are some of the many factors that affect the decision-making process (Perčić et al., 2022). Most likely, these barriers constrain the ability to operate sufficiently on electrical vessels.

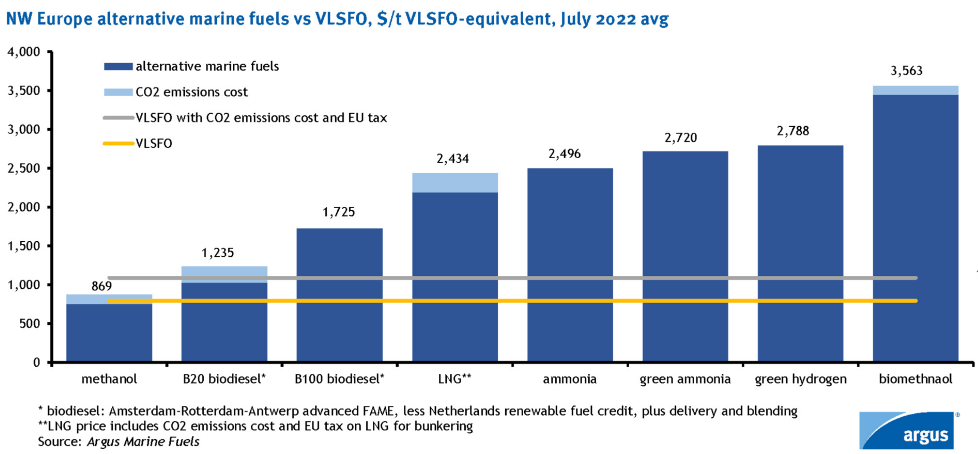
The production of biofuel also faces barriers considering logistics. Distribution, storage and production are three aspects that decrease the incentive with biofuel. Firstly, transporting and storing large quantities of biomass feedstock demand infrastructure as a prerequisite for effective distribution. In-effective distribution has a further impact on greenhouse gas emissions, especially if the transportation of the respective biofuel is provided by fossil fuel (Kim & Dale, 2016). The infrastructure is also costly and may impact the overall cost related to biofuel. Secondly, the storage requirements necessitate the need for specialised tanks, fueling stations and warehouses. The issues related to production are the need for land and how it may affect food production and security (Kim & Dale, 2016).

The barriers fuel producers, shipping corporations, and ports face during the shipping industry's transition to alternative fuels. The feasibility of various fuel options, including LNG, ammonia, hydrogen, electrical vessels, and biofuel, is assessed based on energy density, safety regulations, and cost estimates. There are operational inefficiencies, infrastructure requirements, concerns about flammability, storage restrictions, and high energy consumption. It is essential to overcome these obstacles to enable the widespread adoption of environmentally friendly fuels and attain sustainability goals in the maritime industry.

3.2.2 Prices- and Costs of Sustainable Fuels

The most significant individual cost in shipping is fuel, which can account for more than 50% of daily costs (Furuichi & Otsuka, 2014). According to Hansson et al. (2019), the price of fuels is the most crucial economic factor for decision-makers. Additionally, it is crucial to look at how the various alternative fuels can be compared against VLSFO. In Table 2 below, today's most relevant fuels: methanol, ammonia, LNG, biodiesel and hydrogen, compared to VLSFO. The price of VLSFO includes CO2 emission cost and EU tax, and all the alternative fuels with CO2 emissions cost.

Table 2 - NW Europe Alternative Marine Fuels vs VLSFO, $/t VLSFO-equivalent, July 2022 (Lloyds list, 2022)



In July, methanol was the only alternative marine fuel that costs less than VLSFO at $869 per tonne. However, bio-methanol costs $3,563 per tonne, which is approximately 3.5X the price of VLSFO. The price per tonne of B20 and B100 biodiesel was $1,235 and $1,725 respectively. Shipowners have been experimenting with B20-B40 biodiesel and fuel oil mixtures to reduce CO2 emissions while maintaining a price below that of biofuel with 100% purity (B100). In July, a B20 blend consisting of 20% advanced FAME and 80% VLSFO would have cost 1.2 times as much as VLSFO. In July, the average LNG premium over conventional marine fuels increased to $2,434 per tonne, nearly 2.5 times the price of VLSFO. The EU has made progress in diversifying its gas supplies.

However, even if Norway and Azerbaijan could maximise exports, these efforts are likely only partially to compensate for lost deliveries from Russia, according to the International Energy Agency (Lloyds list, 2022). In addition, ammonia and green ammonia were valued at $2,496 per tonne and $2,720 per tonne, respectively. In other terms, roughly 2.5 times the price of VLSFO. Hydrogen is priced at $2,788 per tonne, and marine shipping considers it a viable fuel option beyond 2030 (Lloyds list, 2022).

The alternative fuels, except methanol, are priced higher than VLSFO in July 2022. Shipping is a cost-intensive industry, and shipowners can make considerable profits in peak times, but they need a cost-effective mindset in downtime. Shipowners are becoming more environmentally aware but are dependent on turning a profit when investing in greener fuels. This provides incentives to choose the cheapest option of fuel. Therefore, if the shipping industry switches to alternative fuel, the prices must become more competitive compared to VLSFO. The table below shows a future fuel price forecast from 2020 - 2050, indicating greener fuels' future competitiveness.

Table 3 - Estimated Alternative Fuel Prices - 2020 to 2050 (Solakivi et al., 2022).

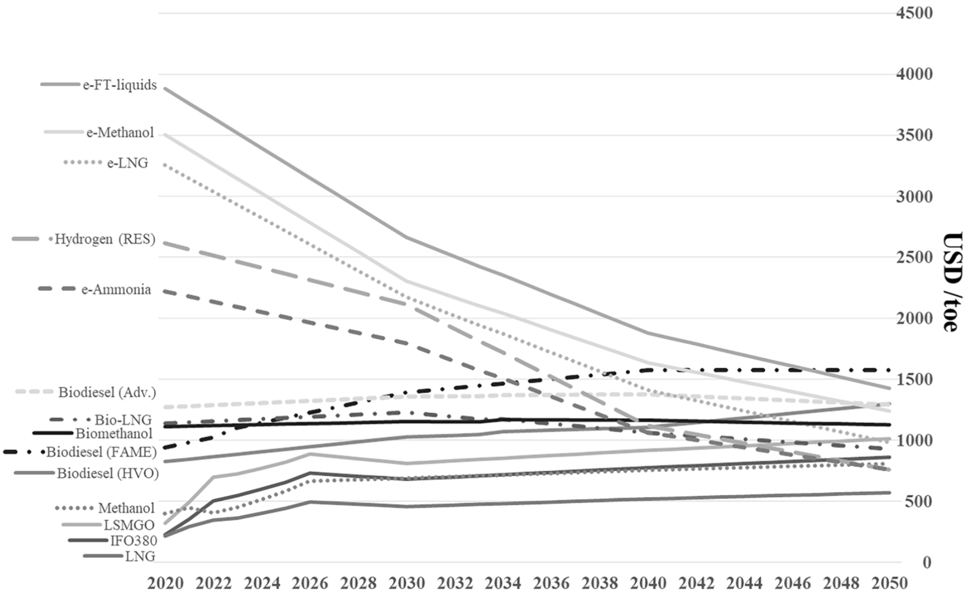


Fig. 1. Medium ("basic") scenario fuel price forecast (EUR/toe).

Even considering the effects of EU ETS and ETD, the primary result indicates that conventional fuels such as IFO380 and LNG will remain competitive in the long term. The production cost of methanol per unit of energy is comparable to that of IFO380. However, the production capacity of sustainable methanol poses challenges, as most methanol produced today is derived from fossil fuels. Biodiesel will continue to be more costly than fossil diesel, and bio-LNG will continue to be more expensive than its fossil counterpart. However, the envisioned regulation will affect the comparative competitiveness of the alternatives, as emission trading and fuel taxes raise the price of fossil fuels. Therefore, the competitiveness of advanced (second and later generation) biofuels will increase, and it is estimated that they will be competitive with FAME biodiesel by 2030, while HVO will be less expensive to produce until almost 2050. In 2044 and 2048, Bio-LNG will be cost-competitive with LSMGO and IFO380, respectively. According to the projection, the cost of producing hydrogen will reach the price of LSMGO in 2045 and IFO in 2048, whereas LNG will likely maintain its cost competitiveness beyond 2050. E-fuels (electricity-produced fuels) will continue to be more expensive to produce. However, their relative competitiveness will increase as their production costs decline and fossil fuels become more expensive. In addition, Solakivi et al. (2022) emphasise that producing cheap electricity is crucial to producing e-fuels. If the necessary supply of cheap electricity is not facilitated, e-fuel prices will not be able to compete.

The results of the forecasts indicate, despite the EU ETS and ETD, that alternative fuel prices will remain significantly higher than fossil fuel prices for an extended period. According to Lindstad et al. (2021), it is anticipated that it will take longer for alternative fuels for current engine technologies to become cost competitive. Considering only the fuel price, the shipping industry will likely continue to rely on fossil fuels for a long time.

Solakivi et al.'s current study demonstrates that emission reduction with fuels will not be cost-effective for an extended period. This result highlights the importance of energy and operational efficiency in reducing shipping emissions. In the short to medium term, shipping will likely wind up paying for a licence to pollute rather than being able to reduce emissions.

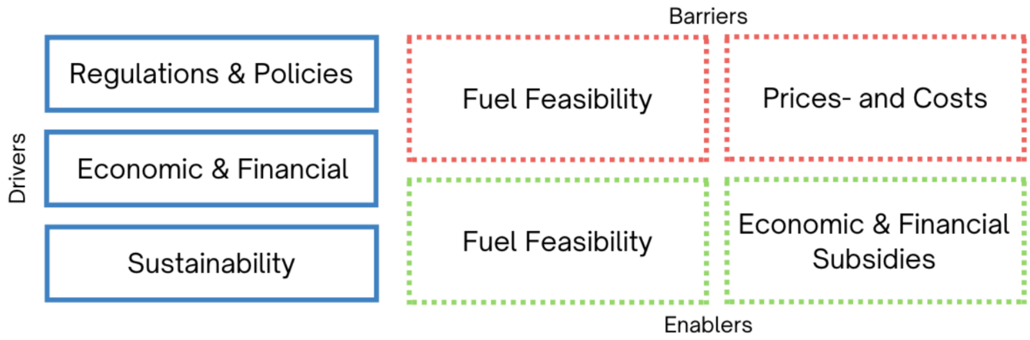
Another cost-effective solution for shipping companies is to use dual-engine technology. However, the cost related to retrofitting the engines is difficult to predict. However, some concrete examples highlight the possible cost of this process. For instance, a cruise ship and a container ship cost USD 11 million and USD 30 million due to this process, respectively (Solakivi et al., 2022). In addition, it is predicted that the cost for the shipping industry towards 2050 is estimated to be $1 trillion to meet the targets from IMO, whereas the uncertainty in regards to the technical feasibility of the retrofitting process is still present (Dinneen, 2022)

The results from the fuel price forecast can assist shipping companies in deciding which technologies to invest in. Whether a shipping company retrofit existing vessels or select an alternative fuel for a new build, the barrier is the investment and operational costs.

3.3 Enablers Considering the Transition to Alternative Fuel

Enablers in the shipping industry related to implementing alternative fuel are driven by cost and the objectives to reduce greenhouse gas emissions. In addition, technical maturity, safety regulations, and demand for fuel and solutions are weighted in the process of going forward with the most feasible solution (Prussi et al., 2021). Various fuels are available in the shipping industry. However, the industry is still uncertain. Thus, enablers in this chapter emphasise fuel feasibility enablers and economic and financial subsidies, as illustrated in the figure below.

Figure 8 - Listed Enablers Considering the Transition to Cleaner Fuels



3.3.1 Fuel Feasibility Enablers

IMO stringent environmental regulations are one of the drivers towards alternative fuels from heavy fuel oil (HFO). HFO has also been extracted into different less polluting marine fuels such as LSFO, VLSFO, ULSFO, LSMGO and IFO 380. In order to comply with the restrictions set by IMO and EU, several shipping companies have implemented exhaust gas cleaning systems (EGCS), or "scrubbers" as it is called. A scrubber cleans the sulphur dioxide through an integrated system on the boat, enabling ships to comply with the restriction of 0,5% of sulphur emitting (DNV, 2018b; Makkonen & Inkinen, 2018).

Even though scrubbers have several barriers, it has been the shipping industry's leading solution for complying with the 0,5% SOx emission limit set by IMO (IMO, 2023d). Specifically, LNG has become a viable fuel option since the fuel can comply with the regulations with the 0,5% SOx emission (Xu & Yang, 2020). Compared with ships that solely operate with conventional fuels, it is shown that LNG ships can reduce CO2 emissions by 20% (Xu & Yang, 2020).

The second applicable fuel is ammonia which is a substance that can be made from fossil fuels, biomass, or other renewable energy sources like wind and photovoltaics, where an excess of electrical energy can be turned into a non-electric form of energy (Valera-Medina, 2018). Gerlitz et al. (2022) document that ammonia, as a carbon-free fuel, fits the IMO's goals and is a possible contender for fully-fledged clean shipping. Additionally, it allows for extended maritime routes with minimal cargo room loss at a fair cost. Beyond 2030, ammonia, produced by renewable power electrolysis of water, might become a significant bunker fuel (Vedachalam et al., 2022).

Thirdly hydrogen is one of the cleanest potential fuels (McKinlay et al., 2021). Important to note that this highly depends on how the hydrogen is produced. For instance, if hydrogen is produced by fossil fuel with carbon capture and storage, it can be considered an environmentally friendly fuel (Law et al., 2021).

The fourth combustion is the electrical propulsion system. In contrast, Nguyen et al. (2020) discuss implementing electrical vessels as an option and consider whether electric propulsion can meet the required designs and technical standards. This is specifically conducted to highlight whether electric vessels have the same or increased efficiency and the capability of being a sustainable propulsion system. The availability of electric propulsion systems has brought several benefits to ship owners. This includes improved compliance with international laws, increased flexibility and reliability, reduced operating costs, and enhanced access to advanced automation capabilities. Thanks to the integrating of electrical systems and power supply equipment in maritime transport over the last several decades (Nguyen et al., 2020). Operating on electric fuel is the environmental option compared to the other fuel types (Perčić et al., 2022).

Moreover, methanol's characteristics are defined by the financial risks and engineering hurdles that are required due to safety factors. However, most of the technology required for safe methanol storage and ship deployment is deemed mature (McKinlay et al., 2021). Furthermore, some considerations enable the use of methanol in the shipping industry. Capacity constraints regarding storage and transport are efficient, and requirements for temperature and pressure are not as rigid as for other substances, such as LNG. Brynolf et al. 2014 highlight further that the energy density of methanol is higher than LNG, which makes the fuel alternative more attractive. The toxicity aspect of the fuel increases its attractiveness as well. As the toxicity of the fuel also plays a significant role in the decision-making process, Shi et al. (2023) elaborate that methanol is less threatening to human and marine environments than HFO and ammonia.

Lastly, biofuel is generally a non-fossil alternative and has a significant role in decarbonising the shipping industry (Tan et al., 2022). In practical terms, it means that the bio-diesel can operate on diesel-driven engines where little to no modification is needed (Balcombe et al., 2019). Furthermore, compared to conventional fossil fuels, biofuels have lower energy content, and thus more biofuel is required to fulfil the exact utilisation as HFO. The benefits of biofuel are that biofuel consumption leads to a significant decrease in sulphur and approximately 60 - 100% Co2 reduction compared with HFO. The exact reduction rate depends highly on which biofuel is considered. Therefore, the emissions from biofuel require more compliance from the shipowners, increasing the cost of biofuel (Solakivi et al., 2022).

Due to several reliability and performance aspects of the different fuel types mentioned above, it is essential to implement a dual engine that contains a high degree of feasibility. In addition to reducing greenhouse gas emissions, the shipowners experience an enhanced competitive market among the charterers. To increase competitive power, the charterers experience the necessity to upgrade their existing fleet, which satisfies the operational standards (Bui et al., 2022). Considering the fuels mentioned above, dual-fuel engines importance has emerged as one of the most promising enablers. This is because of the reduced nitrogen oxide (NOx), CO_2, and almost complete elimination of particulate matter (PM) and SOx emissions generated from their dual fuel operation. Another viable option in addition to the dual engine system is retrofitting the existing engine system, so the need to invest in a new build decreases. Eventually, the retrofitting and the investment done for this specific reason will be a way of hedging against significant economic losses in the longer run. An important note is that the retrofitting of the engines is applicable for several fuel types; hence the feasibility aspect is being complied with.

3.3.2 Economic and Financial Subsidies for Sustainable Fuels

As emphasised by Dinneen (2022), the industry is required an investment cost of close to $1 trillion to meet the targets from IMO. Naturally, the stakeholders in the industry are hesitant to invest in a highly uncertain environment. Thus, as an incentive, economic subsidies are a prerequisite towards the transition. Economic subsidies are characterised as monetary funding provided by the government towards the different stakeholders in the shipping industry. Subsidies are mostly given for a specific service or under certain conditions, but they can also be given without any given expected behaviour from the firm that receives the capital (Merk, 2020). Specific subsidies in the shipping industry are commonly reducing corporate tax. Hence the effective tax burden is lowered if the firms can reach the sustainability aims (Merk, 2020).

Economic subsidies are explicitly intended for firms in the shipping industry to be directed towards a more sustainable path and enable the process by making it less costly. Since the industry is capital-intensive, economic subsidies are an essential enabler towards the transition. Therefore, governmental organisations, such as Enova, must also provide financial support. Related to the Norwegian shipping industry, Enova provides financial support for developing technologies that lead to reducing and eliminating CO2 during operational procedures (Enova, 2023). Furthermore, Enova supports innovative solutions that decrease the required energy levels and solutions that contribute to increased energy efficiency for operating functionally. As for now, the support specifically for electrification of the fleet, development of hydrogen-driven vessels, and facilitation for shore power for the Norwegian maritime industry stands for approximately 1 billion NOK (Enova, 2023).

3.4 Collaborative Partnerships

Chandler et al. (2019) state that when people combine their perspectives and worldviews to create new ideas, they create synergies. Sandberg (2007) found three major factors when considering collaboration in supply chains. First, the intensity of the collaboration and the positive impacts received from the collaboration has a significant correlation. Second, senior management is a crucial driver of higher-intensity collaboration. Third, the difference between practice and theory regarding supply chain cooperation is significant. Cao and Zhang (2010) explain process efficiency, offering flexibility, business strategy, enhanced quality and innovation as five collaborative advantages. The three factors from Sandberg (2007) and the five factors from Cao and Zhang (2010) can assist in solving principal-agent problems.

Liao et al. (2017) emphasise that collaboration in supply chain management is essential for reaching a common goal. Collaboration is more than just the intersection of common goals but a collective commitment to attain a common goal. When faced with competition for restricted resources, firms that collaborate can receive more resources, recognition, and rewards. Stank et al. (2011) stated that developing partnerships with various SC partners increases collective accountability for long-term sustainability. Collaboration is essential in the shipping industry because governments and organisations that promote the transition to greener fuels depend on fuel producers. The fuel producers are dependent on ports to buy the fuel and distribute it to the ships owned by shipping companies. All the actors depend on each other to reach the goals set by IMO for 2050, which highlights the importance of collaborative partnerships.

Ramanathan et al. (2011) divide supply chain collaboration hurdles into organisational and operational categories, with behaviour problems as a sub-category. Brynolf et al. (2016) identify environmental awareness, regulations and enforcement, and technical solutions as critical to collaborate to substantiate environmentally sustainable shipping. Gunasekaran et al. (2015) and Lun et al.

(2016) mention that collaboration can increase excellent value, such as competitive advantages and improved business performance. In addition, Lun et al. (2016) state that collaboration in the shipping industry can lead to minimising transaction costs and improved effectiveness of sustainable shipping management.

Ramanathan et al. (2011) highlight some significant challenges regarding resource sharing. It is difficult to decide, for example, what information needs to be shared with other SC partners without jeopardising privacy. Essentially, Nyaga et al. 2009 emphasise that SC trust will lead to long-term collaborations, and building trust in an SC collaboration is a team effort which includes all participants.

The implementation of greener fuels is a complex matter, and Foretich et al. (2021) conclude that it requires a global perspective that encompasses a wide range of stakeholders and collaboration with numerous partners throughout the shipping industry. Song et al. (2016) stated that cooperation in the shipping industry should be emphasised to a greater extent to address the future structural changes in the sector. Furthermore, scholars argue that for greener fuels to be deemed a feasible solution, the importance of collaborative partnerships must be acknowledged (Al-Enazi et al., 2021).

Within a collaborative partnership, collaboration between the different actors must be reliable. According to Bø et al. (2023), reliability is defined as the probability of all required materials and products flowing through a supply network under arbitrary conditions, maintaining the same level of efficiency and effectiveness. Concerning the shipping industry, the supply of specific fuels must be present with a low likelihood of disruption. The most important aspect of reliability is trusting partnerships with suppliers. Eventually, this will ensure flexibility, enhancing the stakeholders' reliability (Bø et al., 2023).

3.4.1 Principal-Agent Theory

Dirzka & Luo (2021) define principal-agent problems as a disagreement about priorities between a person or organisation (agent) and the principal they have appointed, and an agent may complete actions that do not align with the principal's interests—for example, highlighting the intensity of the collaboration as a critical factor between the principal and the different agents. The willingness of both the principal and an agent to collaborate in listening to what the two parties need from one another to collaborate and reach the target of only using zero-emission fuels depends on their intensity in collaboration. Principal-agent problems will occur for fuel producers, shipping companies and ports in the transition to more environmental-friendly fuels. The principal in today's transition is the governments and organisations working towards a more sustainable future, and fuel producers, shipping companies, and ports are the agents. The principal has different problems with the agents as their interests differ. Considering fuel producers, their most significant interest is to produce and sell fuel, while the principal is demanding fuel producers research and develop more environmental-friendly fuels, which is costly for the producers. Another principal-agent problem is between the principal and shipping companies. The issue is that the principal demands shipping companies to build their new ships using environmental-friendly fuels, i.e. LNG. This can be a massive risk for the shipping companies since their ships can last for approximately 20-30 years, and in that period, the industry might have opted for another fuel than LNG. Another principal-agent problem is between the principal and ports. The problem is that ports must invest considerable amounts in infrastructure to facilitate the storage of new fuels and the infrastructure for ships to refuel. If a port invests in a fuel option that will not be fully utilised, it will be a risk where the port can lose the capital tied up to the infrastructural investment.

3.5. Risks & Risk Management

Risk is a circumstance where the likelihood and impact of unexpected macro- and micro-level events or conditions that adversely influence any part of a supply chain leading to an operation, tactical or strategic level failures or irregularities (Bø et al., 2023; Ho et al., 2015). Top risk professionals generally acknowledge the leading risk management standards now available to be COSO and ISO 31000 (COSO, 2023; ISO, 2023; Sison & Doran, 2023). However, in 2017 the Committee of Sponsoring Organisations (COSO) updated their risk management framework to help companies effectively identify, assess and manage risks (COSO, 2022). To reduce risks in the transition of implementing greener fuels, the different actors need to know how to identify and assess risks using a risk register and manage them. In order to help fuel producers, shipping companies, and ports identify, assess and manage risks, the COSO ERM (2017) is highly applicable to all the stakeholders. The figure below illustrates the framework and how component 1 is the fundament for strategy, objective setting, and risk appetite until the performance is reviewed and the information is shared up and downstream.

Figure 9 - COSO ERM Framework (2017)

The COSO ERM framework consists of five elements: (1) Mission, vision & core values, (2) Strategy development, (3) Business objective formulation (4) Implementation & performance. These four elements have an impactful effect on the last element (5), enhanced value. These elements are more thoroughly described through the five risk management components listed. The revised COSO ERM framework's five components are complemented by a set of guiding principles to manage risks, as shown in Table 4. They define procedures that, irrespective of an organisation's size, type, or sector, can be used to manage risks an organisation can encounter. Following these components can give management and the board a fair expectation that the organisation is aware of the risks related to the transition to alternative fuel. Furthermore, the framework is designed to resemble the DNA of an organisation, emphasising the significance of treating this framework as the very essence of the organisation. The shipping industry contains a variety of firms with different objective settings, financial capabilities and sizes.

The five components in the COSO ERM framework are respectively; (1) governance and culture, (2) strategy and objective setting, (3) performance, (4) review and revision, and lastly, (5) information, communication and reporting. More precisely, the first component, "governance and culture", emphasises the significance of risk management and establishes oversight responsibilities. Culture relates to an entity's ethical values, intended behaviour and risk awareness. The second component, "strategy and objective-setting," establishes the risk appetite, the basis for the strategy development. The strategies are then developed by identifying, assessing and responding to potential risks. The performance component identifies risks that may impact the strategies or the objectives. The risks are prioritised by severity, considering the risk appetite established in the previous component. The fourth component reviews the obtained performance and considers whether changes in strategies and objectives are required. The fifth and last component necessitates the transparency of information-sharing up and downstream in an organisation considering external and internal aspects.

Table 4 - Guiding Principles for the Five Risk Management Components

Governance & Culture	Strategy & Objective-Setting	Performance	Review & Revision	Information, Communication, & Reporting
1. Exercises Board Risk Oversight 2. Establishes Operating Structures 3. Defines Desired Culture 4. Demonstrates Commitment to Core Values 5. Attracts, Develops, and Retains Capable Individuals	6. Analyzes Business Context 7. Defines Risk Appetite 8. Evaluates Alternative Strategies 9. Formulates Business Objectives	10. Identifies Risk 11. Assesses Severity of Risk 12. Prioritizes Risks 13. Implements Risk Responses 14. Develops Portfolio View	15. Assesses Substantial Change 16. Reviews Risk and Performance 17. Pursues Improvement in Enterprise Risk Management	18. Leverages Information and Technology 19. Communicates Risk Information 20. Reports on Risk, Culture, and Performance

Within the performance component, several tools are used to identify, assess, prioritise and implement mitigation strategies for the identified risks. Risk identification is needed to later have the possibility to assess, prioritise and eventually develop mitigation strategies to handle the respective risk. Furthermore, risk identification aims to identify all critical risks and potential future uncertainties to manage them proactively (Fan & Stevenson, 2018). The risks concern the environment, collaboration between partners, and internal organisational risk. Risks due to delays and disruptions are also presented as significant factors considering risks related to uncertainty (Sodhi & Tang, 2021).

Risk assessment identifies the potential threats to achieving the business objectives and their potential outcomes (Medina-Serrano et al., 2020). In qualitative risk assessment, the impact of an arbitrary risk can be ranked from low, medium, high, or on a scale from 1 - 3, for instance. The impact of risk is determined during the risk assessment. In contrast, the probability of a risk occurring is decided through in-depth analysis by the given actor or by a third-party expert assessing the risks. The results are then mapped in a risk heat map to illustrate the severity of the risks. It is worth noting that the actors have their perception of how an unpredicted disruption will impact their operation. After the assessment, it is possible to prioritise the risks in a risk register to identify the highest probability of occurrence and the risk that has the most significant impact on achieving the business objectives. Practically the risks severity is calculated by the formula below;

Impact of the risk x Probability for the risk to occur = Risk

Thus, implementing mitigation strategies further to respond to the identified risks is self-explanatory. One mitigation strategy is developing contingency plans to reduce risk and respond effectively to disruptions. However, developing such plans involves specific difficulties due to the ongoing risk changes. Additionally, the cost associated with developing the plans must be weighed against the cost of not having the plan and facing the consequence (Bø et al., 2023).

3.5.1 Transaction Theory

Transaction costs can be divided into costs related to coordination and risk (Yigitbasioglu, 2010). Uncertainty could be one indicator that drives up the coordination cost and the risks associated with a transition. Information sharing between the stakeholders is essential to reduce risk and transaction costs. Withdrawal of information could cause deviations in the forecast, the increased lead time between the actors, shortages and price fluctuations, which in sum is an increase in the transaction cost (Agrawal et al., 2009).

The infrastructure needed to use environmental-friendly fuels successfully includes the ability to produce, transport, and store them. Depending on the fuel, ports, terminals, and ships, one may need to add more specialised infrastructure for supplying, storing, delivering, and using environmental-friendly fuels. The required investments must consider the complexity that evolves around implementing other fuel types (Foretich et al., 2021).

3.5.1.1 Fuel Producers

Fuel producers must consider that transitioning to greener fuels needs economies of scale. One of many risks associated with economies of scale is the unknown demand for different types of fuels. In addition, the fuel types that are wanted to be invested in must comply with the infrastructure of the ports and ships. There are pros and cons of the current alternative fuels. In addition, the production, distribution and capitalisation are still underdeveloped regarding other fuel types, which all affect fuel producers financially.

Considering greener fuel options has some drawbacks since alternative fuel options face norms and regulations. The implementation may increase financial risks and engineering hurdles due to safety factors. In addition, the corrosion rate influences the decision-making process of greener fuel since a high corrosion rate can lead to more maintenance, even though the fuel is more environmentally friendly (Foretich et al., 2021; Kesieme et al., 2019). All these environmental-friendly fuels affect fuel producers differently but are all transactions and investments the actors need to evaluate in the transition towards a more sustainable future.

3.5.1.2 Shipping Companies

According to Zhang et al. 2021, the average lifespan of a conventional ship is 25 years. As a result, the lifetime of the vessels brings into focus the need to incorporate fuels that are anticipated to be utilised in the market similarly, which is difficult to foresee. In addition to looking out for their best interests, shipping firms must meet the standard set by the IMO concerning pollution, which is determined by the EEDI and assessed by the CII (IMO, 2023c). Before making significant investments in their shipping fleets, shipping firms must take a number of factors into account. These factors include the ability to satisfy demand, access current transport capacity, operational cost, and fuel availability, and achieve emission objectives simultaneously (Zhang et al., 2021). There is a possibility that the expenses involved with investing in ships that are not "fit for purpose" may be significant and unexpected. This is because the ships must be maintained, retrofitted, or abandoned.

3.5.1.3 Ports

The port infrastructure is essential for port operations, which serve the ships and cargo that pass by (Waterborne, 2023). Port infrastructure varies by country, but an efficient port shall facilitate activities such as necessary operations on vessels and the ability to handle cargo by locomotives and trucks, as well have facilities for warehousing and storage (EPA, 2022). Regarding adopting environmental-friendly fuels, the ports shall invest in infrastructure that can store the different fuel types. Proper fuel storage is a prerequisite to efficiently utilising environment-friendly fuel types. Further investment done at the ports must be demand-driven as the consequence of doing transactions without considering the demand will be a failure in the end.

3.5.2 First-Mover Advantage

Green‐oriented innovative solutions are no longer perceived as a residual part of a firm's innovative actions but as an integral part of its strategic choices, which are necessary to improve its existing capabilities and competitive position (Berrone et al. (2013); Leyva‐de la Hiz, Ferron‐Vilchez, & Aragon‐Correa, 2018; Rennings, 2000). Companies at the cutting edge of environmental innovations can influence consumers' cognitive position more effectively, generating greater preference and loyalty for their products or services due to their environmental image (Ramesh et al., 2018; Alpert & Kamins, 1994).

On the other hand, environmental innovations tend to be more intricate than non-environmental innovations because they require "the combination and integration of various new and heterogeneous technologies and knowledge components." (Quatraro & Scandura, 2019). In addition, environmental innovations are likely to be more uncertain than non-environmental ones because regulatory and political uncertainty must be added to the technological uncertainty resulting from their higher complexity; IMO's changes to their environmental policy affecting the shipping industry are examples of this (IMO, 2023a).

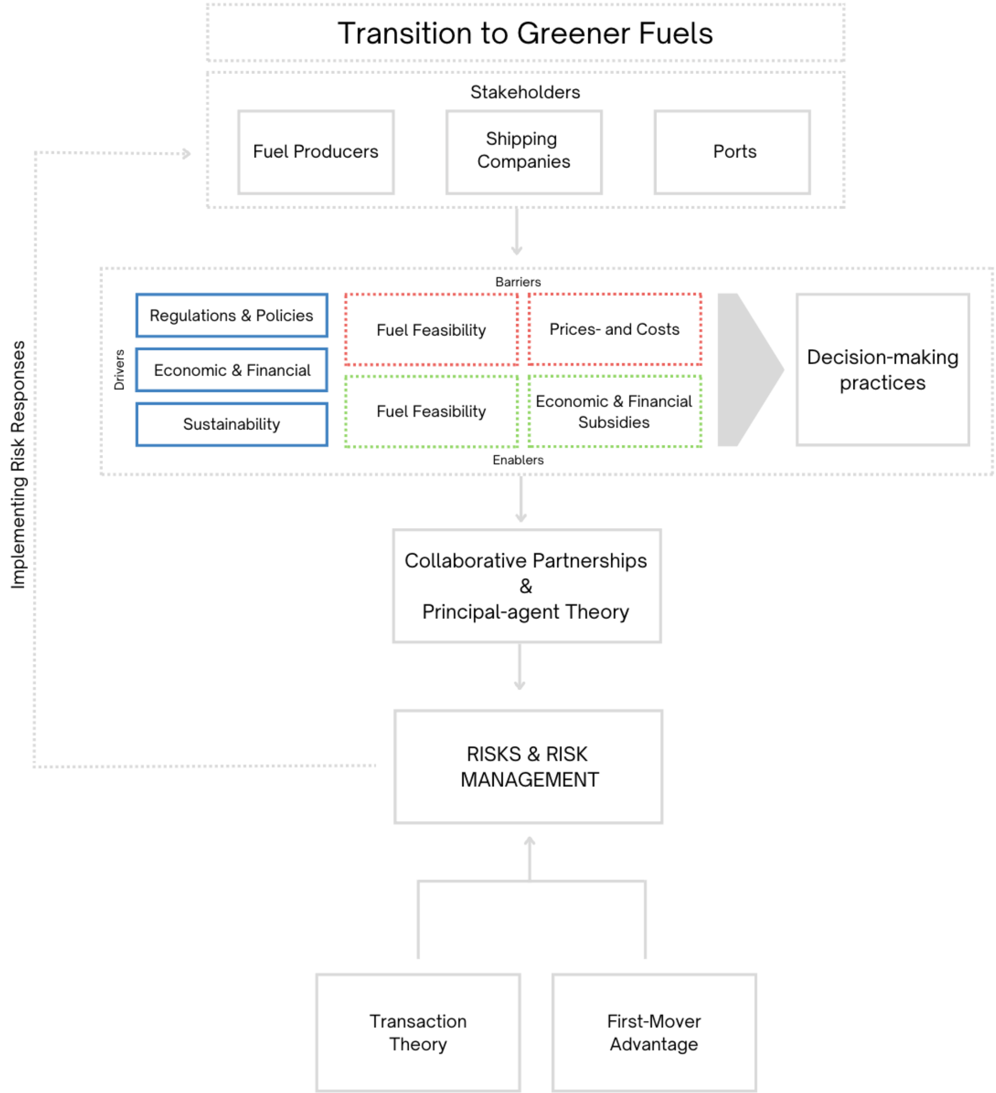
Lieberman & Montgomery (1998) argued that every applied study of first-mover advantages provides evidence of the accumulation of resources and capabilities when entering a market. However, they also highlight that first-mover disadvantages and follower advantages have recently garnered significant attention. They suspect the prospective advantages accruing to followers may be as significant as those accruing to pioneers.

Despite the identified benefits of being the first to market, some authors argue that the first mover advantages should be taken seriously (Cleff & Rennings, 2012). Although companies patent their new product or service, they can sometimes only partially enjoy the advantages of being the first to market due to inadequate protection of intellectual property rights against imitation by other companies (Mansfield, 1985). In addition, pioneers cannot enjoy free-riding on the investments of others (Cleff & Rennings, 2012). Instead, they must learn from their own mistakes and not those of others, a situation that may become more critical as innovations become more complex, as in the case of environmental innovations (Orsatti et al., 2020; Petruzzelli et al., 2011). In this regard, pioneers in environmental innovations may incur significant development costs due to combining various technologies and exploring various scenarios; thus, they must complete the introduction phases, as second movers frequently do (Lieberman & Montgomery, 2013). For instance, Aragón Correa and Leyvade la Hiz's (2015) longitudinal analysis of patents revealed that firms that exploited existing well-known technologies performed better on the market than those that explored innovations, highlighting the difficulty of combining various technologies. Considering shipping companies, this can be a factor that slows down the transition towards alternative fuel as stakeholders do not view the upside of being a first-mover.

3.6 Conceptual framework

The conceptual framework is based on the topic and illustrated in Figure 10. The framework illustrates the thesis's focus on the perspective of the three stakeholders. The framework is then structured based on the thematic approach described in section 2.5, starting with drivers, barriers and enablers considering the transition to greener fuels. This part of the framework illustrates that the drivers, regulations & policies, economic & financial and sustainability create barriers, fuel feasibility, prices and costs. In addition, the drivers create the enablers; fuel feasibility and economic and financial subsidies. For shipping stakeholders, knowledge of these drivers, barriers and enablers is essential to improve their decision-making practices regarding risk management. Theme 1 affects theme 2, which is about collaborative partnerships and principal-agent theory, leading to theme 3. Risks and risk management is the central part of the conceptual framework. Through angles of transaction theory and first-mover advantage, this part of the research study will contain risks and ways to manage those risks through COSO ERM. After implementing the risk mitigation strategies, these will affect the stakeholders. As the transition to alternative fuel is undergoing significant changes, this framework has been adapted to be used even during significant changes in the shipping industry.

Figure 10 - Conceptual Framework, made by authors.



Chapter 4 - Findings and Analysis

The following chapter will present our findings from the primary data collection. To manage risks, our results demonstrate how the interviewed experts view how addressing drivers and barriers, leveraging the enablers and encouraging collaborative partnerships decreases the risks faced by shipping stakeholders in the transition to greener fuels. We continued our thematic approach to structure and analysed the primary data we collected from the interviews (Appendix 5). We, therefore, examined three themes: (1) Drivers, barriers and enablers considering the transition to alternative fuel, (2) Collaborative partnerships, and (3) Risks and risk management. We based our interviews on the themes to answer our research question. Our findings are separated into the themes and substantiated by relevant quotes from the interviewees. We have divided our subheadings 4.1, 4.2 and 4.3 into the three themes we have focused on. Therefore 4.1 focuses on drivers, barriers and enablers from fuel producers, shipping companies and ports considering the transition to alternative fuel in the shipping industry. 4.2 focuses on the stakeholder's insights considering how collaborative partnerships can substantiate a transition to alternative fuels. 4.3 focuses on different risks we have found during our primary collection and how risk management can support the different actors when considering investments in the transition to sustainable fuel.

4.1 Drivers Considering the Transition to Sustainable Fuels

4.1.1 Insights from Fuel Producers

Our findings from the interview with the fuel producers gave us insight into drivers for the transition to alternative fuel from a fuel producer's perspective. ID-6 and ID-12 highlighted regulations and policy implementations set by IMO, EU and other governments as key drivers. However, ID-6 highlighted the lack of knowledge from the implementers considering fuel-specific adaptations. ID-6 explained:

"Politicians adopt and implement laws and guidelines for the shipping industry that are not based on knowledge of the specific alternative fuels. Politicians do not have enough knowledge to implement the changes they are implementing, which will eventually lead to supply-demand problems for shipping companies and ports."

Based on this insight from ID-6, this is not a positive driver and can result in a future barrier considering supply and demand problems. That statement is highly correlated with ID-6's next driver: pressure from the media and public opinion. ID-6 explained:

"The media has a lot of power in relation to politicians. If politicians want to have the greatest possible support from voters, they have been pressured to promote environmentally friendly solutions that are not possible. If politicians do not promote the environmental friendly solutions we "dream" of, they get fewer voters, because the media slaughters them and reduces the party's support in an election campaign."

These two statements form the foundation for the finding that drivers are not only positive but that politicians, together with the media and the public, can lead the battle for climate neutrality by 2050 against a situation where major supply and demand problems can arise due to shortages of resources such as electricity. The specialists are the fuel producers, and their insight into the extraction of various fuels is naturally better than politicians who use environmental friendly aspects as part of marketing for more outstanding electoral support.

4.1.2 Insights from Shipping Companies

Considering drivers seen from a shipping company perspective, ID-1, ID-2, ID-4, ID-8, ID-11, ID-13, and ID-14 substantiated regulations and policy implementations as the most important driver for the transition to alternative fuel even though ID-2 substantiated by ID-1 expressed that the regulations often come very unpredicted leading to vast and unpredicted costs. As a result, ID-8 emphasised economic and financial funding from organisations such as Enova as a key driver. To cope with all the costs, shipping companies must consider sustainable fuel. In addition, ID-1 explained how both the availability and compatibility of sustainable fuel options are crucial drivers for shipping companies:

“The main obstacles of implementing environmental-friendly fuels for shipping companies are availability of sustainable fuel options and that the alternative fuel is compatible with existing infrastructure.”

Accessibility and compatibility of sustainable fuels are essential drivers from a shipping company perspective. Shipping companies depend on the availability of affordable, feasible, and environmental friendly fuel sources that can easily fit into their existing infrastructure. With various sustainable fuel options, shipping companies can choose the best one for their operational requirements, vessels, and geographic considerations. A seamless transition is ensured by compatibility with the current infrastructure without substantial adjustments or expenditures for new fueling systems.

Secondly, ID-8 highlights that a driver towards the transition is whether the sustainable fuels suggested can be as energy-efficient as existing fuels:

“To facilitate the transition to alternative fuel it is essential to focus on the alternatives that are energy-efficient.”

ID-8 examplied by saying:

“To have the same operational capability as HSFO, it is required significantly more hydrogen to obtain the similar operational capability.”

Additionally, other energy-efficient alternatives are drivers towards the environmental objectives set by IMO such as hull optimisation. ID-8 emphasised:

"Energy conservation is more optimal if the ships are designed in a specific way. More specifically; the correct design of the hull on the ships can lead to energy-and fuel savings. In other words, greater utilisation of the specific fuel type."

The emphasis on energy-efficient alternatives is essential for facilitating the transition to cleaner fuels. Shipping companies may improve fuel utilisation and reduce their carbon footprint by implementing energy-saving technology, procedures, and vessel designs. Energy efficiency improves economic performance and is consistent with sustainability objectives and environmental requirements. Shipping companies can reduce operational costs and improve competitiveness by consuming less fuel. As a result, a significant driver for shipping companies to manage their transition to sustainable fuels successfully is investing in energy-efficient technologies.

4.1.3 Insights from Ports

ID-3, substantiated by all the other interviewed ports, highlighted the three most important drivers. First of all, demand for alternative fuels is the most crucial driver. ID-3 explained:

"Ports are very interested in the future and facilitating different fuel solutions in order to make the transition to alternative fuels easier in addition make sure that they attract new customers by offering fuel types of new ships are using."

Secondly, the availability of fuels and fuel producers is a significant driver for ports as this substantiates their ability to supply the demand for environmental friendly fuels. ID-3 explains:

"In order to facilitate environmentally friendly fuels at ports one needs trustworthy fuel producers who can supply the specific fuel of demand."

The last driver is to implement the fuel alternatives that are the easiest to obtain, as well as the most cost-effective solutions. ID-3 highlighted:

"Electricity is easier to facilitate than other alternative fuels."

Addressing these factors is crucial for ports looking to take part in transitioning towards alternative fuels. Ports can effectively contribute to a greener shipping industry, promote sustainability, and align with the changing needs and expectations of the shipping sector by meeting the demand for environmental friendly options, securing relevant fuels and fuel producers, and concentrating on easier-to-implement alternatives, like electricity

4.2 Barriers Considering the Transition to Sustainable Fuel

4.2.1 Insights from fuel producer

Our findings from the fuel producers' interviews gave us insight into how barriers hinder the transition to alternative fuel. ID-6 highlighted several barriers from a fuel producer's perspective. Initially, the interviewee was sceptical about using hydrogen and ammonia as an alternative fuel. ID-6 substantiated by ID-10 explained:

"Hydrogen and ammonia are produced through an industrial process that requires a lot of electricity. There is in addition high demand for hydrogen and ammonia, but where will the power/electricity come from?"

So, hydrogen and ammonia are not clean energy sources compared to, e.g. electric fuel cells. Energy is also lost as hydrogen and ammonia are produced through an industrial process. ID-6 exemplifies:

"Production of fuels like hydrogen and ammonia approximately 40% of the kWh produced is lost. Typically, it takes 60 kWh of electricity to produce one kilogram of hydrogen = 36 kWh"

Based on this, the fuel producer is sceptical that we will have enough electricity to produce hydrogen and ammonia as demand increases. In addition, ID-6 is generally sceptical about the energy loss that occurs during fuel production, such as hydrogen and ammonia. It is not the most energy-efficient option, as approximately 40% of the energy is lost during production.

The next barrier builds on the first barrier ID-6 highlighted. Namely*, "Where will the power come from?"* Although everyone talks very positively about renewable energy sources such as wind turbines, ID-6 believes that renewable energy sources have several barriers:

"Suggesting that power should come from wind turbines is not well thought through" and *"Offshore wind turbines and farms demand enormous space and therefore it is a problem to occupy land mass, and therefore we must build them at sea which is a costly operation."*

Several barriers to transitioning to sustainable fuels were brought to light from a fuel producer's perspective. The production of fuels like hydrogen and ammonia requires a lot of electricity, which raises questions regarding its availability and source. Second, using wind turbines and offshore farms as renewable energy sources is difficult due to their drawbacks, including space requirements and energy generation capacities. These results highlight the importance of removing these barriers to successfully transition the shipping sector to alternative fuels.

4.2.2 Insights from Shipping Companies

Our findings from interviews with multiple shipping companies have identified several barriers. Firstly, the price and supply-demand imbalance present significant challenges. Alternative fuels are currently more expensive, as ID-8 explained:

"Current alternative fuels are too expensive, 2-6x the price of HFO."

In order to compete with HSFO, the supply and demand need to increase. ID-8 substantiates ammonia as an example

"Production of ammonia equals approx. 150 million metric tonnes. In order, to be able to compete with HFO, production and demand must increase to approx. 800 million tonnes."

Secondly, our interviews revealed various barriers associated with specific alternative fuel types. ID-8 substantiated ID-6's statements on hydrogen:

"Hydrogen is produced through an industrial process where an energy loss occurs when extracting green hydrogen" and *"In principle, hydrogen should not be moved. Hydrogen is expensive to transport. Logistics and infrastructure around hydrogen are extremely challenging. Furthermore, hydrogen is a significant safety risk."*

Additionally, ID-8 emphasised that ammonia also has numerous technical and infrastructure barriers in its early stages of development. This includes assuring safe handling since ammonia is extremely toxic. All our interviews with different shipping companies revealed different barriers with alternative fuels, but ID-1 understated that all alternative fuels cannot compete with HSFO considering fuel utilisation.

Lastly, ID-2 highlighted:

"There is no particular first-mover advantage for shipping companies due to shipping being such a capital-intensive industry."

This statement was substantiated by ID-1 and ID-4 which highlighted the lack of first-mover advantage for shipping companies.

4.2.3 Insights from Ports

Our findings disclose that ports face three significant barriers. These barriers include the limited demand for alternative fuels from shipping companies, the requirement for huge infrastructure investment, especially for fuel storage and bunkering, and conflicts of interest with government and municipalities regarding port expansion and city development.

The first barrier is that ports experience a limited demand for sustainable fuels, limiting the port's deployment. The focus and priorities of ports are largely determined by shipping companies. ID-3 substantiated by ID-5 explained:

"Since ports facilitate the shipping companies, they become dependent on what the shipping companies focus on. Since shipping companies do not have a first-mover advantage considering alternative fuels this may be an activity or event which decreases the incentives for transition to alternative fuel for ports."

This is a barrier to the transition to sustainable fuel but is not necessarily something that the ports can do much about as they operate according to demand from the shipping companies.

The second barrier our interviews with ports revealed was that alternative fuels entail substantial infrastructure investments, especially for fuel storage and bunkering, as ID-3 highlighted: *"Investments in infrastructure to bunker/store the* *fuel. This is an obstacle but not impossible to overcome.*" Furthermore, ID-3, substantiated by ID-5, ID-7 and ID-9 highlighted that port expansion is expensive:

> *"The cost is 2,5 MNOK per 1 metre expansion"* and *"a lot of cost and few support schemes provided by the government and municipalities for developing the ports."*

The reason for this leads us to the third barrier our interviews revealed, which was that ports and the government and municipality often have a conflict of interest regarding city development and port expansion. This conflict may delay the adoption of sustainable fuel alternatives as the ports are restricted from expanding. ID-3 brought up this barrier substantiated by ID-7 and ID-9, stating:

> *"Governments and municipalities slow down the process to environment-friendly fuel options, while the traffic into the ports increases. The government and municipality wants to develop the city. On the other hand, the port wants to expand. Therefore, there is a conflict of interest between the municipality and the port."*

4.3 Enablers Considering the Transition to Sustainable Fuels

4.3.1 Insights from Fuel Producers

Our findings from the interview with the fuel producer revealed two essential enablers that can help address the barriers. The first enabler includes the potential for electrification through nuclear power, and the second focuses on the role of technological advancements in addressing the challenges associated with the production of alternative fuels. Since the production of alternative fuels such as hydrogen and ammonia are heavily based on electricity, ID-6 emphasised the importance of using more energy-efficient energy sources such as nuclear power if the shipping industry should be able to meet the future electricity demand.

"A feasible solution for all parties in the shipping industry is electrification using nuclear power because of the energy crisis the world now finds itself in because of the war in Ukraine."

Furthermore, he especially emphasised LNG is difficult to obtain:

"Access to natural gas with a view to LNG is difficult to obtain after the war between Russia and Ukraine because Russia limits access, which has led to a gas crisis."

Although LNG can be difficult to acquire, the interviewee sees LNG as the only realistic sustainable fuel, as of now:

"For a transition to environmental friendly fuels, the global markets need to ensure availability of fuels, especially of LNG as that is the only realistic option at the moment."

The second enabler is that technological advancements play a vital role in enabling fuel producers to address the barriers related to the production of alternative fuels (ID-6; ID-12). Technological advancement can assist in overcoming barriers such as energy loss during the production of fuels such as hydrogen and ammonia. As ID-6 stated:

"Approximately 40% of the kWh produced during the production of e-fuels such as hydrogen and ammonia is lost."

By investing in research and development, the producer of sustainable fuels can investigate innovative approaches, optimise production processes, reduce energy losses and increase the efficiency of sustainable fuels.

4.3.2 Insights from Shipping companies

Our findings considering enabling factors that arose from interviews with several shipping companies were identified as (1) Analyse the most energy-efficient and applicable alternative fuels considering a retrofit or newbuild. Such as the use of LNG and bio-LNG are relevant alternatives, and (2) EU incentives in the shipping industry will assist the transition to sustainable fuel.

ID-8, substantiated by ID-1 and ID-2, highlighted the importance of focusing on the most energy-efficient alternatives, such as the use of LNG, bio-LNG or even dual engines combining diesel and LNG as the most feasible alternatives with the potential to reduce emissions and enable the transition to sustainable fuels. The global availability of LNG, with approximately 400 million tonnes sold annually, demonstrates that it is a feasible alternative. However, it must be said that ID-6 emphasised:

"There is not enough supply and production of LNG to fulfil the demand in the foreseeable future."

Therefore, bio-LNG can be developed to be a viable, sustainable fuel source and, at the same time, contribute to reducing agricultural sector emissions. ID-8 explains:

"Bio LNG is a relevant alternative as methane from agriculture and animal excrement is a major emission factor. Bio LNG consists of 96% methane, and we can separate the methane from food waste and the cow faeces and convert this to biogas. But bio-LNG has various logistical challenges. The reason why this can facilitate an environmental friendly conversion to alternative fuel is that the production of bio-LNG will reduce emissions from the agricultural sector while at the same time offering an environmentally friendly fuel."

The second enabler from several interviews with shipping companies was the importance of the EU incentives and economic incentives in general. The incentives encourage the adoption of sustainable fuels, and ID-8 highlighted the crucial role incentives have considering driving the transition to sustainable fuel, mainly focusing on LNG:

"EU incentives the transition to LNG in the shipping industry, which leads to an increased biogas production. The expected produced volume is to be 25 million tons of biogas which is a constraint because the industry needs more."

4.3.3 Insights from Ports

Our interviews with multiple ports found that there is one leading enabler regarding the transition to alternative fuels. The identified enabler is the preparation for port expansion and cooperation with fuel producers to provide alternative fuel on demand. This proactive approach enables ports to implement alternative fuel systems without disrupting their current operations and guarantees the availability of alternative fuels when required. ID-3 explained:

"Forward leaning ports are planning on expanding their ports to be able to implement more alternative fuels" and *"Ports in general will need to expand their port so that the implementation of alternative fuel systems does not interfere with their current and growing operations"* and *"Thirdly, they are trying to get fuel producers to do the infrastructure investments of the tanks. In essence, ports rent out their space to fuel producers in order for them to sell their fuel."*

In general, all the ports we interviewed had a forward-leaning attitude. They are ready and eager to facilitate the transition to sustainable fuel. However, they depend on demand from shipping companies to have the incentives to expand their ports and facilitate bunkering options.

4.4 Collaborative Partnerships

4.4.1 Insights from Fuel Producers

Our finding from a fuel producer's perspective indicates that the transition to sustainable fuel is a complex process which can only be solved through collaborative partnerships. ID-6 highlighted the limited degree of collaboration between the fuel producers and the importance of collaboration with ports and shipping companies to be crucial towards the transition..

The most notable finding from ID-6's perspective was the limited collaboration between fuel producers. Each company's development of new technology creates a naturally competitive environment that finds it a disadvantage to share innovative improvements with other fuel producers. As ID-6 emphasised substantiated by ID-12:

> "*Collaboration between fuel producers is not that common as they are continuously developing different technologies which are not that favourable to share with other fuel producers*".

This statement reflects the industry's willingness to maintain a first-mover advantage through innovating and developing existing technology. Consequently, this willingness to be the first-mover impedes collaborative efforts to transition to sustainable fuels.

Despite the limited collaboration between the fuel producers, a collaboration between fuel producers, ports and shipping companies is a common practice. Collaborating with the other stakeholders from a fuel producer's perspective aims to establish a resilient supply chain considering alternative fuel. Understanding the vitality of logistics and infrastructure, fuel producers are eager to collaborate with ports and shipping companies. ID-6 emphasised:

"However, fuel producers collaborate all the time with ports and shipping companies in order to substantiate a resilient supply chain.".

The statement emphasises the importance of having a reliable supply chain. Collaboration guarantees even more efficiency and availability of alternative fuels and enhances the sustainability of the fuel supply chain.

4.4.2 Insights from Shipping Companies

By conducting interviews with shipping companies, we gained valuable insights into the most important considerations and practices associated with collaborative partnerships. Several key points were highlighted from the interviews. The most important takeaway was the high degree of collaboration and information-sharing among shipping companies, the importance of collaboration between shipowners and charterers, and the information sharing through published reports made by the shipping companies themselves

Transparency and availability of recent and relevant information are essential, especially during the transition phase. Our interviews revealed a relatively high degree of collaboration - and information sharing among the shipping companies. ID-13 highlighted the latest collaboration between them and a fuel producer. The fuel producer had patented an innovative hydrogen technology that C13 wanted to implement in their vessel technology. Additionally, ID-14 exemplified the importance of a collaborative partnership, considering a venture C14 had started recently. Collaboration stood in the centre as C14 could not finalise the project themselves but needed to collaborate with other firms that could complement their weaknesses. Furthermore, ID-9 emphasised the importance of transparency and information sharing.

"*Transparency and availability of recent and relevant information are essential in the transition phase. However, it seems there is a high degree of collaboration and information sharing among the shipping companies*".

As this quote indicates, collaboration facilitates information-sharing and intends to navigate the complexities. Furthermore, the transition could be more successful if the emphasised stakeholders in the shipping industry were more transparent. Collaboration enables the exchange of knowledge and expertise, thus leading to a more frictionless transition. As ID-1 stated substantiated by ID-14:

“Openness in-between actors creates greater availability of information, which can lead to a more effective transition towards alternative fuel.”

Although collaboration between shipowners and charterers is not broadly exploited, collaboration is necessary to facilitate a functional relationship in the shipping industry. Shipowners and charterers must, through collaboration, be able to meet the given requirements and assure and maintain operational efficiency. As ID - 1 emphasised:

"Some form of collaboration between shipowner and charterer is necessary to facilitate a functioning relationship between the actors.”

Shipping companies gather their information through published reports. These reports contribute to a broader understanding of the industry and increase awareness of sustainable fuel options. Even though the collaboration is not entirely direct, the information-sharing by the reports is one way of collaboration in the industry. This is as well emphasised by ID-1:

"In general, there is a lot of information sharing between shipping companies through different reports that are published on the transition to alternative fuel."

Information and knowledge sharing are fundamental advantages for shipping companies. Given the risk and uncertainty of being a first-mover of sustainable fuel, shipping companies naturally benefit from collaboration and information-sharing. Specifically, the shipping companies can overcome the obstacles because they can hedge due to the collective expertise and insights from engaging in collaboration. This is further confirmed by ID-1, and substantiated by ID-2:

"For shipping companies, there are necessarily no disadvantages in collaboration through sharing information and knowledge. The reason for this is that shipping companies are not particularly interested in being a first-mover considering the transition to alternative fuel as there is a lot of risk tied up to these investments."

4.4.3 Insights from Ports

Through interviews with port representatives, we retrieved valuable insight into their perspective on how collaborative partnerships can assist in solving the implications. Multiple key takeaways were identified and highlighted that the ports have a more significant level of collaboration between ports compared with the other stakeholders. In addition, the ports had a positive attitude of having a first-mover advantage compared to fuel producers and shipping companies. Furthermore, the port representatives were exclusively optimistic about collaborating with the other stakeholders and the potential benefits of it. However, the representatives highlighted the implications they were facing with their respective municipalities.

Compared to shipping companies and fuel producers, the level of collaboration between ports is extensively greater. A high level of collaboration promotes transparency and knowledge sharing between the ports, as ID-3 emphasised substantiated by ID-5, ID-7, and ID-9:

“Transparency is the advantage of collaboration. However, a degree of collaboration among ports is higher than the level of collaboration between shipping companies”

Secondly, being a first-mover related to implementing sustainable fuel options, acquiring a forward-leaning port, and at the same time facilitating the required transition, which reduces GHG emissions. As stated by ID-3 and substantiated by ID-5 and ID-7:

"First-mover advantage exists for ports as they gain a good reputation as forward-leaning ports, which facilitates sustainable fuel solutions to decrease greenhouse gas emissions."

Collaboration between the various actors at the port considering the operational procedures is crucial and is stated by ID-3 and substantiated by ID-5, ID-7 and ID-9:

"We collaborate with shipping companies, fuel producers and everyone else at every stage. We have to since we are a link point. i.e. Operational collaborations at the port, collaboration with fuel producers in order to supply fuels at the ports, collaboration with shipping companies when ships are planned to dock and collaboration between other ports to find solutions on which port should supply which fuel as it varies how many ships are docking"

Furthermore, collaboration guarantees minimised friction in operation, effective coordination, and exchange of information between the various stakeholders, which is beneficial for this transition. Additionally, collaboration enables the opportunity to acquire valuable experience, discover innovative solutions for various port operations, and obtain economic benefits. Ports enhance their overall operational efficiency through collaboration, which is further stated by ID-3, substantiated by ID-5, ID-7 and ID-9:

"Through collaboration, you gain experience, solutions for the different operations which have to be done at a port, and economic benefits"

Collaboration contributes to continuous development, knowledge sharing, and cooperative problem-solving. Specifically for ports, it enables ports to adapt and adjust solutions through the transition. As indicated, collaboration has several benefits. However, collaboration with local municipalities is challenging. This is explained due to the differences in the objectives between the ports and the municipalities, which can further hinder the efforts for port collaboration with the local municipality. ID-3 stated and substantiated by ID-9:

"However, our port and ports in general need to deal with the municipality which often can be a bit tricky as a municipality may have another agenda"

ID-3 has frequently observed the municipalities' reluctance to accept proposals from the ports regarding their operations. For ports to successfully navigate towards implementing alternative fuel options, the ports must overcome these challenges where both ports and municipalities must establish successful collaborations.

4.5 Risks and Risk Management

4.5.1 Insights from Fuel Producers

Several significant vital points emerged during the interviews with the fuel producers, highlighting the risks they face. These key points shed light on the risks associated with the availability of renewable power sources and the supply of fuels, risks specific to different fuel types, and the uncertainty prevailing in the energy market. Considering the availability of renewable power sources in order to be able to produce and supply enough fuels such as ammonia and hydrogen, ID-6 emphasised:

"Risks considering fuel producers facing the transition to alternative fuel is availability of renewable energy sources in order to produce and supply fuel and

sustaining economic growth" and *"It is highly needed to have enough or similar amount of power from other energy resources."*

Based on ID-6's quote substantiated by ID-12, the risk is balancing the investment in alternative fuels and maintaining economic growth. The reason for this is that investments in production equipment for alternative fuel production are capital-intensive. Secondly, the transition to sustainable fuels introduces risks to each fuel type. Sustainable fuels aim to have a less environmental impact, although some might be riskier than conventional fuels. For instance, LNG and ammonia can be very damaging if it leaks, while hydrogen poses a substantial safety issue due to its flammability. ID-6 explained:

"The different fuels pose different risks that can be more environmentally damaging than just sticking to VLSFO and developing fewer polluting diesels. This can e.g, be the probability of leakage of LNG, ammonia and hydrogen under production and refuelling is present. This can eventually lead to more methane related emissions and toxic emissions."

Based on this quote, fuel producers are the best-qualified individuals and organisations to view the different risks. By encouraging the idea of finding ways to extract diesel in more environmentally friendly ways, one can significantly reduce emissions instead of only focusing on new fuels, as alternative fuels contain risks and barriers. The third risk fuel producers need to consider is uncertainty in the energy markets. ID-6 highlighted that:

"There is a worldwide energy deficit, which increases the uncertainty that evolves around fuels options."

The uncertainty in the energy markets is an aspect of a more extraordinary macroeconomic play all actors must consider. However, fuel producers might be heavily affected in their future operational investments.

4.5.2 Insights from Shipping Companies

Significant risks and difficulties associated with this transition were uncovered during interviews with the shipping companies. These key points highlight the investment risks, operational difficulties and compatibility issues, and regulatory uncertainty that shipping companies encounter. The first risk ID-1 highlighted was investment risk considering alternative fuel. Risks associated with poor investment decisions considering which fuels shipowners will focus on in the future are a massive concern for shipping companies when considering charterers' requirements. The shipping corporations may suffer considerable financial losses due to poor investment choices and further loss of charterers. ID-1 highlights:

"Risks shipping companies are facing considering the transition to alternative fuel is wrong investments done by the charterers requirements. Tens of millions in investments can be lost if invested in wrong fuels" and "Shipping companies might end up doing investments that are highly uncertain to meet the requirements set from the charterers."

The second risk that emerged from the interviews with the shipping companies was operational and compatibility challenges. The lack of knowledge considering an alternative fuel'sfuel's lifespan, development, accessibility and availability poses a risk to shipping companies. These elements immediately affect how they should operate short term, but long-term implications can also occur, resulting in financial losses. Also, shipping companies cannot guarantee compatibility with current engine systems. ID-1 substantiated by ID-2 explains:

"Some risks facing shipping companies are uncertainty of the lifespan and the development of the fuel types, and which fuel types that are the most applicable one in the future is hard to tell. This affects the operations directly and can potentially contribute to major economic losses. The recognised fuels being compatible with existing engine systems, or if a major overhauling is required to, for instance, satisfy the CII criteria."

The third risk from a shipping company perspective is to react to IMO's unpredictable regulations as ID-2 emphasised:

"Unpredictable regulations from authorities such as the EU, the IMO and governments pose a huge risk for shipping companies."

This increases the risk and expense burden on ship owners. For shipping companies, adjusting to new and unforeseen regulations can pose serious financial difficulties, as ID-2 further highlighted:

"The necessary costs associated with the required re-adjustments due to directives and regulations from EU and IMO. The requirements often come very unpredicted which leads to huge and unpredicted costs related to these adjustments."

Additionally, ID-2 examplied the regulations set from IMO and the EU with an analogy:

"The regulations set from regulators can be compared with FIFA saying that there will be new football rules for the upcoming world cup. Then the national teams ask what the rules are, and then FIFA says that they do not know yet."

In other words, from a shipping company perspective it seems that the regulators have set un-achiveable aims considering the given timeline This creates huge uncertainty and poses huge risks for shipping companies operations and financials.

4.5.3 Insights from Ports

The interviews with several ports gave essential insights into the risks that they encountered. The crucial role of infrastructure- and space optimisation, financial and municipal support, and cooperation for risk reduction are all highlighted.

Firstly, the lack of municipal financial support for infrastructure expansion poses risks for ports, as emphasised by ID-3. ID-3 further highlights that a lack of port funding schemes for development plans hinders the implementation of necessary changes.

“Risks ports are facing considering the transition to alternative fuel is that the municipality does not support the ports expansion financially. There are few support schemes for developing ports for the necessary transition.”

The lack of financial support can affect ports negatively as they may not be able to facilitate environmental-friendly fuels, which can result in ports not being competitive. On the other hand, if they focus on facilitating alternative fuels, it may be at the expense of other operational activities because of space constraints. The second risk relates to alternative fuels' port safety risks. Especially, ID-7 brought up:

“Stricter security measurements are required when handling the alternative fuels. Alternative fuels pose risks such as hydrogen is a significant safety risk, and ammonia is extremely toxic if it starts leaking.”

In addition, ID-5 and ID-10 highlighted that hydrogen needs significant security parameters on the ports. The consequence is that other operations at the port are affected, such as the placement of various objects and buildings since they cannot be placed right next to the hydrogen tanks to optimise space. On behalf of the ports, ID-8 emphasised that security measurements in crucial. Therefore ports need to consider the consequences of leakage during, e.g. refuelling. In addition, ports are often located in larger cities where a possible explosion or toxic leak would be catastrophic.

Chapter 5 - Discussion

This chapter will discuss existing literature collected through the secondary data collection against the empirical findings collected during the primary data collection. We have limited the discussion to three themes: (1) Drivers, barriers and enablers considering the transition to alternative fuel, (2) Collaborative partnerships, and (3) Risks and risk management in order to answer our research question. During sections 5.1-5.3, drivers, barriers and enablers considering the transition to alternative fuel will be covered, which is a discussion based on the literature review in sections 3.1-3.3 against our findings in sections 4.1-4.3, respectively. Meanwhile, collaborative partnerships in section 5.4 are based on the discussion between sections 3.4 and 4.4. Section 5.5 covers the implementation of the COSO ERM framework in order to identify, assess, prioritise and suggest risk mitigation strategies for the five main risks we have identified based on comparing similarities and deviations between existing literature and our empirical findings.

5.1 How Drivers Force the Transition to Sustainable Fuels

There are multiple drivers for the transition to alternative fuel when comparing the literature review and the empirical findings from the stakeholder interviews. We will compare the literature review against our findings and discuss how regulations and policies, economic and financial drivers, and sustainability affect the transition to alternative fuel. The table below lists the drivers based on the literature and our findings.

Table 5 - List of Drivers Discussed Based on Theoretical Background and our findings, made by authors.

Drivers	Description	References
Regulations and Policies	The literature review and the empirical findings considers the regulations and regulatory frameworks implemented as drivers. IMO, EU, and other governing entities' regulations and policies serve as important drivers for improving energy efficiency and reducing GHG emissions in the shipping industry. The EU's ETS and ETD systems, as well as the IMO's MARPOL Convention - 1978/83 Annex VI and GHG Strategy, have significantly influenced the shift towards alternative fuels. Even though policymakers may lack thorough technical understanding, the overwhelming pressure from media and public opinion favouring a green transition also serves as a driver. Fuel producers caution that policymakers, under the influence of this prevailing sentiment, may make mistakes in their decision-making processes.	Longarela-Ares et al. (2020); ID-1; ID-2; ID-4; ID-6; ID-8; ID-11; ID-12; ID-13; ID-14
Economic and Financial Drivers	Compatibility of alternative fuel is emphasised as important for achieving lower costs, energy efficiency, and a financially sustainable transition. Access to resource and funding opportunities is identified as necessary to support future investments in compatibility of new fuels. Economic and financial drivers significantly drive the shipping industry, encompassing access to financing, outside funding, decreased operational expenses, and profitability. Energy-efficient technology like hull optimisation is exemplified to improve fuel efficiency and reduce operating costs.	Longarela-Ares et al. (2020); Nian et al. (2019); Agudelo et al. (2022); ID-1; ID-8
Sustainability & Triple-bottom Line	Sustainability is a crucial driver for transitioning to alternative fuels, with focus on the triple bottom line. *People* consider the importance of safety in relation to alternative fuels, considering impacts on safety and potential societal changes as an important sustainability driver. *Planet* focus on reducing GHG emissions in the shipping industry, driven by IMO regulations and policy implementations. *Profit* considers the financial benefits and economic factors which drive sustainable decision-making.	Fasoulis & Kurt (2019); McKinlay et al. (2021); Solakivi et al. (2022); IMO (2023d); ID-1; ID-2; ID-3; ID-6; ID-8

5.1.1 Regulations and Policies

The IMO, EU and other governing entities' regulations and policies are essential drivers based on Longarela-Ares et al. (2020) and ID-12. They both direct and sustain the shipping industry's commitment to improving energy efficiency and reducing GHG emissions. For instance, the EU's ETS and ETD systems and the IMO's Marpol Convention - 1978/83 Annex VI were involved in the initial GHG Strategy 2018. All of these have significantly influenced the shift toward alternative fuels. The literature review views the regulations and the regulatory frameworks implemented as drivers. However, the literature review section *3.1.1* is only based on the perspective of IMO.

Viewed from the perspective of fuel producers, ID-6 cautioned that policymakers could make mistakes due to a lack of thorough technical understanding. Although favourable for promoting a green transition, the pressure from the media and public opinion may also lead to unduly ambitious plans or a lack of the required flexibility to adjust to actual circumstances.

The perspective of shipping companies ID-1, ID-2, ID-4, ID-8, ID-11, ID-13, and ID-14 substantiates the regulations as a primary driver considering the transition to sustainable fuel. However, ID-2, substantiated by ID-1 and ID-8, highlight that IMO's regulations often come very unpredicted, which leads to vast and unpredicted costs related to these adjustments.

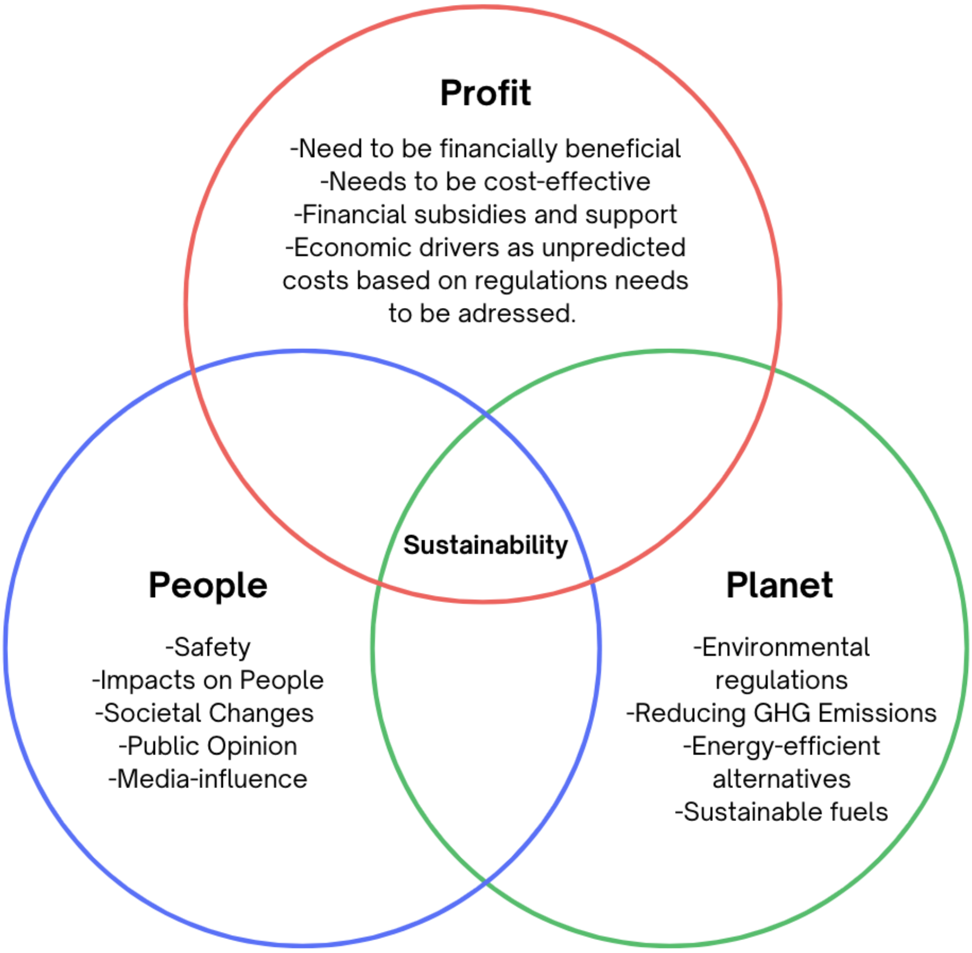
5.1.2 Economic and Financial Drivers for Alternative Fuel

Another significant driver for the shipping industry is economic and financial drivers. Access to financing, outside funding, decreased operational expenses, and profitability are all critical drivers, according to Longarela-Ares et al. (2020), Nian et al. (2019), Agudelo et al. (2022) and ID-1 and ID-8. ID-1 and ID-8, substantiated by Agudelo et al. (2022), highlight that access to resources and funding opportunities will be necessary to fund future investments in the compatibility of new fuels. Furthermore, ID-1 and ID-8, substantiated by Longarela-Ares et al. (2020); Nian et al. (2019); Svanberg et al. (2018) emphasised the importance of compatibility of alternative fuel, attempting to lower cost and energy efficiency for a seamless financially sustainable transition. Additionally, ID-1 and ID-8 exemplify energy-efficient technology like hull optimisation, which can improve fuel efficiency and lower operating costs.

5.1.3 Sustainability & Triple Bottom-Line

As Fasoulis & Kurt (2019) state, sustainability goals are a crucial driver for transitioning to alternative fuels. In order to discuss how sustainability is a key driver, we base the discussion on the triple bottom line. View the revised triple bottom line illustrated below.

Figure 11 - Revised Triple Bottom-Line Framework, made by authors.



Considering people, McKinlay et al. (2021); Solakivi et al. (2022) underscore the importance of safety concerning alternative fuels. The decisions regarding selecting and implementing these fuels must consider the impacts on people, both in terms of safety and indirectly, through the potential societal changes such a transition could bring about. The interview with ID-8 substantiated the importance of safety as alternative fuels such as ammonia since it is highly toxic. Additionally, ID-6 highlights the powerful influence of public opinion and media on this transition. They argue that politicians are driven by public and media pressures to adopt and implement guidelines and laws that may not necessarily be feasible or fully understood by them. Hence, it underscores the importance of informed decision-making and bridging knowledge gaps for a safe and effective transition to alternative fuels.

From the planet perspective, the literature emphasises that sustainability in the shipping industry is aimed at the industry's GHG emissions, driven by regulations set by the IMO to reduce greenhouse gas emissions (IMO, 2023d). Substantiated by the conducted interviews, fuel producers, shipping companies, and ports all pointed to regulations and policy implementations as significant drivers. Despite the challenges and potential barriers they might present, the interviewees all see these environmental regulations as a significant influence in pushing the industry towards sustainable fuels. Furthermore, ID-8's emphasis on energy-efficient alternatives and hull optimisation signifies a holistic approach to reducing environmental impact, extending beyond alternative fuels.

The profit component of the triple bottom-line framework considers whether the use of alternative fuels is financially beneficial. Solakivi et al. 2022 emphasised how economic factors are vital to sustainable decision-making in the shipping industry. The economic drivers became evident in the interviews with shipping companies and ports. From the perspective of shipping companies, ID-1, ID-2, and ID-8 emphasise economic and financial drivers as crucial, as these firms are particularly concerned about unpredicted costs related to regulations and the need for financial support from organisations to facilitate the transition to alternative fuels. Given the potential impacts on operational costs, these fuels' availability and compatibility are also critical factors. From the port's perspective, ID-3 highlighted that the most significant drivers were the demand for alternative fuels and the availability of fuel producers, indicating a clear link between supply, demand, and the economic feasibility of providing alternative fuels. ID-3 also emphasised the importance of profitable, cost-effective solutions, with electricity highlighted as easier to facilitate than other alternative fuels.

5.2 How Barriers Hinder the Transition to Sustainable Fuels

There are multiple barriers to the transition to alternative fuel when comparing the literature review and the empirical findings from the stakeholder interviews. We will compare the literature review against our findings and discuss how fuel feasibility barriers and alternative fuel prices and costs affect the transition. The table below lists the barriers from both the literature and our findings.

Table 6 - List of Barriers Discussed Based on Theoretical Background and Our Findings, made by authors.

Barriers	Description	References
Fuel Feasibility Barriers	High energy requirements and losses in the production of alternative fuels (hydrogen and ammonia) are widely recognized concerns. Concerns raised about the availability and source of electricity for alternative fuel production. Imbalance between supply and demand of alternative fuels is a significant barrier to adoption. Various technical barriers need to be addressed, including early-stage technological issues with ammonia and logistical/safety considerations for hydrogen transportation. Safe handling is crucial due to the toxicity of certain alternative fuels like ammonia. Our findings and the literature consistently identify policy and regulatory barriers. Alternative fuels' feasibility depends on port-municipality conflicts and government infrastructure backing.	Law et al., 2021; Kurien & Mittal, 2022; Schinas & Butler, 2016; ID-6; ID-8
Prices- and Costs of Alternative Fuels	High prices and cost volatility of alternative fuels are major barriers to adoption. Alternative fuels are currently more expensive than traditional ones, impacting shipping companies' willingness to adopt them. Substantial infrastructure upgrades are needed, particularly for fuel storage and bunkering at ports, adding to the cost barrier. Shipping companies play a significant role in driving demand for alternative fuels. Overcoming capital access barriers, securing external financing, and spreading investment risk among stakeholders are crucial for meeting demand. Lack of a first-mover advantage in the transition to alternative fuels slows down the overall transition since ports and fuel producers depend on shipping companies' investment.	Dinneen, 2022; Lindstad et al., 2021; Longarela-Ares et al., 2020; Solakivi et al., 2022; Psaraftis & Larsen, 2010; Prussi et al., 2021; ID-1; ID-2; ID-3; ID-4; ID-5; ID-7; ID-8; ID-9

5.2.1 Fuel Feasibility Barriers

Our findings and the existing literature have widely recognised the high energy requirements and losses in producing alternative fuels like hydrogen and ammonia (Law et al., 2021; ID-6). ID-6 expressed concerns about the availability and source of electricity for producing these fuels. ID-6 and ID-8 also pointed to the imbalance between the supply and demand of alternative fuels as a significant barrier to their adoption.

On the technical side, our findings have identified several barriers that need to be overcome. These barriers vary from early-stage technological issues related to the use of ammonia to logistical and safety considerations associated with the transportation and flammability of fuels like hydrogen. Given the toxicity of certain alternative fuels, such as ammonia, obtaining safety concerns is crucial (Kurien & Mittal, 2022; Law et al., 2021; ID-6; ID-8).

Finally, policy and regulatory barriers have been consistently identified in the literature and our findings (Schinas & Butler, 2016; ID-6). Conflicts of interest between ports and municipalities and the availability of government support for infrastructure expansion can significantly influence the feasibility of using alternative fuels.

5.2.2 Prices- and Costs of Alternative Fuels

Our findings and the literature (Dinneen, 2022; Lindstad et al., 2021; Solakivi et al., 2022; Psaraftis & Larsen, 2010; ID-8) have highlighted the high prices and cost volatility of alternative fuels as a significant barrier. As it currently stands, alternative fuels are more expensive than traditional ones, hampers shipping companies' willingness to take the lead in their adoption. This cost barrier is compounded by the need for substantial infrastructure upgrades, particularly for fuel storage and bunkering at ports (ID-3, ID-5, ID-7; ID-9).

On the demand side, Prussi et al. (2021) point to the significant role that shipping companies play in driving demand for alternative fuels. Longarela-Ares et al. (2020); ID-3; ID-5 substantiate this further by emphasising that demand depends on overcoming capital access barriers, securing external financing, and spreading the associated investment risk among various stakeholders. Moreover, ID-2, substantiated by ID-1 and ID-4, emphasise the lack of a first-mover advantage in the transition to alternative fuels. This may slow the transition for all stakeholders since both ports and fuel producers depend on shipping companies investing in sustainable fuel.

5.3 How Enablers Facilitate the Transition to Sustainable Fuels

There are several enablers for the transition to alternative fuel when comparing the literature review and the empirical findings from the stakeholder interviews. We will compare the literature review against our findings and discuss how fuel feasibility enablers and economic- and financial subsidies for alternative fuel affect the transition. The table below lists the barriers from both the literature and our findings.

Table 7 - List of Enablers Discussed Based on Theoretical Background and Our Findings, made by authors.

Enablers	Description	References
Fuel Feasibility Enablers	Technological development and maturity are critical enablers for alternative fuels. Technological advancements enhance the efficiency of alternative fuel production, such as hydrogen and ammonia. Dual fuel engines and retrofitting are emphasised as significant enablers, with a focus on options like LNG. Different fuel sources, including LNG, bio-LNG, and dual engine technology, are considered for adoption. Other alternative fuels explored in the literature include ammonia, hydrogen, methanol, biofuel, and electric propulsion. The infrastructure development, especially at ports, is crucial for enabling the adoption of these alternative fuels. Ports play a proactive role in expanding infrastructure and collaborating with fuel suppliers.	Valera-Medina, 2018; McKinlay et al., 2021; Peri et al., 2022; Xu & Yang, 2020; Prussi et al., 2021; ID-1; ID-2; ID-3; ID-4: ID-5; ID-6; ID-7; ID-9; ID-12
Economic and Financial Subsidies for Alternative Fuel	Economic incentives, particularly subsidies, are identified as a key enabler for the transition to alternative fuels. Subsidies aim to reduce corporate tax burdens and steer firms towards sustainability goals, making the transition less expensive. Subsidies are necessary to facilitate the transition, considering the capital-intensive nature of the shipping industry. Governmental organisations like Enova are crucial sources of financial support for technological innovations that can reduce CO_2 emissions and improve energy efficiency. Fuel producers highlight the importance of investing in R&D to overcome obstacles in alternative fuel production, necessitating financial support.	Dinneen, 2022; Merk, 2020; Enova, 2023, ID-6; ID-8; ID-12

5.3.1 Fuel Feasibility Enablers

Technological development and its maturity are critical enablers identified by ID-6, ID-12 and Prussi et al. (2021). Technological advancements are seen as crucial in enhancing the efficiency of alternative fuel production, like hydrogen and ammonia, as seen from the perspective of fuel producers (ID-6). Prussi et al. (2021) also underscore how technological advancements can impact the practicality of alternative fuels (Prussi et al., 2021).

Xu & Yang (2020) emphasise dual-fuel engines and retrofitting as significant enablers. Furthermore, they discuss the viability and benefits of using alternative fuels, such as LNG, in dual engines. This was substantiated by ID-1, ID-2 and ID-8, highlighting the importance of concentrating on the most feasible options that have the potential to cut emissions and facilitate the transition to alternative fuels. Regarding adopting alternative fuels, Xu & Yang (2020), backed by ID-1, ID-2, and ID-8, highlights the potential of different fuel sources such as LNG, bio-LNG and dual engine technology.

Lastly, infrastructure development, specifically at ports, is viewed as a critical enabler according to both ports and shipping companies (ID-3, ID-4, ID-5, ID-7 and ID-9). Both fuel producers depend on selling fuel at ports, and shipping companies depend on ports considering refuelling, making them crucial enabler. Ports demonstrate a proactive approach by committing to expand and collaborate with fuel suppliers to facilitate the provision of alternative fuels (ID-3). While this is not significantly discussed in the literature, it underscores the essential role infrastructure adaptation plays in adopting alternative fuels.

5.3.2 Economic- and Financial Subsidies for Sustainable Fuels

In both the literature and our findings, economic incentives, specifically subsidies, emerge as a critical enabler for the transition to alternative fuels. Dinneen (2022) emphasises that the industry must invest close to $1 trillion to meet IMO objectives, causing stakeholders to hesitate in such an uncertain environment. In order to facilitate the transition, economic subsidies are necessary (Dinneen, 2022; Merk, 2020; ID-8). Subsidies are typically granted for particular services or under specific conditions, reducing corporate tax burdens if goals for sustainability are met (Merk, 2020).

These subsidies aim to steer firms in the maritime industry toward a more sustainable path and make the transition less expensive. This is especially important considering the capital-intensive nature of the shipping industry. ID-8 highlights governmental organisations such as Enova as essential sources of financial support for technological innovations that reduce or eliminate CO2 emissions during operational procedures. Additionally, Enova supports innovative solutions that reduce energy demand and improve operational energy efficiency (Enova, 2023).

Our findings from interviews with fuel producers and shipping companies support the importance of economic incentives. The fuel producers stress the significance of investing in research and development to address the obstacles associated with producing alternative fuels. The capital required for such advancements, such as minimising energy loss during hydrogen and ammonia production, highlights the need for financial support (ID-6; ID-12).

5.4 Discussion of Collaborative Partnerships

The analysis of our results and the literature review emphasise the critical need for collaborative partnerships as we implement cleaner fuels. There are similarities and variations when comparing the critical findings from collaborative partnerships from our research with the literature review.

5.4.1 Collaboration Between Stakeholders

Collaboration throughout the supply chain is essential for reaching a shared objective (Liao et al., 2017; Cao & Zhang, 2010; Sandberg, 2007). This viewpoint was verified by ID-1, ID-2, and ID-3, demonstrating the value of collaborative partnerships between fuel providers, ports, and shipping businesses to build a reliable supply chain that considers alternative fuel. The empirical findings, however, also showed a lower level of cooperation among fuel producers due to competition (ID-6). Nyaga et al. (2009) argued that the value of trust in supply chain partnerships is based on a team effort, which all interviewees supported. Transparency was promoted by the high level of cooperation and information sharing, particularly among shipping companies (ID-13, ID-14). It implies that transparency among stakeholders increases information availability and promotes a more successful shift to alternate fuels substantiated by ID-1, ID-2, ID-3, ID-4, ID-5, ID-6, ID-7, and ID-8. ID-9, ID-10, ID-11, ID-12, ID-13 and ID-14).

5.4.2 Principal-Agent Relationship during Collaboration

The literature review's principal-agent theory explains potential conflicts in collaboration caused by different stakeholder priorities (Dirzka & Luo, 2021). The empirical results support this viewpoint by outlining difficulties in port engagement with local municipalities (ID-3, ID-9). This implies that conflicts and difficulties occasionally arise while working together in partnerships are essential for transitioning to alternative fuels. Considering shipping companies as agents, their adaptability has been tested to a considerable degree considering their principal IMO, EU and other governing entities expecting them to drastically make huge investments based on regulations such as the initial GHG strategy (IMO,2019).

However, shipping companies are actively solving the transition through collaborative partnerships. ID-14 emphasised how their company has started actively searching for collaborative partnerships to assist them with resources they lack to reduce their environmental footprint. From the fuel producer's perspective as an agent, they are impacted by the demand for further research and development of energy-efficient solutions by the principal (ID-6). Implementing collaborative partnerships between fuel producers is difficult because of their naturally competitive environment, as emphasised by ID-6. However, fuel producers must collaborate with shipping companies and ports to understand their needs. Engaging in collaborative partnerships, whether fuel producers, shipping companies, or ports, is an essential tool to solve the principal-agent relationship IMO, the EU and other governing entities have put on the discussed agents.

5.5 Discussion of Risks & Risk Management

The analysis of our results and the literature review emphasise the critical need for risk and risk management as we implement sustainable fuels. There are similarities and deviations when comparing the critical findings from risks and risk management from our research and the literature review. In addition, we use the COSO ERM framework to identify, assess, prioritise risks, and create applicable risk mitigation strategies.

5.5.1 Identifying & Assessing the Five Main Risks

The risks identified from the literature review and the insights gained from interviews with fuel producers, shipping companies, and ports highlight the complexities and challenges in transitioning to alternative fuels. This section discusses the most significant risks, as listed in Table 8.

Table 8 - List of Risks Discussed Based on the Theoretical Background and our Findings, made by authors.

Risks	Description	References
Investment Risk	Balancing investments and sustaining economic growth is a challenge. Fuel producers major concern prior to conducting investments is the demand. Shipping companies and ports major concern is the applicability of the fuel in their excising operational procedures.	Dinneen (2022); Foretich et al. (2021); Zhang et al. (2021); ID-2; ID-3; I D-6; ID-8; ID-12.
Fuel Related Risk	Cleaner fuels pose risks related to leakage and safety issues, and the risks are not thoroughly assessed. Fuel producers can adjust their production relying on market demand and regulations. Shipping companies and ports face challenges related to the cleaner fuels. Those are e.g., storage, handling, and toxicity of the fuels.	Gerlitz et al. (2022); Law et al. (2021); McKinley et al. (2021); ID-1; ID-2; ID-3
Uncertainty & Regulatory Risk	Uncertainties in the energy market, and uncertainties in upcoming regulations from IMO and EU are elements that drives up this specific risk. Fuel producer and ports are the stakeholders that can adjust their strategies to comply with regulatory changes with minimal impact on existing operational procedures. Shipping companies, on the other hand, face significant impact as this risk affect the ship design, propulsion type and chosen fuel.	McKinley et al. (2021); ID-2; ID-5; ID-6; ID-7; ID-8; ID-9
Infrastructure & Financial Support Risk	Ports do not have financial support from the municipalities; thus, the process for facilitating the usage of cleaner fuel option at the ports is not efficient as intended. Shipping companies faces obstacles related to the operational infrastructure. Specifically related to fuelling the vessels if they operate with cleaner fuel. Developing and facilitating for fuelling with other fuel can be substantial financial burden for the shipping company.	Gerlitz et al. (2022); Kurrien & Mittal (2022); McKinley (2021); ID-3; ID-4
Operational and Compatibility risk	Shipping companies and ports face high impact of this risk. Substantial modifications of the ships, storage, and handling of the fuels on their respective infrastructure are some of the concerns. Additionally, there are concerns related to the lifespan of the vessel operating on cleaner fuel, and the development process of the fuels. As for now there is uncertainty of which fuel to bet on.	Schinas & Butler (2016); Kurien & Mittal (2022); McKinlay et al. (2021); Zhang et al. (2021); EPA (2022); ID-2; ID-3; ID-4; ID-5; ID-7; ID-10

Furthermore risk management frameworks and tools are essential in order to minimise the impact associated with the most common risks. In order to prioritise the mentioned risks above, it is recommended to use a risk register to identify, assess and lastly evaluate / prioritise the risks. The risks discussed in 5.5.1.1 - 5.5.1.5 are the most common risks among the three stakeholders and the grounds for the risk assessment is based on the literature review and from our findings. The three stakeholders have different risk - perception, and thus the risk assessment is not entirely similar. The probability of occurence and the impact varies from a scale of 1 - 3. As stated in section 3.5; *risk * impact = total risk* which varies from scale of 1 - 9.

Table 9 - Risk Register, made by authors.

Risk Identification			Risk Assessment				Risk evaluation Updated automatically		
Risk ID	**Risk**	**Cause**	**Probability (scale 1 to 3)**	**Impact on Fuel Producers**	**Impact on shipping companies**	**Impact on ports**	**Total risk Fuel producer**	**Total risk Shipping Compant**	**Total Risk Ports**
1	Investment Risks	Large financial commitment is associated with the transition to alternative fuel	3	2	3	1	6	9	3
2	Risks Related to Spesific Fuel Types	Fuel feasibility related to safety concers	2	1	3	2	2	6	4
3	Uncertainty And Regulatory risks	Uncertainty prevailing in the enegy and the unpredictability of regulations poses risks.	2	1	3	0	2	6	0
4	Infrastructure And Financial Support Risk	Lack of financial support and necessary infrastruture for alternative fuels	2	2	2	3	4	4	6
5	Operational and Compatibility risk	Operational challenges and compatibility concerns with current infrastructure.	3	1	3	3	3	9	9

5.5.1.1 Investment Risk

Dinneen (2022) pointed out the significant investments required in transitioning to sustainable fuels, which could lead to financial instability if the investments do not yield the expected results. This finding is substantiated by ID-6 and ID-8, where they emphasised the challenge of balancing the investment in sustainable fuels while maintaining economic growth and the possibility of substantial losses due to poor investment choices, especially concerning charterer requirements.

Firstly, ID-8 and Zhang et al. 2021 state that investment risks are more severe for shipping companies than for fuel producers and ports. As stated in Table 9, the industry itself is very capital-intensive. Thus it may lead to significant losses if investments are made based on the wrong grounds. Table 9 indicates the probability (3) of the need to commit capital to meet sustainability goals and how it impacts the stakeholders. Considering the fuel producers, there are several implications related to committing capital for projects determined by the demand for different fuel alternatives. The underlying concern of being a first-mover is related to the underlying knowledge gap and the feasibility concerns of the fuels. This is additionally emphasised by Prussi et al. (2021) and Quatraro & Scandura (2019) and substantiated by (ID-6; ID-12). The impact it has on fuel producers is 2 and not as severe as for the shipping companies (3) due to their position in the market where they are the supplier of the fuels. Their primary concern is to rely on the demand for the respective fuel.

Secondly, shipping companies face investments where they must choose fuels applicable to future operational standards, which is highly unpredictable due to the knowledge gap regarding alternative fuel options. Hence the impact is ranked as high (3). Furthermore, investment in changing the fleet or retrofitting the vessels will have substantial financial implications if the fleet or engine systems are not applicable as intended. Another concern related to the investment risk is the potential reduction in cargo space and utilised energy. More precisely, the probability of needing more space for fuel instead of filling the cargo area with goods which generate revenue is present. From a broader perspective, such changes in space constraints and utilisation of energy sources impact the supply chain. A reduction in transported goods and an increased need in the volume of the respective fuel options to achieve the exact utilisation as HFO lead to longer lead times and increased fuel costs. Furthermore, disruptions in the supply chain due to the shipping companies need to be more sustainable and impact several actors towards the end-customer in a supply chain. In addition, the ship owners face financial losses if their investments do not align with the charterer's requirements, and they are explicitly vulnerable to unpredicted regulatory changes, which is emphasised by Foretich et al. 2021; Kesieme et al. (2019) and additionally also stated by ID-2.

Thirdly, ports face investment risks related to infrastructure expansion and development to accommodate sustainable fuels. As indicated, the investment risk has a lower impact (1) since the investments done at the ports are applicable for several fuel types, as substantiated by ID-3 as well. Furthermore, the ports are passing on the risk to the fuel producers by letting them rent land on the port, making it accessible for them to supply respective fuel options.

5.5.1.2 Risk Related to Specific Fuel Types

Gerlitz et al. (2022); Schinas & Butler (2016); Mckinley et al. (2021) bring out the risks related to the use of sustainable fuels. The "risk related to specific fuel types" contains a median probability of 2, which is highly dependent on the type of fuel and the set of challenges and risks associated with those, respectively. As emphasised by Gertlitz et al. (2022); Law et al. (2021); Mckinley et al. (2021), it is expected that fuels reduce greenhouse gas emissions, but the risks related to the fuel options are not necessarily assessed. The risks implicate the three stakeholders differently, but it is crucial to assess the risks. Furthermore, ID-6 states the issues of where the power to generate sustainable fuel will come from. The risk of insufficient electricity resources is related explicitly to ammonia and hydrogen production. It has an essential saying in supplying the amount of fuel in demand (ID-6).

For the fuel producers, it is a relatively low risk from their perspective, therefore rated as (1). Being the initial actor in the supply chain, they can adjust their production according to the demand from the market. Furthermore, they are more flexible to adjust by regulatory requirements than the other stakeholders and are more flexible to consider safety requirements to mitigate the risks. On the other hand, shipping companies face a high impact on the risk related to different fuel options, hence rated as (3) in the register. As emphasised by Foretich et al. (2021); Kesieme et al. (2019) and further substantiated by ID-1, and ID-2, shipping companies face risks related to storage, handling and safety concerns. In addition, they face risks regarding whether sustainable fuels apply to the existing infrastructure. Furthermore, the impact on the ports is rated as medium. The ports must also manage the risks associated with the different fuel types. This includes obtaining safety requirements and dealing with increased toxicity in the event of leakage. ID-3 stated that the ports have a lesser impact considering the fuels due to their applicability to supply the fuels using the same tanks for storage, which is less costly. Therefore the impact at the ports is rated as (2).

5.5.1.3 Uncertainty and Regulatory Risks

ID-6, substantiated by ID-2, highlights the uncertainty prevailing in the energy market due to a worldwide energy deficit and the unpredictable regulations from organisations such as the EU and IMO. These views are consistent with the perspectives shared by fuel producers and shipping companies. ID-2 clarified the shipping companies' perception of the unpredictable regulations and underlined the complexity and risk involved. The risk register applies the "uncertainty and regulatory risks" associated with the transition to a median probability 2. Considering the regulations in the shipping industry, the dynamic and uncertain environment impacts the three stakeholders differently but is a significant reason for how they are incentivised towards the transition. As stated by ID-6, change in regulatory frameworks impacts fuel producers. Even though they are adaptable to implementing new strategies or adjusting their fuel production according to regulations, they still face challenges regarding the uncertainty in demand and the pricing of alternative fuel options. However, their impact is rated as (1) due to their better ability to adjust according to regulations. This is explained due to their operations being more agile and responsive to regulatory changes than the other stakeholders, as emphasised by ID-2, ID-5, ID-7 and ID-9.

On the other hand, the impact on shipping companies is rated as significant, with a score of 3. McKinlay et al. (2021) emphasise that regulatory changes can substantially impact the economics and operation of the shipping industry, which is also stated by ID-2 and substantiated by ID-8. Regulations significantly impact ship design, propulsion type, and fuel selection. New regulations may necessitate substantial modifications to the infrastructure or even a phase-out of the vessels. The primary concern that ID-2 states is that the shipping companies are in a situation where they do not know which fuels will be compliant, which impacts their strategic planning and investment decisions.

ID-3 states that the impact on the ports is minimal to none, therefore rated as (0). Ports must provide the necessary infrastructure for managing various types of fuels. However, they are often able to respond to changes in regulations. The investments determine the port's impact to accommodate the future fuel mix. Specifically, the investment done at the ports must be feasible to operate with several fuels in order to be beneficial.

5.5.1.4 Infrastructure and Financial Support Risk

Insights from ports shed light on the infrastructure and financial support as risks not discussed broadly enough in the literature. ID-3 and ID-5 emphasised the lack of municipal financial support and the absence of port funding schemes as risks that could hinder necessary changes. They also mentioned the safety risks that different fuels pose to their operations and the risk of not being competitive if they cannot facilitate sustainable fuel options. Therefore this risk is rated as (3).

Infrastructure and financial support are necessary for facilitating sustainable fuel, and the associated risk is determined due to the unpredictability related to this concern. As our risk register indicates, these risks have a medium impact (2) for fuel producers. These risks are mostly related to the infrastructure requirements for producing and facilitating alternative fuel. For instance, as emphasised by Gerlitz et al. (2022), Kurrien & Mittal (2022) and McKinley et al. (2021), ammonia and hydrogen are highly reliant on infrastructure that fulfils their requirement. The financial support for such facilitation is substantial, and lacking such support could hinder the transition from being effective as intended. However, as noted by ID-3, there are only space constraints at the ports that limit the fuel producers' ability to supply sustainable fuel. However, financial support for the expansion of the port is essential. On the other hand, shipping companies face infrastructure-related obstacles, specifically considering port-fuelling along the routes, as ID-4 emphasised. The lack of such operational infrastructure features deceives the transition and thus obtains a medium impact (2) score for the shipping companies. As this facilitation requires significant investments, the financial burden related to the development of the port can be substantial for shipping companies. (Kurien & Mittal, 2022; Foretich et al. 2021)

5.5.1.5 Operational and Compatibility Risk

ID-2 and ID-4 highlighted operational and compatibility risks, such as the uncertainty of an alternative fuel's lifespan, development, and compatibility with current engine systems, as the most severe ones. In our risk register, the operational and compatibility risk was given the maximum probability (3) of occurrence related to the transition to alternative fuel. As for the other risks above, the impact of risk varies by the stakeholders, whereas the impact is less significant for the fuel producers and of high severity for shipping companies and ports.

The fuel producers' low impact (1) on this risk can be explained due to their engagement in the production and distribution of fuels. Therefore they experience less of an operational and compatibility impact during the transition process than the other stakeholders. The fuel producers may need new production technologies and changes in handling the fuel in the supply chain. However, these obstacles are not as severe considering the shipping companies and the ports.

This risk has a significant impact (3) on the shipping companies. Alternative fuels necessitate substantial modifications to the operation and fuel systems of ships.

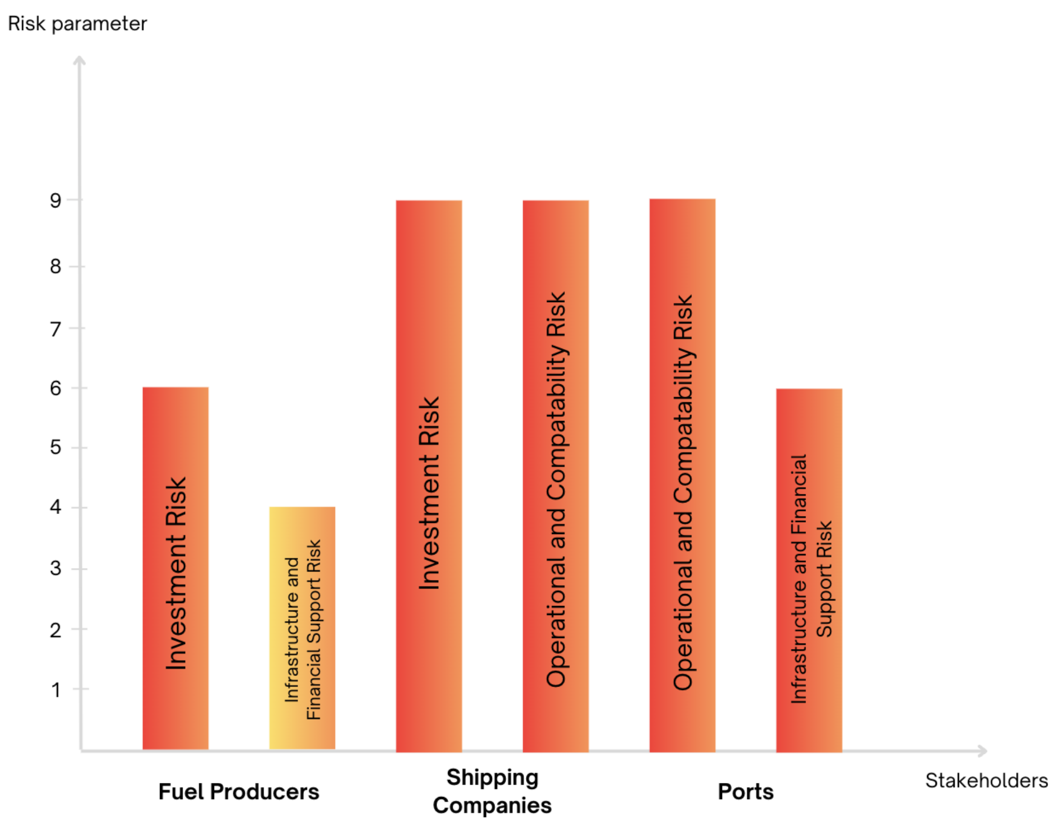
This includes necessary modifications to the engine system, the ability to store fuel, and handling procedures (Schinas & Butler, 2016), (Kurien & Mittal, 2022), (McKinlay et al., 2021). Further, shipping companies face uncertainty considering their vessels' lifespan and alternative fuel development (Zhang et al., 2021). As ID-1 and ID-2 stated, compatibility with existing engine systems is crucial, and alternative fuel options have a high probability of the need to overhaul the engine system.

Similar to shipping companies, ports face a high impact (3) for this risk category. Ports are crucial in the fuel supply chain and must modify their operations to facilitate alternative fuel storage, handling, and distribution (EPA, 2022). Moreover, the compatibility of the fuel options with existing port infrastructure is challenging for the ports. As stated by ID-3, some port expansion is required to facilitate alternative options. As ID-5, ID-7 and ID-10 have emphasised, stricter security measures and more extensive safety parameters are necessary when handling certain fuel types. Thus the necessity for substantial operational changes and space optimisation are necessary.

5.5.2 Risk Prioritisation & Risk Mitigation Strategies

After identifying and assessing the risk, it is essential to prioritise the most severe risks to mitigate their impact. As emphasised, the three stakeholders have different risk perceptions. Therefore, the risk register prioritises the risk according to severity (Fan & Stevenson, 2018). An important note is that the most severe risks are mitigated. The most common risks for all three stakeholders are investment, infrastructure and financial support, and operational and compatibility risks. The most severe risk is assessed based on the total risk score achieved in the risk evaluation, as shown in Table 9 and highlighted in Table 10. View tables 11, 12 and 13 for each stakeholder's mitigation strategy.

Table 10 - Diagram of Prioritised Risks, made by authors.



5.5.2.1 Mitigation Strategies for Fuel Producers

Starting off with fuel producers, the most critical risk they need to assess is the risk related to investment and the risk related to the infrastructure, whereas the severity of the total risk is rated to be 6 and 4 respectively (Table 10). In order to mitigate the investment risks it is crucial to investigate areas which makes the decision-making process related to necessary investment less risky..

Table 11 - Mitigation Strategies for Fuel Producers

Fuel Producer	<u>Mitigate Investment Risk:</u> Conducting a cost-benefit analysis gives the possibility to assess the viability and the longevity of the investments. To hedge against major economic losses the fuel producers should consider the technical maturity, safety concerns and the market demand of the fuels. <u>Mitigate the lack of Infrastructure and Financial Support</u> Actively engage with government officials and policymakers to seek funding programs, tax incentives and subsidies for development of the infrastructure. <u>Collaborative Partnership</u> Collaboration facilitates for alignment of investments and thus reduces the related risks and additionally ensures compatibility.	Agudelo et al. (2022); Bø et al. (2023); (Foretich et al. (2021); Kesieme et al. (2019); Longarela et al. (2020); Lun et. al (2016); Nian et al. (2019); Prussi et al. (2021); Stank et al. (2011); ID-3; ID-5; ID-6; ID-7; ID-12

Firstly it is essential to start investigating the incentives that are present in order for the required transition. As emphasised by Longarela et al. (2020), Nian et al. (2019), and Agudelo et al. (2022), the main incentive to conduct investments is the longevity of the investments. As uncertainty evolves in the shipping industry, conducting a cost-benefit analysis highlighting the most crucial aspect regarding utilising the different fuel options is crucial. In order to mitigate the risks of conducting investment in an uncertain environment, the cost analysis shall indicate which fuel to bet on by considering the technical maturity, safety concerns and the market demand of the respective fuel, which is also emphasised by Prussi et al. (2021).

The second risk is related to the infrastructure and the lack of financial support (Foretich et al., 2021), (Kesieme et al., 2019), (ID-5, ID-6, ID-7, ID-12). To mitigate the absence of financial support, the fuel producers shall consider engaging actively with government officials and policymakers for efficient infrastructure development. In practical terms, the fuel producers shall seek funding programmes, tax incentives and other subsidies to facilitate alternative fuel production. By highlighting the economic, environmental, and social benefits, the fuel producers have a legitimate case to seek financial support. Eventually, it will smoothen up the burden of making the necessary developments to facilitate alternative fuel options before investing in sustainable fuel.

5.5.2.2 Mitigation Strategies for Shipping Companies

Table 12 - Mitigation Strategies for Shipping Companies

Shipping Company	Mitigate Investment Risk The shipping companies should conduct a thorough feasibility assessment of the fuel options. Furthermore, the companies should assess the availability of fuel options along the routes prior to conducting investments. Mitigating operational and compatibility risk Increase own knowledge of fuel feasibility to ensure its compatibility with existing infrastructure. Align fuel options with shipping company´s operational procedures to reduce operational and compatibility concerns. Collaborative Partnership Engaging in collaboration will increase the allocation the resources more precisely and efficiently.	Anderson et al. (2016); Dinneen (2022); Fasoulis & Kurt (2019); Gerlitz et al. (2022); Longarela-Ares et al. (2020); Prussi et al. (2021); Zhang et al. (2021); ID-4; ID-6; ID-8; ID-14

The most crucial risks from a shipping company's view are the risks associated with investment and the risks associated with the operational and compatibility aspects (Zhang et al., 2021) of the fuels mentioned in the sub-chapter 5.5.1.5. Both risks are rated as 9 in severity (Table 9 & Table 10) and necessitate the importance of assessing them. To mitigate the investment risk, it is necessary to conduct a thorough feasibility assessment of the fuel options in order to be beneficial in the aspects regarding the technical, economic and operational considerations (Brynolf et al., 2016; Dinneen, 2022; Fasoulis & Kurt, 2019; Gerlitz et al. 2022 Longarela-Ares et al. 2020; Prussi et al., 2021; ID-6; ID-8). Increasing the shipping company's knowledge level related to the fuel's feasibility will ensure compatibility with the existing infrastructure. Considering the investment risk, it is essential to explore the suitability of the fuel options. Alternative fuel options must be available along the routes (ID-4). If the applicability and availability of the fuels are assessed thoroughly considering the operational procedures for the respective firm, the risk related to investing in fuel options that do not satisfy these concerns is reduced. Additionally, it will reduce risk-related operational and compatibility concerns.

5.5.2.3 Mitigation Strategies for Ports

Table 13 - Mitigation Strategies for Ports

Port	Infrastructure Risk Mitigation Conduct a feasibility assessment which considers the demand, potential ROI, operational efficiency, and environmental benefit. It is important to examine the characteristics of the fuels, such as toxicity, flammability and corrosion rate in order to assess to compatibility of the fuel type. Highlight the necessary infrastructure development required for storage and bunkering of cleaner fuel. Enhance the infrastructural adaptability of cleaner fuels to optimise operational procedures. Mitigating operational and compatibility risk Examining fuel characteristics such as toxicity, flammability and corrosion rate will decrease the risk of whether the fuels are compatible or not. Collaborative Partnership Through collaboration the ports can gain access to funding schemes that reduces the financial burden required for the development of the ports. Further collaboration enhances the knowledge-sharing, best practice agreement and aligned technological development.	Bø et al. (2023); Foretich et al. (2021); Kesieme et al. (2019); Mckinlay et al. (2021); Shi et al. (2023); Stank et al. (2011); ID-3; ID-5; ID-7; ID-9;

The risk assessment shows that the ports must prioritise the "infrastructure and financial support risks" and "operational and compatibility risks", as highlighted in Table 10. The severity of the risks is rated as 6 and 9, respectively (Table 9). To mitigate the first risk, conducting a feasibility study, such as for shipping companies, is necessary. However, the ports must thoroughly examine the demand, the potential returnment on the investments, operational efficiency and environmental benefits. It is worth noting that ID-3, ID-5, ID-7, and ID-9 emphasised that they are more adaptable to change. However, it is important to highlight such factors to prioritise the investments and ensure efficient allocation of resources. Moreover, to mitigate operational and compatibility risks, the fuel producers shall develop and modernise the infrastructure at the ports by being adaptable to alternative fuels. Enhanced infrastructure adaptability ensures that tanks and bunkering facilities are more feasible considering the operational procedures related to fuel handling. Furthermore, to ensure compatibility, the ports shall examine the characteristics of the fuels (toxicity, flammability and corrosion rate) in order to mitigate the risk related to compatibility (Foretich et al., 2021; Kesieme et al. 2019; McKinlay et al., 2021; Shi et al. 2023).

5.5.2.4 Mitigating Risks by Enhancing Collaborative Partnerships

A mitigation strategy that applies to all the stakeholders is engaging in collaborative partnerships with other stakeholders within and outside their category. More precisely, fuel producers collaborate with other fuel producers, ports with other ports, and shipping companies with other companies. Additionally, their collaboration with each other is also beneficial. From a fuel producers' perspective, engaging in collaborative partnerships increases information-sharing. This is beneficial for gathering information about specific fuels, as the industry still has a knowledge gap and uncertainty. Furthermore, information-sharing prevents the production of incompatible or unsafe fuel options; however, as ID-6 emphasised, which is also substantiated by ID-12, the fuel producers find it a disadvantage since it affects the competitive advantage. From a fuel producer's perspective, it is beneficial to collaborate with the two other stakeholders since a collaborative partnership between fuel producers and shipping companies is beneficial in terms of better understanding each other's operational procedures. This alignment reduced the risk of producing fuels that are not demanded. Moreover, a collaborative partnership between ports and fuel producers highlights the necessary facilitations for the storage and bunkering of the fuels. Such partnership will eventually decrease the logistical bottlenecks and supply chain disruptions. (Bø et al. 2023; Lun et al. 2016; Stank et al. 2011).

Shipping companies have several benefits from engaging in collaborative partnerships. Firstly the shipping companies get the ability to reduce their risk exposure associated with the transition. By collaborating with fuel producers and ports, shipping companies can allocate their resources, expertise, and investments (Liao et al., 2017). The collaborative partnership enhances infrastructure development and makes aligning investment plans with other stakeholders easier. In that sense, the risk of investing in deficient technology is significantly reduced.

ID-14 stated that collaborative partnerships enhance the possibility of gaining mutual benefits for all the stakeholders by gaining access to capital, knowledge and technology as some of the benefits. Concerning investment risk at the ports, highlighted by ID-3 and ID-5, they state that it is desirable to spread the risk among the stakeholders evenly. As well as the other stakeholders above, the ports benefit from engaging in collaborative partnerships. The ports can access funding schemes that reduce the financial burden through collaboration. Additionally, the ports are more capable of sustaining safety concerns due to the involvement of all the stakeholders through knowledge-sharing, best practice agreements and technology development, reducing the risks with the most impact.

Chapter 6 - Conclusion

The research study aimed to investigate how risk management strategies can effectively mitigate the identified risks faced by shipping stakeholders during the transition to sustainable fuels. We investigated and addressed relevant drivers, barriers, enablers, and collaborative partnerships' role in managing the identified risks to extract the necessary mitigation strategies. We created this research question to accomplish our aim:

How can risk management reduce shipping stakeholders' risks based on drivers, barriers, enablers and collaborative partnerships in the transition to sustainable fuel?

The master thesis uses qualitative research, including interviews with experts, to better comprehend the transition to sustainable fuel from key shipping stakeholder's perspective. Therefore, we conducted nine in-depth expert interviews, attended Nor-Shipping 2023, watched five presentations of key shipping stakeholders and talked to them after their presentations to gain new perspectives by learning about their unique viewpoints and experiences. Our abductive approach required us to return to the theory between interviews to prepare the discussion between findings and literature.

The theoretical background, empirical findings and discussion is structured through the three themes (1) Drivers, barriers and enablers considering the transition to sustainable fuel, (2) Collaborative partnerships, and (3) Risks and risk management. These themes are used throughout the master thesis to build up our theoretical background and findings to create the discussion, which facilitated the answer to our research question in a structured manner.

Discussing the theoretical background against our findings revealed that by addressing drivers, barriers, and enablers and building collaborative partnerships, risk management may significantly reduce the risks faced by shipping stakeholders throughout the transition to sustainable fuels.

The drivers we discovered while collecting primary and secondary data were quite comparable. Regulatory policies, a global energy deficit, environmental concerns, and the need for sustainable operations primarily drive the transition to sustainable fuels. However, the drivers also entail risks, and the five primary risk categories faced by fuel producers, shipping companies, and ports emerged as investment risks, risks related to specific fuel types, uncertainty and regulatory risks, infrastructure and financial support risk and operational and compatibility risks. Furthermore, we used a risk register to assess and prioritise the five main risks and limit our proposed mitigation strategies to focus on the most critical risks which is investment risk, infrastructure- and financial support risk, and operational- and compatibility risk.

These risks are decreased by risk management by focusing on barriers and enablers. Firstly, an extensive cost-benefit analysis is crucial for investment risks. It enables stakeholders to comprehend the costs, technical maturity, and market demand for various sustainable fuel options, enabling stakeholders to make well-informed investment decisions. Infrastructure and financial support risks can be reduced by actively engaging with government representatives and legislators to seek financing programs, tax incentives, and other subsidies. This can lessen the cost burden of building the infrastructure to support sustainable fuel. Comprehensive fuel feasibility analyses are required to reduce and operational and compatibility risks. Stakeholders can make strategic decisions that reduce risks by assessing the compatibility of sustainable fuels with existing infrastructure, the lifespan of vessels, safety considerations and technological development.

This study also emphasised the importance of collaborative partnerships for efficient risk management. By stakeholders sharing their knowledge, resources, and experience, they lower individual risk exposure. Additionally, collaborative partnerships encourage sharing safety best practices and the alignment of investment plans, infrastructure development, and operational processes for each stakeholder. In all essence, it is crucial to remember that even while working together could at first diminish competitive advantage, the long-term advantages of shared risk management in a volatile market may exceed such worries.

In the abovementioned sections, we have summarised our findings to answer our research question. By methodically addressing the drivers and barriers, leveraging the enablers and encouraging collaborative partnerships, we conclude that risk management decreases the risks faced by shipping stakeholders in the transition to sustainable fuels. The risk mitigation strategies give fuel producers, shipping companies and ports a platform for navigating the risks and challenges of this transition while preserving the long-term viability and sustainability of their operations.

6.1 Limitations & Future Research

The study's limitations must be considered when doing research, as section 2.6 also demonstrates. The study poses several limitations. The first is the subjectivity and bias of our findings and discussion considering fuel producers. Secondly, it follows sample size and generalisability. Thirdly, the time-horison of writing a master thesis poses two contending limitations. Either focusing on conducting more interviews with less time for analysis or conducting fewer interviews while focusing more on analysis. The fourth and fifth limitations consider the geographical scope and quantitative data. The last significant limitation affecting our research study is the quality of the questions asked.

We interviewed all the various stakeholders to obtain diverse perspectives during the expert interviews. We performed nine expert interviews in total. The interviewees included experts who worked for ports, shipping companies, and fuel producers. However, our research's objectivity is partly compromised because we conducted so many interviews with experts in the relevant domains. Only one interview was conducted with a fuel producer, while four were conducted with shipping companies and port operations. In addition, during Nor-Shipping 2023, we watched five company presentations given by three shipping companies, one fuel producer and one private equity firm. We valued the presentation from the fuel producer, who provided a different perspective than the fuel producer we interviewed. However, we acknowledge that we should have conducted more interviews with fuel producers especially. This has affected the study's findings from the perspective of fuel producers. If we had conducted more interviews in that field, we would have gotten a better understanding and a more objective perspective.

Secondly, whether our sample size of nine in-depth expert interviews and our attendance at Nor-Shipping 2023 was enough to respond to our research question is debatable. We would have gotten a more generalisable research study if we had conducted more interviews with all three stakeholders. This limitation leads us to the third limitation, time restriction.

Due to the time-horison of the master thesis, we had to make a choice that created different limitations whatever one may choose. We could have conducted more interviews by focusing only on increasing the number of interviews. However, conducting and analysing the interviews afterwards is time-consuming. If we had conducted more interviews, it would have affected the time used for analysis, which would further affect our findings and discussion. Therefore, we had to balance the number of interviews and the analysis to extract everything from the interviews conducted properly.

The fourth limitation is our study's need for more geographical scope. We deliberately chose not to limit our thesis geographically as several stakeholders we interviewed operate internationally and depend on the global development of sustainable fuels. Our interviews, however, are conducted primarily with

Norwegian-based stakeholders, which limits our findings to being influenced by a specific geographic region. Even though, though several of the interview objects have international operations and answered our questions based on an international perspective, we highlight that ports specifically answered our questions based on national operations.

The fifth limitation is the study's need for more quantitative data considering the extent of the proposed risk management strategies. The thesis is based on qualitative research, and we have focused on gathering significant amounts of descriptive data through interviews, presentations and secondary literature. However, the lack of quantitative data considering the impacts of the risk management strategies proposed would have given the three stakeholders we want to support a greater utilisation when reading our research study. We recognised this limitation during our data collection phase. However, we needed to prioritise themes 1 and 2 as we assessed the knowledge of drivers, barriers and drivers, and collaborative partnerships as two themes that needed to be addressed to substantiate our thesis's risks and risk management perspective. Therefore, we acknowledge that the need for more quantitative data is a limitation considering the extent of the proposed risk management perspectives.

The sixth limitation of the study is our limited competence in the shipping industry and sustainable fuel options. Therefore, we could not create an interview guide which extracted the most valuable insights during the primary data collection phase. We highlight the second part of the interview guide, which consists of drivers, barriers and enablers. Initially, we called theme 1 "Overview of the transition to sustainable fuel in the shipping industry." Based on feedback, we were recommended to change this, and therefore, we changed it to "Drivers, barriers and enablers considering the transition to sustainable fuel." This change was done after we conducted the interviews, and therefore we have yet to list the specific questions of drivers, barriers and enablers. However, questions 4, 5 and 6 initiated discussions considering barriers and enablers. Drivers, we discussed implicitly based on our interest in why the shipping industry has been forced to transition to sustainable fuel. Despite our abductive approach, we acknowledge that we would have gotten more valuable insights by conducting interviews later, even though that would have affected our analysis due to the limited time-horison.

These limitations pose opportunities for future research, and we have suggested two areas for future research. These areas are based on thoughts we have had during writing but have been unable to analyse due to time restrictions. The first area addresses the fifth limitation, focusing on researching quantitative data considering the financial consequences of the identified risks and risk management strategies for the different stakeholders. Through in-depth research of the financial impacts considering the different risks and how risk management strategies can decrease the financial impacts would be highly beneficial for the three stakeholders.

Our interview with the fuel producer was the second area we considered applicable for future research. Even though ID-6 projected a biased perspective, as mentioned in the first limitation. The interviewee contributed some fascinating insights elaborating that the supply of energy to sustain the transition to sustainable fuel is not enough to satisfy future demand. Due to the limited time-horison, we needed more time to review the topic. There needs to be more research on the topic, and why we suggest researchers analyse if the energy market can supply future demand.

Chapter 7 - Reference list

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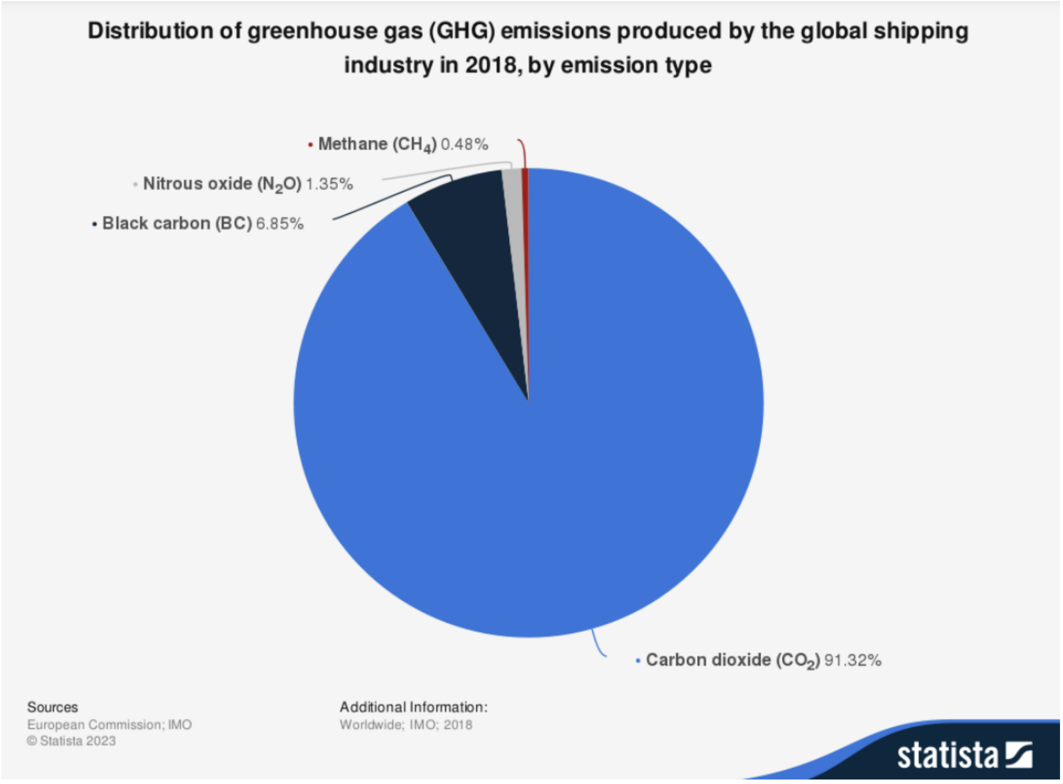
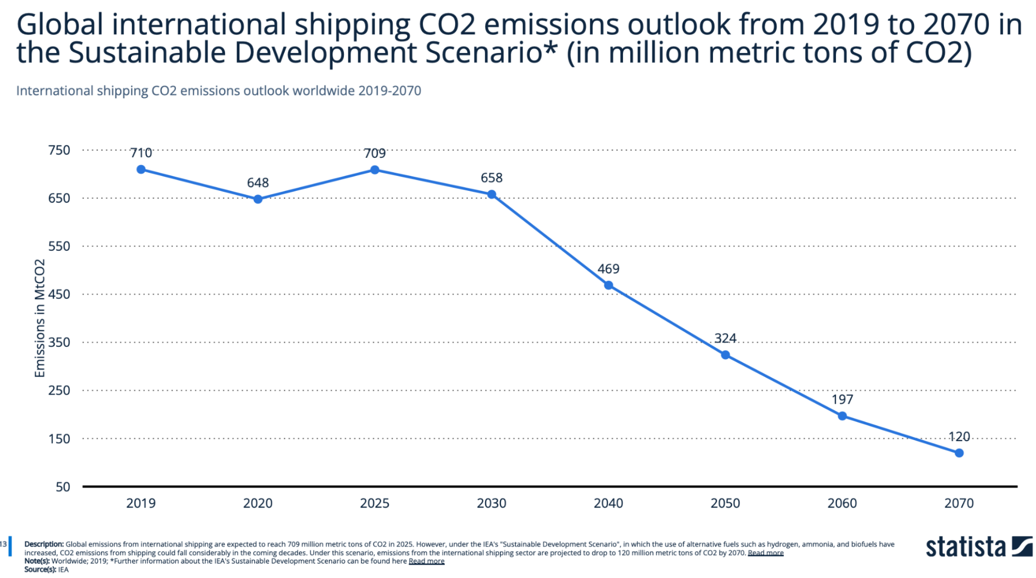
Appendix

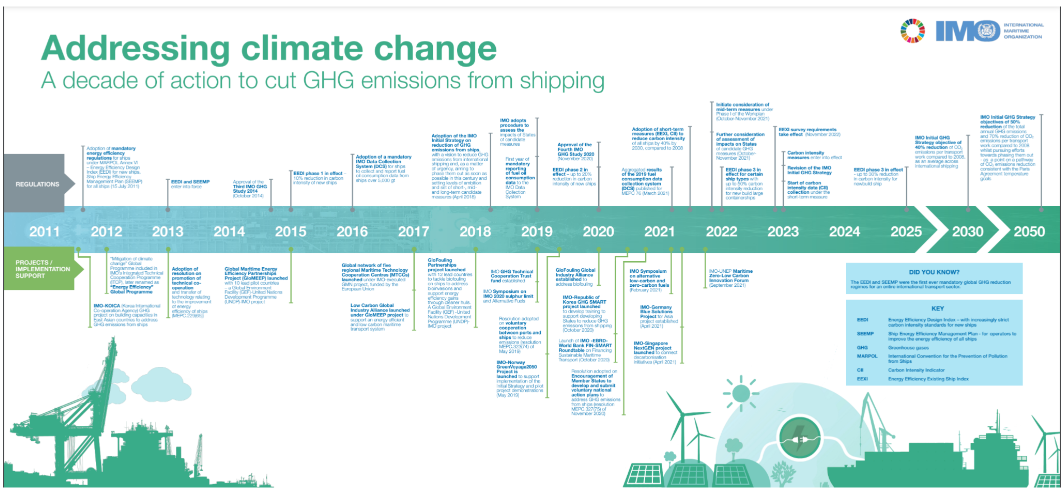
Appendix 1 - Distribution of GHG Emissions Produced by the Global Shipping Industry in 2018, by emission type.



Appendix 2 - Global International Shipping CO2 Emissions Outlook from 2019 to 2070 in the Sustainable Development Scenario* (in million metric tons of CO2).



Appendix 3 - Addressing Climate Change



Appendix 4 - Interview Guide

Interview guide
Purpose of the questions: - Gain general knowledge from the contact person *Intention:* - Learn more about the interview subject, their function in the focal firm, and any potential opinions on our research topic. *Questions:* 1. What is your job title? Which department do you work in? 2. What are your daily tasks? 3. What is your field of interest?
Purpose of the questions: - Driver, barrer and enablers considering the transition to alternative fuel *Intention:* - Get insights into drivers, barriers and enablers considering the transition to cleaner fuel *Questions:* 4. What are the main obstacles of implementing environmental-friendly fuels in the shipping industry? 5. What do you think needs to be facilitated for transition to environmental-friendly fuels? (Infrastructure) 6. Which activities in the shipping industry decrease the incentives for transition among different shipping companies? 7. How will ports be affected by implementing environmental-friendly fuels regarding aspects such as their infrastructure and capacity? 8. Will it reduce factors such as delivery accuracy? How will it affect the operations at the ports?

9. What do you think is the feasible solution for all parties in the shipping industry? (Ports, shipping companies, fuel suppliers)
Purpose of the questions: - Collaborative partnership *Intention:* - Get insights into the importance of collaborative partnerships considering the transition to alternative fuel *Questions:* 10. How can collaboration between competitive companies lead to necessary transitions? 11. What are the benefits and disadvantages for both (or several parties) in a collaborative relationship? 12. Do you engage in collaborative relationships? Why/Why not? What do you seek to gain from it? / What do you characterise as a disadvantage? 13. What type of collaborative relationship do you engage in? (Information sharing, collaborative investments, conduct equal decision making? 14. When do you find it as a disadvantage to engage in a collaborative relationship?
Purpose of the questions: - Risk management *Intention:* - Identify, assess and evaluate how to manage different risks and costs connected to the implementation of environmental-friendly fuels *Questions:* 15. What risks do you consider the ports are facing with environmental-friendly fuels? 16. What are the main costs to view from your position considering

implementing environmental-friendly fuels?

17. To what extent can collaboration among different actors in the supply chain reduce the overall risk related to the transition towards greener solution?
18. What risk mitigation strategies are recognised as best practice (for now) to reduce cost related to the required transition?
19. Which CSFs (critical success factor) must be satisfied before considering a transition / implementing environmental-friendly fuels?
20. How does the uncertainty in the energy market influence the decision making process regarding the transition towards implementing sustainable fuel options?

Appendix 5 - Theme Scheme for Primary Data Collection

Themes	Stakeholders	Similar quotes and information
Theme 1 Drivers, barriers and enablers considering the transition to greener fuels	Fuel producers	"Politicians adopt and implement laws and guidelines for the shipping industry that are not based on knowledge of the specific alternative fuels. Politicians do not have enough knowledge to implement the changes they are implementing, which will eventually lead to supply-demand problems for shipping companies and ports. The reason for this is because e.g., Hydrogen and ammonia are produced through an industrial process that requires a lot of electricity. There is in addition high demand for hydrogen and ammonia, but where will the power come from?" Suggesting that power should come from wind turbines is not well though through as on average a wind turbine must produce electricity for at least 10 years for it to be able to generate as much energy as it is required to build it. Offshore wind turbines and farms demand enormous space and therefore it is a problem to occupy land mass and therefore we must build them at sea. Which is a costly operation. Access to natural gas with a view to LNG is difficult to obtain after the war between Russia and Ukraine because Russia limits access, which has led to a gas crisis. However, LNG is the best way to burn fossil fuels because it turns into water. LNG is in addition more expensive than diesel because of price dynamics. The media has a lot of power in relation to politicians. If politicians want to have the greatest possible support from voters, they have been pressured to promote environmentally friendly solutions that are not possible. If politicians do not promote the environmentally friendly solutions we dream of, they get fewer voters, because the media slaughters them and reduces the party's support in an election campaign. "Production of fuels like hydrogen and ammonia approximately 40% of the kWh produced is lost. Typically, it takes 60 kWh of electricity to produce one kilogram of hydrogen = 36 kWh. "Oil will be burnt/sold/consumed anyway for a long period of time, why not emit sulphur dioxide at sea where it creates the least harm for the environment?" "For a transition to environmentally friendly fuels the global markets need to ensure availability of fuels especially of LNG as that is the only realistic option at the moment. However, there is not enough supply and production of LNG to fulfil the demand in the foreseeable future." The activities that decrease the incentives for transitioning to alternative fuels in the shipping industry is availability of electricity, prices - alternative fuels are much more expensive. "A feasible solution for all parties in the shipping industry is electrification using nuclear power because of the energy crisis the world now finds itself in because of the war in Ukraine." "There is no particular first-mover advantage for shipping company due to shipping being such a capital-intensive industry."
	Ports	"Some of the main obstacles of implementing environmental-friendly fuels Considering Norway, demand is the biggest obstacle as ships do not generally fuel up on the ports in Norway. They fuel up in Europe (Hamburg, Bremerhaven and so on…) » "Investments in infrastructure to bunker/store the fuel. This is an obstacle but not impossible to overcome. Tanks can be used for several fuels if cleaned properly. This predicts that the shipping industry is focusing on one fuel type at a time." « Ports are very interested in the future and facilitating different fuel solutions in order to make the transition to alternative fuels easier in addition make sure that they attract new customers by offering fuel types of new ships are using.

		"In order to facilitate environmentally friendly fuels at ports one need trustworthy fuel producers who can supply the specific fuel of demand. Secondly, Drammen Port needs to make space for the tanks the fuel will be stored in. Thirdly, they are trying to get companies like Equinor to do the infrastructure investments of the tanks. In essence, ports rent out their space Equinor for them to sell their fuel." "Electricity is easier to facilitate than other alternative fuels. » "Ports facilitates the fuel that has the highest demand from shipping companies which necessarily is not environmental-friendly fuels, since the most used fuel is still HSFO." "Since ports facilitate the shipping companies, they become dependent on what the shipping companies focus on. Since shipping companies do not have a first-mover advantage considering alternative fuels this may be an activity or event which decreases the incentives for transition to alternative fuel for ports." "Forward leaning ports are planning on expanding their ports to be able to implement more alternative fuels. Ports in general will need to expand their port so that the implementation of alternative fuel systems does not interfere with their current and growing operations." "Alternative fuel takes up space and therefore interferes with capacity and operations if the ports do not expand." "Some ports may experience that implementation of alternative fuel will affect their operations if they do not have the capacity and are not able to expand their port." "Government and municipality slow down the process to environment friendly fuel options, while the traffic into the ports increases. The government / municipality wants to develop the city. On the other hand, the port wants to expand. Therefore, there is a conflict of interest between the municipality and port."
	Shipping companies	"The main obstacles of implementing environmental-friendly fuels for shipping companies are Availability on sustainable fuel options and that the alternative fuel is compatible with existing infrastructure." "Building new ships is not always the solution, the environmental threats of destroying ships that are only 20 years old, when in reality they last another 20 years, is immense." "Some activities for shipping companies that decrease the incentives for transition is Capacity constraints sat by the respective fuel type. The alternative fuel must obtain existing efficiency and in addition have less or similar impact on the space constraints due to bunkering of fuel on the ships. The CII rating classify / rates the ships by how many tons that are moved with the consumption of a respective fuel. These numbers can indicate wrong estimations in relation to actual GHG emissions, and thereby have an impact CII rating. The point is that the rating system of the ships is not up to date." " Not the delivery accuracy specifically, but to maintain the same efficiency as HSFO is questionable with environmentally friendly fuels. The operations at ports will vary depending on the availability of the specific fuel type." "Some of the main barriers are: Price, current alternative fuels are too expensive, 2-6X the price of HFO. - Higher demand than supply - production of ammonia equals approx. 150 million metric tonnes. In order, to be able to compete with HFO, production and demand must increase to approx. 800 million tonnes. Hydrogen is produced through an industrial process where an energy loss occurs when extracting green hydrogen.

		- Typically, it takes 60 kWh of electricity to produce one kilogram of hydrogen = 33 kWh. Energy-inefficient. - In addition, power is a limited resource. - In principle, hydrogen should not be moved. Additionally, hydrogen is expensive to transport. Logistics and infrastructure around hydrogen are extremely challenging. - Furthermore, hydrogen is a significant safety risk. Ammonia: - Toxic emissions Electro fuels: - Does not view the future of electro fuels as a realistic alternative." "To facilitate the transition to alternative fuel it is essential to focus on the alternatives that are energy efficient. - Focus on energy conserving technology, methods, and design. To have the same operational capability as HSFO, it is required significantly more hydrogen to obtain the similar operational capability. LNG: - 400 million tonnes LNG in sales on a global scale annually. Bio LNG is a relevant alternative as methane from agriculture and animal excrement is a major emission factor. Bio LNG consists of 96% methane, and we can separate the methane from the cow faeces and convert this to biogas. but bio-LNG has various logistical challenges. The reason why this can facilitate an environmentally friendly conversion to alternative fuel is that the production of bio-LNG will reduce emissions (100.000 tonnes) from the agricultural sector while at the same time offering an environmentally friendly fuel. EU incentives the transition to LNG in the shipping industry, which leads to an increased biogas production. The expected produced volume is to be 25 million tons of biogas which is a constraint because the industry needs more. Carbon capture - Where shall it be stored? How can carbon capture be optimised? Ammonia is not legal to use because of toxic emissions. Ammonia driven engines do not exist for now but are continuously developed and researched." "Activities in the shipping industry that decrease the incentives for transition among different shipping companies can be: - IMO is agnostic. They are only setting constraints for emission. - In addition, power (electricity) is a limited resource." "How will shipping companies be affected by implementing environmental-friendly fuels regarding aspects such as their infrastructure and capacity? - Energy conservation is more optimal if the ships are designed in a specific way. More specifically, the correct design of the hull on the ships can lead to energy-and fuel savings. In other words, greater utilisation of the specific fuel type. - Optimal planning such as weather routing will optimise the fuel consumption. It will have an impact on capacity. - The shipping industry also views investments in sail driven ships, e.g. As Flettner rotors that save production of HFO by 10-12% per ship. Which reduces carbon emissions. - In addition, ships can save up to 4-5% on hull optimisation. - For LNG driven ships the cargo is affected since the LNG is at its boiling point when the ships sails."

Theme 2 Collaborative partnerships	Fuel producers	"Collaboration between fuel producers is not that common as they are continuously developing different technologies which is not that favourable to share with other fuel producers." "However, fuel producers collaborate all the time with ports and shipping companies in order to substantiate a resilient supply chain."
	Ports	«Transparency is the advantage of collaboration. However, a degree of collaboration among ports is higher than the level of collaboration between shipping companies. » "First mover advantage exists for ports as they can gain a good reputation as forward leaning ports which facilitates sustainable fuel solutions to decrease GHG emissions. » "We collaborate with shipping companies, fuel producers and everyone else at every stage. We have to since we are a link point. I.e., Operational collaborations at the port, collaboration with fuel producers in order to supply fuels at the ports, collaboration with shipping companies when ships are planned to dock and collaboration between other ports to find solutions on which port should supply which fuel as it varies how many ships are docking." "Through collaboration you gain experience, solutions for the different operations which have to be done at a port and economic benefits." "However, Drammen port and ports in general need to deal with the municipality which often can be a bit tricky as a municipality may have another agenda. The port and municipality are collaborating, but Einar often experienced them as reluctant to proposals from the port about their operations. This serves as a disadvantage for ports when collaborating with their local municipality."
	Shipping companies	"Transparency and availability of recent and relevant information is essential in the transition phase. However, it seems there is a high degree of collaboration and information sharing among the shipping companies. Worth to mention that few to none shipping companies prefer to obtain "first-mover advantage" due to uncertainty in regard to alternative fuel. The reason for this is that shipping companies do not gain great advantages for being a "first-mover" within a specific fuel as it is mostly a lot of risk connected to huge investments in infrastructure." "There are different ambitions among the different actors (shipping companies, fuel producers and ports), but in general the shipping industry is ready and is planning for a transition to alternative fuel in order to create a more sustainable industry." "Example of competition between fuel producers: Shell, Equinor and Trafigura sell a lot of HSFO and naturally want their fuel to be sold. On the other hand, Yara produces ammonia and wants the market to purchase their product. Therefore, the competition between the different fuel producers does not create a foundation for collaborative relationships. The "first-mover" advantage is greater for fuel producers as opposed to shipping companies. The reason for this is that if most of the shipping industry started to operate ships on ammonia, Yara got a great position with a reputation of being a reliable supplier of ammonia. There is less incentive to collaborate between different fuel producers like Shell, Equinor and Yara. » "Benefit of collaboration: Openness in-between actors creates greater availability to information which can lead to a more effective transition towards alternative fuel." "Even though charterers set requirements, it does not necessarily mean that the shipowners and charterers collaborate to a huge degree, but some form of collaboration between shipowner and charterer is necessary in order to facilitate a functioning relationship between the actors."

		«In general, there is a lot of information sharing between shipping companies through different reports that are published on the transition to alternative fuel. » «For shipping companies there is necessarily no disadvantages in collaboration through sharing information and knowledge. The reason for this is that shipping companies are not particularly interested in being a first mover considering the transition to alternative fuel as there is a lot of risk tied up to these investments. »
Theme 3 Risks and risk management	Fuel producers	"Risks considering fuel producers facing the transition to alternative fuel is availability of renewable energy sources to produce and supply fuel and sustaining economic growth. *"The different fuels pose different risks that can be more environmentally damaging than just sticking to VLSFO and developing fewer polluting diesels. This can i.e., be the probability of leakage of LNG, ammonia and hydrogen under production and refuelling is present. This can eventually lead to more methane related emissions and toxic emissions."* "It is highly needed to have enough or similar amount / level of power from other energy resources. I.e., that the energy extracted from HSFO must be equivalent to energy extracted from Hydrogen / Ammonia / Electricity. (This might require *more* of the specific energy resource than HSFO.) Unless this can lead to great disruptions in shipping supply chains. " «There is a worldwide energy deficit, which increases the uncertainty that evolves around fuels options. »
	Ports	"Risks ports are facing considering the transition to alternative fuel is that the municipality does not support the ports expansion financially." "There are few support schemes for developing ports for the necessary transition." "If it is suggested to expand the port, the cost is approximately 2,5 MNOK per 1 metre expansion." "Some CSFs that ports need to face to reduce risks are demand for fuels, well organised infrastructure at the ports, Huge areas on the ports which can help facilitate different alternative fuels without affecting the operations at the port, revenue and well managed finances, building good relations through collaboration and networking and long-term thinking." "Realistically, on a week-to-week basis a port needs several tanks with different fuels in each one as ships are driven by different fuels. If the shipping industry managed to focus on one fuel over a longer time-horizon ports need fewer tanks as they do not need to facilitate several fuel types. » "The international energy market is unstable, A lot of European ports needed to cut connections to Russia and find energy and ways to get fuels through other actors." "Considering risk mitigation strategies ports need to focus on information sharing and collaboration between stakeholders." "Stricter security measurements are required when handling the alternative fuels." «The technology development which benefits the operational procedures with environmentally friendly fuel is not broadly researched on. Thus, technological development is immature. » "The main costs are related to necessary investments that are required for the ports to be able to operate with alternative fuels." "Area optimization of the quays is necessary to be able to supply different types of fuel."

		«By collaboration between different actors, ports and shipping companies can reduce their overall risk by considering alternative fuel, but the biggest actors need to implement/ lead the transition. »
	Shipping companies	"Risks shipping companies are facing considering the transition to alternative fuel is Wrong investments done by the charterer's requirements. Tens of millions in investments can be lost if invested in wrong fuels. "Shipping companies might end up doing investments that are highly uncertain to meet the requirements set from the charterers, such as MAERSK." "Some risks facing shipping companies are uncertainty of the lifespan and the development of the fuel types, and which fuel types that are the most applicable one in the future is hard to tell. This affects the operations directly and can potentially contribute to major economic losses. The recognised fuels being compatible with existing engine systems, or if a major overhauling is required to, for instance, satisfy the CII criteria." «Cost of building ships is expensive. Investments needed in existing and new infrastructure on the ships. As mentioned, the industry is capital-intensive. » «The shipping industry overall is very capital-intensive and is therefore dependent on succeeding in the first attempt in the decision-making process regarding use of alternative fuel. » "To reduce the overall risk, the charterer must collaborate with shipping companies, by for instance information sharing. By collaboration it is possible to gain mutual interests more efficiently. (E.g., obtain CII rating). » "Unpredictable regulations from authorities such as the EU, the IMO and governments pose a huge risk for shipping companies." "Unpredictable regulations from IMO (International Maritime Organisation) increases the risk and cost for the ship-owner. major investments could be irreversible, and a potential huge economic loss for the ship-owners." «Different risk mitigation strategies for shipping companies are viewing available information and testing of fuels." "Quantity on the fuels. Is there enough fuel available out there? » «The large shipping companies make way for the small shipping companies. This reduces the risk for the other players. » «Maersk will be a leading player, mitigating the risk for other players. » «The risks related to supply and demand of the alternative fuels." "ENOVA - Incentives and supports firms that want to operate sustainably. However, they are not incentivising and supporting them wisely. It is a risk that economic resources are therefore not properly allocated." "Costs related to expansion and expanding in existing infrastructure." "Their most concerned risks are related to whether the system / infrastructure on our ships can handle other fuel types that are preferred from e.g The EU (or other organisations)." "Secondly there are risks related to the handling of the fuels, i.e risk related to failure of the respective fuel. HFO is a well-known practice and not an issue to rely on".
		"Thirdly there are risks related to safety concerns. For instance, hydrogen is much more flammable. The last point is related to ports, but they can be outranked if they don't follow technological / green development." "Shipping companies' main cost as for now is related to adjusting after new unpredicted regulations. The risk related to the cost of transitioning to alternative fuel has two perspectives. On the one hand, the shipowners face risk related to less demand for their ships from the charterers. This is due to the ships not being compatible with environmentally friendly fuel. On the other hand, the charterers face the risk of not having enough supply of a respective fuel on their routes." "The necessary costs associated with the required readjustments due to directives and regulations from EU, IMO etc. The requirements often come very unpredicted which leads to huge and unpredicted costs related to these adjustments." "Alternative fuels pose risks such as hydrogen is a significant safety risk, and ammonia is extremely toxic if it starts leaking."